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Governance for Industrial Transformation

Proceedings of the 2003 Berlin Conference on the Human Dimensions of Global Environmental Change

Klaus Jacob, Manfred Binder
and Anna Wieczorek (Eds.)

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Industrial Transformation

The Berlin Conferences on the Human Dimensions of Global Environmental Change are the Annual Conventions of the Environmental Policy and Global Change section of the German Political Science Association (DVPW). The 2003 Berlin Conference, held in Berlin on 5-6 December 2003, has been endorsed by the Industrial Transformation Project of the International Human Dimensions Programme on Global Environmental Change (IHDP-IT), and was organised by the Environmental Policy Research Centre of the Freie Universität Berlin. Additional support was provided by the SUSTIME Project of the University of Applied Sciences Lausitz and partners, the Global Governance Project of the Potsdam Institute for Climate Impact Research (PIK), the Freie Universität Berlin and Oldenburg University, and the German Association for Ecological Economic Research (VÖW e.V.).

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Table of Content

Klaus Jacob, Manfred Binder and Anna Wieczorek: Preface 1

Klaus Jacob: Governance for Industrial Transformation – The Scope of the Challenge 7

Anna J. Wieczorek and Pier Vellinga: The Need for Industrial Transformation..............21

Section A: Multi-Actor and Multi-Level Governance

Wolfgang Meyer and Katrin Baltes: Network Failures - How Realistic is Durable Cooperation in Global Governance? 32

Philipp Pattberg: Private Environmental Governance and the Sustainability Transition: Functions and Impacts of NGO-Business Partnerships..................................52

Dietmar Edler and Jürgen Blazejczak: Could Too Little and Too Much Turn Out to be Just Right? – On The Relevance of Pioneering Environmental Policy.........................67

Tania Braga and Irina Mikhailova: Local Sustainability Measurements and Determinants: Investigating Industrial Stress, Economic Performance and Local Governance at Piracicaba Basin (Brazil)..79

Tim Foxon, Zen Makuch, Macarena Mata and Peter Pearson: Innovation Systems and Policy-Making Processes for the Transition to Sustainability 96

Section B: Transition Strategies

Adrian Smith, Andy Stirling and Frans Berkhout: Governing Sustainable Industrial Transformation Under Different Transition Contexts 113

Stefan Zundel: Time Strategies for an Innovation Oriented Environmental Policy.........133

Kornelia Konrad, Bernhard Truffer and Jan-Peter Voß: Transformation Dynamics in Utility Systems. An Integrated Approach to the Analysis of Transformation Processes Drawing on Transition Theory..146

A. Faber, G.A. Rood, J.P.M. Ros: Evaluation of Early Processes in System Innovation.163

K. Matthias Weber, Karl-Heinz Leitner, Katy Whitelegg, Ines Oehme, Harald Rohracher and Philipp Späth: Middle-Range Transitions in Production-Consumption Systems: The Role of Research Programmes for Shaping Transition Processes Towards Sustainability 180

Martin Jänicke: Industrial Transformation Between Ecological Modernisation and Structural Change 201

Section C: Sustainable Business

Staffan Jacobsson and Anna Bergek: Transforming the Energy Sector: The Evolution of Technological Systems in Renewable Energy Technology..208

Jan-Peter Voß: The Governance of Transformation in Utility Systems: Challenge and Practice 237

David Aubin, Pierre Cornut and Frédéric Varone: Resource Ownership in Drinking Water Production. Comparing Public and Private Operators' Strategies in Belgium 257

Simone Klawitter: A Methodical Approach to Multi Criteria Sustainability Assessment of Water Pricing in Urban Areas....277

Jan Nill: Time Strategies of Transitions and the Transformed Role of Subsidies as Environmental Innovation Policy Instrument....295

Joop de Boer: Combining Long-Term and Short-Term Perspectives on Food Choice: The Case of Meat's Animal Origin 308

Corinna Fischer: Users as Pioneers: Transformation in the Electricity System, MicroCHP and the Role of the Users 319

Franziska Wolff: Industrial Transformation and Agriculture: Agrobiodiversity Loss as Sustainability Problem....338

Paula Kivimaa and Per Mickwitz: Driving Forces for Environmentally Sounder Innovations: The Case of Finnish Pulp and Paper Industry 356

Peter Wells and Renato J. Orsato: The Ecological Modernisation of the Automotive Industry 373

Section D: Technologies for Sustainability Transformation

Mads Borup: Green Technology Foresight as Instrument in Governance for Sustainability....386

Jaco Quist and Philip J. Vergragt: Backcasting for Industrial Transformations and System Innovations Towards Sustainability: Relevance for Governance?....409

Joseph Huber: Environmental Policy Shift Through Technological Innovation 438

Ramesh Ramaswamy: Industrial Ecology – A New Platform for Planning Sustainable Societies....448

Section E: New Instruments

Julia Hertin and Frans Berkhout: Assessing the Link Between Environmental Management Systems and the Environmental Performance of Companies: An Eco-Efficiency Approach 459

Erik Hagelskjær Lauridsen and Ulrik Jørgensen: Coherence in Industrial Transformation 479

Ros Taplin: Australian Experience with Greenhouse NEPIs....491

Roger Pierrard: The European Relief Potential of Green Public Procurement: Methodology and Results....502

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Preface

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Current patterns in the production and consumption of goods, energy and services fail to meet basic requirements of environmental sustainability in both industrialised and developing countries. The use of natural resources and the utilisation of the environment as a sink for emissions exceed tolerable rates, and most producers and consumers are still able to externalise costs caused by their emissions or by the extraction of materials at the expense of future generations or of other world regions. Although some indicators point to an increasing decoupling of economic growth from environmental degeneration, most observers agree that this is not sufficient for sustainable economic and environmental conditions. A more comprehensive industrial transformation towards sustainability is hence needed, in particular in the richer countries of the North. But what forms of governance are likely to pave the way for such transformation?

Some scholars view market failure as the chief cause of the problem. They see the state as the appropriate actor with sufficient capacity and legitimacy to correct these failures. Others argue, however, that in addition to market failures, the limited capacities of governments to intervene in market activities are part of the problem. They claim that 'state failure' results from conflicting policy objectives for governments to protect the environment and to further economic growth and employment at the same time. In addition, governments often lack the necessary information and knowledge required for the effective and efficient correction of market failures. Governmental regulations therefore at best support the ecological modernisation of economies by redirecting modernisation processes towards environmentally sounder technologies. Ecological modernisation alone, however, will not overcome structural rigidities, and in many cases, its achievements are compensated, and often overcompensated, by economic growth. The policy recommendations based on this state failure diagnosis vary considerably. Some scholars stress the need to better involve other stakeholders to compensate insufficient state capacities. Others hope that in the long run, autonomous trends of technical modernisation will reduce emissions. A third group of studies stresses the deficits of traditional command and control but also simple incentive based policies. More complex strategies, often in an evolutionary spirit, have been advocated for, such as strategic niche management, transition management, or recently "time strategies" and other types of innovation policies and "ecological industrial policy" which try to modulate ongoing innovation dynamics and rely more on the interaction of political and broader societal forces. Yet it is open if these strategies are likely to bring about the necessary changes.

Given this dilemma of simultaneous market and state failure, the 2003 Berlin Conference on the Human Dimension of Global Environmental Change aimed to bring together new and innovative research in this field – in particular with an empirical emphasis – that indicates possible pathways for the successful governance of industrial transformation processes.

The 2003 Berlin Conference "Governance for Industrial Transformation" focused on political strategies capable of limiting the overuse of natural resources and the emissions from industrial activities. About 140 researchers from all over the world presented and discussed their recent research. The conference has been endorsed by the International Human Dimensions Programme On Global Environmental Change core project on Industrial Transformation. It has been organised by the Environmental Policy Research Centre of the Freie Universität Berlin. It was supported by the SUSTIME Project of the University of Applied Sciences Lausitz and partners, the Global Governance Project of the Potsdam Institute for Climate Impact Research (PIK), the Freie Universität Berlin and Oldenburg University, and the German Association for Ecological Economic Research (VÖW e.V.). Financial Support has been provided by the German Science Foundation.

Plenary Speakers included Nicholas Ashford, Director of the Technology and Law Program, Massachusetts Institute of Technology, Cambridge, Rainer Baake, State Secretary, Federal Ministry of the Environment, Nature Conservation and Reactor Safety, Frans Berkhout, Director of the Sustainable Technologies Programme, University of Sussex, Marina Fischer-Kowalski, member of the IHDP-IT Scientific Steering Committee, University of Vienna; Ken Green, Director CROMTEC/Institute of Innovation Research, Manchester School of Management, Ashok Jaitly, Rural Energy Division, The Energy and Resources Institute (TERI), New Delhi; Jan Rotmans, Director ICIS, University of Maastricht; Pier Vellinga IHDP-IT and Stefan Zundel University of Applied Sciences Lausitz.

This volume represents a selection of thirty papers of the 2003 Berlin Conference. We hope that the volume will contribute to the ongoing academic and political debates on opportunities and barriers for an encompassing industrial transformation.

For the preparation of these proceedings we are indebted to Stefan Lindemann and Jochen Biedermann for their support.

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Governance for Industrial Transformation – The Scope of the Challenge

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Needs and Outline of an Industrial Transformation Research[1]

Despite considerable efforts in cleaning up industrial production since the emergence of modern environmental policy about 30 years ago, the patterns of economic activities are far from environmental sustainability, especially in the industrialised countries. Many problems remain unsolved, many new problems emerge at the horizon. Climate change, the loss of biodiversity, water stress, soil degradation or the exposition to dangerous chemicals are examples for that. Although some indicators point to a decoupling of economic growth from environmental degeneration, the overall consumption of natural resources and the utilisation of the environment as a sink for emissions exceeds tolerable rates. This calls for an encompassing industrial transformation towards sustainability, in particular in the richer countries of the North.

This is not a new diagnosis. The need of fundamental changes in the patterns of production and consumption has been discussed already since the 1970s. That little progress has been made so far, is not a great surprise, given the scope of the challenges of such an undertaking as the industrial transformation of both rich, industrialised countries and to direct the process of development in the industrialising countries.

Lots of academic work has been conducted to analyse the determinants of unsustainable economies, such as external effects of production processes, problems of internalisation, consumer preferences that are not sufficiently considering the environmental burden of consumption and hence the lacking market signals for a more sustainable production. Many scholars with different scientific backgrounds have undertaken research concerning the questions, which policies and regulations are likely to bring forward the necessary change, which actors are able to enforce these policies and which overall necessities, opportunities, and impediments exist for such policies.

Given the rather dispersed fields of research, there is a need for an overarching framework as it is offered in the Science Plan of the IHDP-IT. There are several characteristics mentioned of what could qualify for Industrial Transformation research:

- Industrial Transformation research deals with the relationship between societal, technological, and environmental change;
- Industrial Transformation focuses on systems and system changes that are relevant in view of the global environment (such as the energy system, the food system, and the urban system); systems are defined as chains of related economic activities

[1] Many thanks to Axel Volkery, Simone Klawitter, Kerstin Tews and Per-Olof Busch for comments on earlier versions of this paper

that provide a specific need for society. Thereby it goes beyond single enterprises, sectors and countries.

- Industrial Transformation research relates producer and consumer perspectives, including the incentives and institutions that help in shaping these perspectives;
- Industrial Transformation research is international in scope; and
- The research is necessarily multi-disciplinary, it encompasses economics, political sciences, psychology, sociology and history.

(Vellinga and Herb 1999).

The overall rationale of IT research is to understand the conditions for changes in the relation of society and the environment that lead to a de-linking of economic activities and environmental burden. How can the desired changes in economy-environment relations effectively promoted? Until now it was mainly the state that has been the most important actor to promote improvements in environmental performance. However, because of the dynamic development of the socio-economic and the political systems it is questionable if past patterns of industrial change are likely to occur also in the future. It is called for new forms of governance in particular to cope with the challenges of economic globalisation.

The modes of governance are changing as well. The transformation in governance is usually described by three trends (s.a. Heritier 2002; Hey, Jänicke et al. 2003):

- the broadening of the spectrum of actors involved in the policy making process, and by this the decline of authority of the central government towards non-state actors. To safeguard the participation of the affected stakeholders it is often called for more democracy and new forms of participation;
- the broadening of the instruments applied, away from command and control towards economic instruments and new flexible, co-operative measures with shared responsibilities of government and target groups; and
- the declining importance of the level of national policy making, while other levels both internationally and subnationally gain additional importance.

What does this mean for policies that aim to contribute to an encompassing Industrial Transformation? Many scholars subsume implicitly all political strategies under the heading of industrial transformation that are able (or aim) to influence the choice of technologies and hence the environmental performance of enterprises, branches or consumers. These approaches can be analysed as end-of-pipe strategies, ecological modernisation or green industrial policies.

However, the above cited IHDP-IT Science Plan takes a different direction: It focuses on systems and system changes that are relevant to the global environment. Thereby, the perspective is broadened to the actors that are involved in the production and consumption, the flow of goods and services, and the institutional setting that frames these activities (Vellinga and Herb 1999). It is open to investigation if this opens up some room for manoeuvre within the above depicted new modes of governance.

In the following, recent contributions of political science on strategies that aim at a greening of industries are analysed regarding their possible contribution to an Industrial Transformation, their degree of difficultness and in how far they are affected by the depicted trends of governance.

An analytical framework

Political strategies can be distinguished regarding the actors and their configuration, the policy style, and the instruments that are applied (s.a. Jänicke, Blazejczak et al.

2000). By this criteria it is possible to describe and to distinguish political strategies, and to assess their likely effects.

- **Actors and their configuration**: Policymakers aim at restricting, determining or broaden the set of feasible alternatives for (groups of) actors or to influence the consequences or the evaluation of their action. Target groups can be firms (both polluting sectors as well as 'helping' industries, i.e. producers of environmental technologies, insurance companies, environmental consultants, etc.), private households, but also NGOs, governmental departments or other governments.
  The selection of a policy measures and their specific design is a complex process. A simple two actors model with the policy maker on the one side and the target group on the other side could not explain the policy output. The internal conditions of the policy making process have to be taken into account as well: The relative strengths of environmental authorities in the government is of importance, their abilities to implement policies, the degree of horizontal (among other departments) and vertical (among other levels of government) integration and fragmentation determines the effectiveness of regulations. Frequently, the target groups of environmental policy do have trustees in 'their' governmental departments and by them their interests are well represented in government, objectives of environmental policies are questioned, instruments are applied less strictly. But also the target groups are often not homogenous, in particular if there are innovators that expect to protect their markets by environmental policy measures, the interests of the target group may be fragmented.
  Policy programmes are developed and implemented in a specific actors' configuration. Whether a policy is adopted, implemented and turns out to be effective, depends on a large degree on the participation (and the mutual recognition of legitimacy) of the relevant actors. E.g. the chemical policy changed fundamentally after the environmentalists groups became an accepted participant in the policy networks during the 1980s in many western industrialised countries while e.g. in the steel industry environmentalists hardly have an important role and environmental demands are mainly imposed by the public authorities.
  It is not only governmental actors that issue policies, but also NGOs that may take an equivalent role. Many policy instruments, in particular persuasive instruments are available to private actors as well. Furthermore, NGOs play a vital role in the development of objectives, communicating problems, monitoring the achievement of targets, all of them are important parts of the policy making process.
- **Policy Style**: The effects of policies, in particular those policies that don't imply a complete determination for the target group, largely depend on the policy style. Policy style describes the manner how a policy is formulated and implemented. Policy maker may seek a consensus with the target group or prefer a strategy of conflict. Their behaviour may be calculable or erratic. In particular the effectiveness and the scope of voluntary approaches depends on the (perceived) readiness to implement regulatory measures in case of failure. Innovation effects of policy instruments rely on credible long-term commitments: E.g. the innovation effects of an eco tax will be higher, if a rise in rates is announced for several years in advance, compared to the same tax that is risen on an ad hoc basis.
  Policy analysts as well as policy makers have stressed the importance of long-term objectives in particular to stimulate innovations. However, objectives are cannot chosen freely, they are subject of dispute and change in a bargaining process inside government and with the target group. Therefore, policy objectives are frequently based on a minimal consensus between departments, hence unclear, short termed and not operationalised for target groups.
- **Instruments**: The number of possible instruments is limited only by the creativeness of policy actors. There are many typologies in the literature, mostly based on the degree of determination for the target group. It ranges from

voluntary/persuasive instruments over economic instruments (subsidies, taxes, certificates, etc.), to so called "command and control" measures. Furthermore, instruments can be distinguished regarding direct or indirect effects: direct instruments aim at influencing the behaviour of the target group, while indirect instruments stimulate other actors to enforce environmental friendly behaviour. E.g. liability rules creating insurance companies as actors that influence the environmental performance of a firm. More generally, indirect instruments generate helping interests to solve environmental problems. Policy instruments may be demanding - ranging from technology forcing, support for diffusion of improved technologies, to fixing the current technological standards only.

Policies occasionally aim at stimulating competition, and search processes inside the target group. In order to be successful in this direction it is necessary, that regulation does not determine the target groups behaviour completely (in this case, innovation is not necessary), but to remain flexible. That is in particular a goal of the so called 2nd and 3rd generation of environmental policies.

Different policy instruments are needed for each stage of the development of innovations (Jacob and Jänicke 1998). In early stages, supportive measures are required, and it is necessary to protect innovations from sometimes overwhelming market forces, until learning costs have been refinanced and production is scaled up. In later stages of development, it is more important to support the diffusion of environmental technologies by discriminating the competing old technology, by giving recommendation to adopt to the new technology or by making the new technology even obligatory.

Firms or other target groups are rarely influenced by a single policy measure only, but they are in a most often subject of a complex and hybrid regulatory framework. Thereby, the effectiveness of policy measures depends to a large degree on the institutional, societal and economic context. E.g. a label is effective only if the environmental awareness is high, regulation depend on the capacity for monitoring and enforcement, etc. This may limit also the transfer of policy instruments from one country to another.

The aspect of institutional fit is in particular crucial regarding the adoption of European policies in the Member States. When European policy innovations are implemented by the Member States, the wide range of different regulatory traditions affects the effects of a policy. E.g. the effects of Right to Know acts vary considerable among the Member States. Comparable mechanisms can be expected when it comes to the implementation of multilateral environmental agreements.

There are many different typologies that classify the different approaches of environmental policies, e.g. the distinction of reactive, receptive, constructive and pro-active approaches by Vellinga and Herb (1999) or a comparable typology of Jänicke (1984) who distinguishes measures aiming at repair, end of pipe, ecological modernisation or structural change. Binder (1999) adds to this list the possibility of abandoning economic growth at least as a theoretical possibility to reduce the environmental burden. In the following the strategies for end-of-pipe technologies, for environmental innovations as well as their international diffusion and green industrial policies are analysed using the above depicted framework to estimate their respective degree of political difficultness and the scope of change that can be achieved.

End of Pipe Policies

Initially, environmental policies in industrialised countries largely focused on a clean-up and end-of-pipe approach, because this leaves the core activities of enterprises unchanged, their resistance is not that severe, and therefore this type of policies are easier to be adopted and implemented.

This type of policies rely to a large degree on command-and-control measures, that are imposed on the enterprises by (national) governmental actors. For the enactment of the underlying regulations, the environmental agencies are most important in the government. Other departments may be in opposition against the environmental standards, because they safeguard the economic interests of the target groups. Environmental NGOs are of little importance, they may act as watchdogs or as proponents of stricter standards.

Other levels of government than the national level are hardly of importance. For some environmental pollutants which have a long range dispersal, there are international regime set up (like OSPAR or the LRTP) that lead finally also to stricter national policies than they would have been enacted if there had been unilateral action only. The subnational level has some role to play in the implementation of the regulation and the monitoring of the compliance. However, in this mode of regulation, the nation state remains to be the most important driver.

The policy style is likely to be confrontational, since EOP measures do impose additional costs to the enterprises. The interests of the target group is likely to be rather homogenous in opposition against this type of regulations.

End of pipe measures do require the monitoring and control of the compliance of the regulations. Therefore the costs of regulation can be considerably, administrative capacities have to be build up. Empirically, the costs for the target group are almost neglectible, apart from few branches and enterprises for which standards were imposed that lead to considerable requirements for investment.

The deficits of this policies and the technologies that are favoured by this approach are well known: often, they tend to shift problems from one media to another only, rather than solving them, they are unnecessary expensive, while more encompassing solutions bear even the potential of cost savings, and for many problems end-of-pipe technologies are not available e.g. climate change or land use degradation (Binder 1999). Furthermore, once investments in end of pipe technologies have been undertaken, technological trajectories originate from this. Investments in integrated technologies cannot be expected until the investments are depreciated.

Largely, end of pipe policies do follow a traditional regulatory mode with a single regulator on the one side and a defined target group on the other side. The trends of governance, new actors, new instruments and shifts in the level of governance are of none or minor importance.

Innovation oriented environmental policies

Technological environmental innovations, i.e. new processes and products that have a smaller burden on the environment than the comparable existing technologies, are expected to overcome at least some of the shortcomings of end of pipe technologies. The scope of policies that contribute to such a modernisation is much broader. It challenges the core processes and the products of enterprises. Unlike in the case of end-of-pipe regulations, the requirements cannot be met by adding a division of specialists. It requires R&D efforts by the enterprises, and it interferes with the central operations of enterprises. However, there is also a considerable market potential for technologies with higher efficiency.

There is a lack of investment in the R&D of environmental innovations because of the double externality of the profit that can be achieved by environmental innovations. Firstly, as for any R&D activities, there are spill over effects and secondly because the improvements in environmental quality are a public good the level of investments in R&D is lower than the economic optimum (Carraro 2000; Rennings 2000).

Therefore, the innovation and diffusion of environmental technologies depends largely on public regulation. This has been also underlined by empirical studies on environmental innovations (see Weale 1992; Klemmer, Lehr et al. 1999; Jänicke, Blazejczak et al. 2000). Based on the evaluation of innovation processes policy recommendations were derived in such studies. They encompass the "multi-impulse hypotheses" (Blazejczak, Edler et al. 1999) "design criteria" for environmental policies (Norberg-Bohm 1999) or proposals for a "strategic niche management" (Kemp, Schot et al. 1998).

The set of instruments for innovation oriented approaches are much broader compared to the command and control regulations that are imposed for end of pipe technologies. These type of instruments still play a role when it comes to technology forcing by which a certain standard is set obligatory at a certain future date. Most scholars, however, call for economic, persuasive or self regulatory instruments in order to stimulate successfully the development and diffusion of environmental innovations because such instruments leave some room for manoeuvre for the target group. Of particular importance are R&D subsidies in order to support the development of technologies.

Many studies reveal, that innovation effects cannot be ascribed to single instruments only. While in one case a particular instrument e.g. a product label, successfully stimulates innovations that are introduced into the market, the same policy instrument is not successful in other countries or sectors. Policy instruments are a necessary condition for innovation, but on their own, they are not sufficient.

The wide range of instruments that are applied hints to the fact that unlike in the case of end of pipe policies, there are much more governmental agencies involved in enacting and enforcing this polices than the environmental departments only. It is typically the ministries for the environment, for R&D/innovation and the respective sectoral ministry (agriculture, industry, transport, energy, etc.). Successful innovation oriented environmental polices require the integration of policies of different governmental agencies. However, initially policies of the different departments are fragmented, because of their diverging objectives.

It is still the level of the nation state that is most important for innovation oriented approaches, although their competences are challenged by Europeanisation and globalisation. It remains largely the nation state that frames the national innovation systems and that is able and legitimated to enact policies that direct the innovation activities towards a greening (s.a. Hübner and Nill 2001).

The policy style is often not confrontative but co-operative. However, the effectiveness of voluntary or persuasive instruments depends to a large degree on credible long-term commitments and on the (perceived) readiness to implement regulatory measures in case of failure. The target group is more likely to be fragmented than in the case of end-of-pipe policies. Whenever an innovator enters the stage, that is able to demonstrate the technical and economic feasibility of environmental innovations, the rest of the branch comes under political pressure to legitimise the ongoing utilisation of the old technologies.

The importance of long-term and credible policy objectives for innovation processes and by the above discussed growing importance of self regulatory and persuasive instruments, environmental NGOs may play a more significant role. Many policy instruments, in particular persuasive instruments are available to private actors as well. NGOs contribute to the development of objectives, communicating problems, monitoring the achievement of targets, thereby partially overtaking governmental functions. Growingly, there are private-private alliances between NGOs and firms that have the potential to influence environmental policy making to a large degree (Jacob and Jörgens 2001). However, these resources are hardly utilised strategically in the policy process and empirically the role of NGO actions seems to be limited compared to initiatives of governmental actors.

Finally, innovation oriented environmental policies do require a longer time horizon than end of pipe policies. The time span from invention via market introduction to diffusion takes – depending on the technological sector at stake – often several years, sometimes even a decade.

Strategies for the stimulation of innovations vary regarding the degree of difficultness depending on the scope of the required change. If technologies are available and if they demonstrated their technical and economic feasibility the task is primarily to support their diffusion. Resistance of the target group can be expected only if the affected industries prefer to use their previous technologies for a longer period of time. If the required technologies are not yet on the market or only at high costs, there are two possibilities: Regulators may choose to set standards for a future date (technology forcing) (which is likely to evoke resistance by the target group or other governmental agencies) or they can subsidise the development and marketing of the environmental innovations (which may require considerable financial resources). Empirically it can be shown, that environmental policies more often support the diffusion of existing technologies, rather than requesting the development of new technologies (Conrad 1998, Jacob 1999). Policies are also easier to be adopted, if there are international examples for such policy measures. The examples of pioneering countries are often used to legitimise planned policies.

If environmental innovations are not a causal, sustained solution, the environmental relief might be compensated by subsequent growth processes. These facts were labelled already in the late 1970s as the "dilemma of the N curve" (Jänicke 1979: 111). This dilemma applies not only to clean-up environmental protection (end-of-pipe treatment) but also to efficiency improvements. For example, Japanese industries, between 1973 and 1985, succeeded in saving energy and raw materials in a remarkable way but the high industrial growth in those days simply devaluated this effect (Jänicke, Binder et al. 1997). The overall growth rate must thus always be accompanied by equivalent progress in (compensatory) technology providing environmental relief. This "*hare and tortoise-dilemma*" of ecological modernization is even tightened if there are losers of modernisation: If it is not the polluting industry itself which finds new opportunities in environmental friendly products, the sector often seeks for new sales opportunities for the old product. For example, the successful campaigns of environmentalists against using chlorine in applications free to the environment lead to a considerable reduction in production and consumption, but this has been compensated by the expansion of chlorine uses in other areas (Jacob 2001). Furthermore, an innovation oriented environmental policy is limited by the nature of the underlying problem: For urgent hazardous problems it is not adequate to wait for the polluters to innovate. Other problems, such as land use or the loss of biodiversity are not solvable by technologies at all (Jänicke and Jacob 2002).

Finally, an innovation oriented environmental policy is limited to those sectors where the target group has sufficient capacities to fulfil the expectations of environmental policy. It requires a sector that is able to perform R&D efforts and that has the ability to diversify into less harmful activities.

To conclude, innovation oriented strategies bear many features of the above mentioned trends of governance: New instruments are experimented with, new actors gain importance and, to a minor degree, other levels of policy making than the nation states become relevant. It remains, however, largely a task of national governmental actors to adopt and enforce such measures.

The diffusion of environmental innovations

A strategy aiming at the stimulation of innovation should not be terminated after the market introduction of an environmental innovation. An encompassing modernisation requires both, innovations, that go beyond incremental innovations, but also their internationally widespread application. Since environmental innovations depend largely on regulatory measures, their international diffusion is frequently accompanied by the diffusion of the related policies.

There is a close interlink between the international diffusion of technological innovations and the spread of policies in support of these technologies. This is because policy makers seeking continuously for solutions that can be adopted also in their own countries and the example of other, pioneering countries is used to legitimise their national activities. Sometimes, the diffusion is already anticipated by the target group and therefore the technological standards are adopted if a country that is perceived as frontrunner in a particular field of policy making adopts respective policy measures (e.g. the exhaust gas standards that were enacted in California lead to R&D activities by many manufactures around the globe, or the Swedish prohibition of use of cadmium in the 1970s led to a substitution in all over Europe, without having the same legal requirements). The diffusion of technological and policy innovations is also supported by the fact that they often refer to global environmental needs: Since many environmental problems occur in great many countries at the same time, or are even globally in their nature they enjoy right at the outset a market perspective beyond national markets.

Recent comparative research on the spread of environmental policy among countries reveals an international convergence in the development of national policy patterns (Kern, Jörgens et al. 2000; Kern 2000; Jörgens 1996; Tews, Busch et al. 2003). The diffusion of innovations in environmental policy takes place both directly from one country to another, i.e. by way of imitative policy learning or "lesson drawing" (Rose 1993) and by way of international institutions (e.g. international regime), organisations (OECD, UNEP, World Bank, Greenpeace), or expert-networks (e.g. the International Network of Green Planners) (s.a. Jörgens 2003).

Initially, strategies that aim at utilising the mechanism of internationalisation build on the same set of instruments as any other technology based policy. It has to be noted, however, that there are differences in the international spread of instruments according to the type of policy innovation and the type of the underlying problem. Policies supporting marketable technologies e.g. by improvements in efficiency, are more likely to diffuse than those policies requesting e.g. EOP technologies that bear additional costs. Pioneering national environmental policy is more likely to diffuse, if it refers to environmental problems, which are highly visible and which are on the international agenda, e.g. climate change. Furthermore, distributive instruments (e.g. subsidies) or informational instruments are more likely to diffuse compared to regulatory instruments (e.g. command and control) or re-distributive policies (like ecotaxes).

Empirically, there are considerable differences in the rate of adaptation of environmental technologies and their related policies among the different countries. Some countries are earlier in introducing technologies and the penetration of markets is more encompassing than in others. If their innovations are subsequently adopted in other countries, they can be analysed as *lead markets* (Beise 1999; Beise 2001).

The history of environmental protection is rich in examples for lead markets (Beise, Blazejczak et al. 2003): it encompasses the legally enforced introduction of catalytic converters for automobiles in the United States, desulphurization technologies in Japan, the Danish support for wind energy or the CFC free refrigerator in Germany. Another impressive example is the global diffusion of chlorine-free paper, from the political activities by Greenpeace and the EPA in the United States, by way of the introduction of chlorine-free paper whitener in Scandinavian countries and various Greenpeace campaigns in Germany and Austria, right through to effective political market intervention in Southeast Asian countries like Thailand (Mol and Sonnenfeld 2000). The latter case shows that political action that stimulates internationally successful innovations is not limited to governmental agencies only, but that this function at least regarding the process of setting environmental objectives may also be taken over by environmentalists.

From the analysis of these examples it can be inferred that the successful establishment of lead markets depends largely on the attainment of the image as a pioneer in environmental policy making. These countries are able to frame the expectations of industries on future regulations sometimes even globally. Furthermore, lead countries often dispose on competitive branches that are able to innovate and are that are already leading the technological development. Lead countries are able to raise the often considerable funds that are required to develop and to introduce innovative technologies.

Regarding the actors involved, international agents are of greater importance than in the types of strategies discussed so far. International organisations such as the OECD, the European Commission or UN agencies are continuously searching for best practices in both environmental policy making as well as environmental technologies in order to support their international diffusion. The negotiation in international regime often serve as an arena for pioneering countries that are able to spread their innovations by this (Jänicke 2002). Occasionally, multinational enterprises aim at levelling out different standards and they contributing to the spread of technologies as well as regulation in order to achieve this. Environmental NGOs support the international diffusion, their demands for an adoption of environmental friendlier technologies is additionally legitimated by the example of frontrunners. It has to be noted however, that the demonstration of the feasibility on the national level seems to be of greater importance compared to the transfer activities of often rather weak international actors.

The limits of strategies are very much alike the above mentioned approaches for an ecological modernisation. Additional actors in particular from the international level are more important for these policies, however they do not substitute the national governmental policies. It is unlikely that those innovations diffuse easily, that are lacking a win-win potential, e.g. structural solutions which primarily aim at abolishing polluting industries. However, the potential for such strategies is still under-utilised.

Green industrial policy

Given the shortcomings of strategies of ecological modernisation it is called for even more far reaching approaches that go at the dispense of polluting industries. Green industrial policy is an economic policy that aims at reducing the environmental burden of industrial production by reducing the size of the most polluting sectors (inter-sectoral structural change). Green industrial policy is based on the assumption that the main share of the environmental burden in industrialised countries is caused by few industrial sectors, in particular the extraction of natural resources, energy production, production of metals, production of mineral products, chemical industry and the production of pulp and paper (Binder 2001).

It requires a shift not only in environmental and innovation policies but also in the economic and regional policies of a country. Unlike approaches of innovation oriented environmental policies that aims to identify win-win opportunities at least in the long term, by stimulating marketable and competitive technologies, an approach at the dispense of polluting industries generates losers. To be effective, a green industrial policy needs to have a long-term focus and to be closely interlinked with other policy domains, notably economic policy and regional planning. In general, there should also be some mechanism to deal with, and possibly even to compensate for, the losers of structural change, which will require close links to social and welfare policies (see for example Jänicke, Binder et al. 1997; Binder, Jänicke et al. 2001).

There are few cases in which a green industrial policy has been developed at the expense of highly polluting sectors (Jänicke, Mönch et al. 2000). Examples are the phase-out of Japan's primary production of aluminium or the political strategy of minimising oil consumption after the explosion in oil prices in the early 1970s in many western industrialised countries. Another example is the German government's decision to phase out the use of nuclear power and their agreement with industry on a long-term plan to shutdown nuclear power stations. Other cases, namely the phasing out of coal mining in the Netherlands or of crude steel production in Luxemburg were not driven by environmental objectives although there has been a considerable environmental relief. In many sectors, pure economic rationales have led to the relative reduction of highly polluting industries, such as coal or steel (at times even an absolute reduction); in some cases, this decline even ran against actual industrial policies that governments had enacted to support old industries through subsidies and state protectionism. Hence, there is a considerable potential for environmental relief if this "autonomous" industrial restructuring is even supported by more progressive industrial policies rather than the often defensive and structurally conservative approaches that is primarily influenced by the vested interests of the affected industries. The basic industries still benefit from industrial policies more than sunrise industries regarding subsidies and protectionism (Binder, Jänicke et al. 2001).

Up to now, there is little research on the economic and political conditions for success of a shift of policies that support a decline of heavily polluting industries and support cleaner branches. It is called for a broad integration of different governmental agencies, in particular of the environment and industry, as well as the different levels of policy making from the regional to the national level.

Due to the manifold issues that have to be addressed, different types of instruments have to be applied, covering regulative and economic environmental policy instruments, all kinds of measures of industrial policies, regional planning and social policies to compensate possible losers of structural change and R&D/innovation policies in order to identify other business opportunities. Due to the nature of the policy problem, it is unlikely that persuasive or self regulatory instruments are of great importance for the management of structural change. The sheer magnitude of the problem also makes it unlikely that the losers can be bought out by distributive instruments.

Hence, considerable resistance against these policies can be expected, and the few examples for a purposeful industrial restructuring underline this assumption. The policy style is confrontational rather than consensus seeking.

In respect of non-governmental actors trade unions are important, but it is unlikely that they are promoting a green industrial policies which potentially bear disadvantages for their sector and therefore workplaces. Environmental NGOs played some important role in the restructuring of the Chemical Industries since the late 1980s (Jacob 2001) or in the case of energy industries in Germany with the abolishing of nuclear power and the incorporation of environmental objectives in energy policies (Piening 2001; Foljanty-Jost and Jacob 2004). The sectors that are subject of green industrial policies are often dominated by multinational companies, the goods that are produced by them are subject of international trade and the according trade agreements. By this, national strategies are somewhat hampered, however, the national level of policy making remains the most important.

To conclude, the proposals, as well as the few empirical cases for a green industrial policy follow largely traditional modes of governance, both in respect of the actors involved, instruments that are chosen and the level of governance.

Governance for Industrial Transformation

The scope for policies that are able to influence and to transform systems as understood in the research on Industrial Transformation is even broader than the above described policies. A system in the parlance of IT encompasses the value chains of several branches, as well as the consumers, international trade and the institutional setting on all level of governance from local to international.

Some might argue, that things are complicated enough already, that policy makers hesitate to adopt ambitious polices already in face of the huge demands of an encompassing ecological modernization, not to mention the requirements of a green industrial policy.

However, the broadening of the scope bears additional chances as well. E.g. the perspective on the value chains rather than on the polluting branches might help to identify the "weakest" part of this chain: It can be assessed which branch might have gate keeper functions, which are able to innovate, whose interests are affected by the change and who are the most powerful actors. Accordingly policies can be adapted.

Based on this considerations, the playing ground for the involvement of non governmental actors and of other levels than the national level of policy making, as well as the introduction of new policy instruments can be seen from a different angle: If policy makers currently are not able to impose the required strict regulations, or to set the prices right – what other points for intervention can be found?

The contributions to the 2003 Berlin Conference addressing this issue in manifold directions. The papers in the panel sessions A (multi-actor and multi-level governance) mainly ask for the appropriate level of governance: Is it the nation state that is likely to bring forward the necessary changes? What contributions can be expected by the European level and what can be expected by international agreements? What is the interplay between the different levels of policy making – are the different policies coherent? Several papers deal with the question, if regional initiatives are likely to be successful or if local and regional actors are helpless facing the overwhelming forces of economic development and the global nature of environmental change.

The panel sessions B (transition strategies) are dealing with the question of how transition processes might be organized. What are the possibilities and obstacles to influence technological regimes? The development of transition strategies is impelled by the Dutch government for different sectors – in how far are these efforts likely to be successful? Are they limited to the specific political context and culture of the Netherlands? What actors are likely to promote transition strategies, what instruments are available to bring forward the desired changes? A special focus is given to the question at what point of time interventions are most likely to be successful. It will be discussed, if early phases of transition processes can be effectively influenced by R&D policies. Other contributions analyse, in how far political cycles and business cycles might be adapted to each other, thereby making interventions more effectively and efficiently.

Contributions in panel sessions C (sustainable business) analyse the conditions for action in the various sectors. Special focus is given to water, energy and agriculture. It will be analysed in how far voluntary actions by business actors can be expected and what instruments are likely to stimulate corporate responsibilities. In how far are these persuasive, self regulatory instruments also available to non-state actors? Are the emerging business-NGO partnerships likely to promote changes?

The panel sessions D (technologies for a sustainability transformation) contribute to the informational basis for policies and consumer behavior. What lessons can be drawn from past developments? Is it possible to model future economic developments based on this past experiences? What methods are available to forecast the technological development and to adapt policies accordingly? What are the determinants of consumer behavior and how could these be influenced?

Finally, the panel sessions E (new generations of instruments) discusses if the new generation of instruments that are currently adopted in many countries around the world are contributing to the undertaking of Industrial Transformation. Several papers evaluate the effectiveness of environmental managements systems that have been introduced some years ago. What are the possibilities for governmental policies to set right the prices? What persuasive and informational instruments are in practice to stimulate voluntary action; what kind of opportunities and impediments can be observed in their application? It has to be investigated if the trend to more flexible instruments with a low degree of determination is symbolic policy only or if they contribute to substantial outcomes.

A cross cutting issue of the conference is the question in how far the experiences with new actors, new instruments and the incorporation of new levels of government are likely to be applicable in Southern countries as well. Are policy innovations of this kind limited to the rich industrialized countries only, given the often poor financial, economic and administrative resources in less developed countries? Or just the opposite: Are new instruments, new actors or the incorporation of the international and subnational level able to level out this deficits? To make a fruitful discussion possible in this respect we avoided to put papers together in a separate panel session, but instead we distributed this contributions on problems in developing countries in the various sessions.

The 2003 Berlin Conference shall not be the final effort in strengthening research activities facing the urgent need for an encompassing Industrial Transformation. It aims at stimulating the international and interdisciplinary debate on this issues. Hopefully, many new research projects and co-operations will follow out of this meeting.

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The Need for Industrial Transformation

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1. Introduction

Until the 1960's the post war economic growth was considered a great achievement of modern societies, as it was able to assure stability and welfare. The end of 1960s, however, brought criticisms of economic growth for what was seen as its darker side. The 1972 Report to the Club of Rome was a warning to the world about fatal effects of continuous exponential economic growth and its consequences: increasing pollution, overexploitation of renewable resources, exhaustion of non-renewable resources (Meadows 1972). A heated debate over economic growth and the environment was started between the supporters, who considered economic growth good for the environment and the antagonists, according to whom economic growth was the root cause of the environmental degradation and for that reason should be reduced or even reversed. As a result, in the late 1980s theoretical investigation of the relationship between economic growth and environment was started, many computer models and future forecasting were developed, but the debate could not be put to rest due to a lack of environmental data as well as differing opinions and values about what is a sustainable future. The first empirical studies were carried out only in 1990 and they revealed the existence of an inverted U curve relating use of energy and materials with income, the so-called Environmental Kuznets Curve (EKC) (Panayotou 1997). The curve was consistent with the observation that in some of the developed countries environmental pressure has been reduced while economic growth has continued. In 1992 the World Bank published a report (World Bank 1992) suggesting the possibility of delinking economic growth from its environmental burden (de Bruijn, 1999). 1992 was also a year of the Rio Earth Summit, during which the countries of the OECD committed themselves to sustainable development and since May 2001 the decoupling of environmental pressures from economic growth became one of the main objectives of the OECD Environmental Strategy for the First Decade of the 21st century (OECD, 2002).

Since the first environmental movements of the 1960s the OECD countries have been successful in using regulatory instruments to reduce pollution and overexploitation of natural resources. Technology advances made it possible to increase life expectancy, improve resource use, reduce pollution and better understand how life support systems operate at a global level. All OECD countries have developed a portfolio of environmental policies and many socio-economic imbalances have been addressed especially in more environmentally aware countries. The report by Azar (Azar et al., 2002) on the past trends and prospects for the future decoupling indicates that there has been *some* decoupling of *some* emissions in *some* developed countries. Part of the explanation being the shift of some industries from developed to developing countries. However, according to Johnson (Johnson 2002, 26) "…despite all the elegant rhetoric that surrounds discussions about sustainable development, we are far from heaving made significant progress toward that goal". One would wonder why.

This chapter analyses the complexity of global environmental problems (section 2) and the difficulties with solving them in a traditional way (section 3). In section 4 we propose a transformation of production and consumption systems as a way to approach global environmental problems and we present foundations of the Industrial Transformation project of the International Human Dimensions Programme. The name of the project is clarified in section 5. Section 6 presents a short overview of the current knowledge on societal transformations and in section 7 we look into different messages that Industrial Transformation carries around the world. We close the chapter with a concluding section 8.

2. Complexity of global environmental problems

Figure 1: Local Average Income Levels and Environmental Quality.

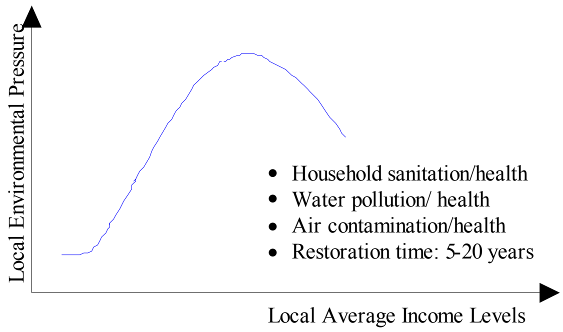
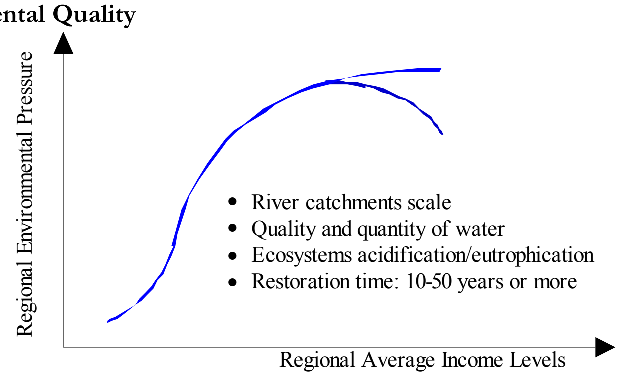


Figure 2: Regional Average Income Levels and Environmental Quality

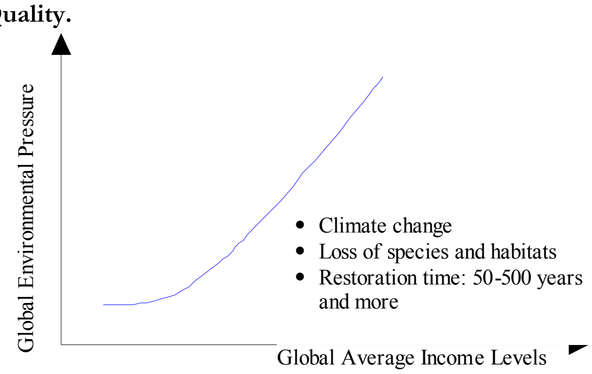


When we take a closer look at the Environmental Kuznets Curve as presented by the World Bank we discover that indeed it is true but only for local environmental problems such as air contamination or water pollution in the cities (Vellinga 2002). The empirical evidence (Azar et all 2002) confirms that indeed growing income levels can be combined with improvement of local environmental quality (Figure 1). This is probably for two reasons: firstly, because people take action based on health impact observations and secondly: because costs and benefits play out at the same (local/national) level and within one generation. Therefore as income levels go up and as local environmental/health problems become manifest, there is a driver and there are financial means to introduce technologies and regulations (incentives and institutions) that reduce pollution and protect the health of the population. Many cities and many countries in the industrialized part of the world have gone through this curve. However many cities in developing countries are still in the upward part of the curve and they suffer from multiple problems, not only environmental.

When we talk about environmental problems that are manifest at a regional level, such as acidification and water quantity/quality issues at the scale of river catchments, there is less evidence that people successfully address these problems as income levels go up. One reason is that upstream and upwind industrial and agricultural activities benefit from the ability to pollute and overuse environmental resources such as water and air, while downstream and downwind, people and nations experience the negative impacts. Another reason for continued environmental degradation as income levels go up, is the time delay between the act of polluting and the effect of pollution downstream. There are some examples of regions and environmental problems where the curve has been pulled downward but this is not a general empirical finding. For most regions of the world the jury is still out.

Similar curves drawn for global environmental problems such as climate change and loss of species and habitats do not resemble Environmental Kuznets Curves at all. Empirical data illustrate that there is no income related levelling off point when we look at the relation between income and emissions of greenhouse gasses (given the predominant use of fossil fuels). The OECD list of red lights (problems that have worsened in the past, or are expected to do so in the future), next to the greenhouse gas emissions, also includes: decline in tropical forest coverage, overfishing and loss of biodiversity (Environmental Outlook, 2001). Environmental problems at this level are challenging because income levels correlate with energy use and present day energy use is coupled with CO_2 emissions. Similarly, the space and resources we use for our activities (housing, transport, food and also recreation) grows linearly with income projections going up; this is at the expense of natural habitats. There is also no direct correlation with human health impacts so the sense of urgency to address these issues is generally low. Finally those who could take first actions – the developed and richer countries - are the least vulnerable to the effects of global environmental change and they do not feel immediate urgency to take any action. Indeed, a critical feature of global environmental change is the time scale of biophysical response: climate responds to changes in the concentration of greenhouse gasses at a time scale in the order of decades to centuries and more.

Figure 3: Global Average Income Levels and Environmental Quality.



Global environmental change is thus so very difficult to approach in the traditional way in which environmental problems have been addressed so far because the activities that cause these problems (energy use, food production, mobility) are deeply embedded in our cultures. The global environmental problems often originate from different sources, are characterised by a great number of stakeholders and their interests and are marked by large uncertainties. They are also urgent and require action before the effects actually become visible.

3. How have we solved environmental problems so far?

Let's analyse trends in societal response to environmental problems over the last 50 years. Figure 4 presents a number of stages in societal response to environmental problems. In most of the OECD countries environmental policies were initiated in the period between 1960 and 1970. The first set of policies can be characterized as predominantly reactive: policies driven by visible negative effects such as massive fish killing in polluted rivers and health problems related to air pollution and chemical waste. The response can be characterized as "end of pipe", implemented by technical specialists. An important philosophy was keeping the cost down. In response to the oil crises in the 1970s, these policies were complemented with ideas about efficiency gains in the production process. This required the involvement of managers. Optimisation of resource use became the major driving philosophy.

Figure 4: Development stages in corporate and societal response (adapted from Winsemius and Guntram 1992 and Vellinga and Herb, 1999)

B)	End-of-pipe	Process	Product	System
C)	Specialists	Managers	Sector	Society
D)	Minimisation	Optimisation	Acceleration	Vision

A) response phase C) main actors

B) focus of attention D) driving philosophy

From, say 1990 onward, new approaches can be recognized where environmental concerns are transformed into opportunities for developing and selling new products. The driving philosophy for such strategies is acceleration: developing new markets based on environmental performance and green image. A major question is: will the approach focused on green products be powerful enough to limit global environmental change to acceptable proportions. The answer is: probably not. Green products are only marketable when they fit in the larger physical and institutional framework. A hydrogen car needs an infrastructure with hydrogen service stations, and renewable energies can only compete in a market where the price of fossil fuel use reflects all environmental cost. There are plenty of technologies available or within reach for clean production, such as zero emission power plants and zero emission cars and ecological and/or low input farming systems. Still they do not easily enter the market for two reasons: one - they may not fit in the present energy, transport, food production and consumption systems, which are "locked-in" with status quo interests including education, research, infrastructure and not in the least commercial interests; and two - the incentive structure through its historical development favours the present system of sharing private and public costs (in any fiscal, property, international trade and liability system of rules and regulations some cost are internalised in the price of production and consumption while other cost are born by the public, e.g. health cost, or future generations, e.g. climate change or other species e.g. loss of biodiversity).

4. Transformation – a panaceum?

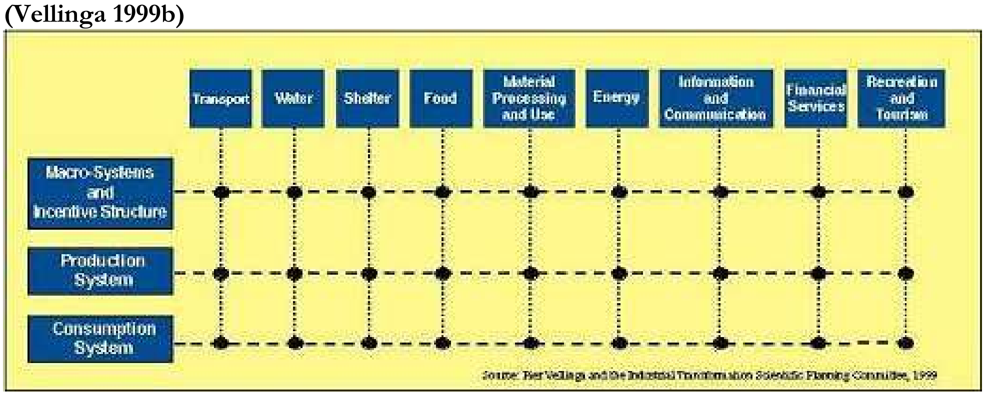
Global environmental change will test, in an unprecedented way, the capacity of the human species to manage their activities in a pro-active manner, especially when we want to combine growing income levels with a significant reduction in the impact of human activities on global life support systems. Such an approach will have to focus on systems and systems change. A system being defined as a chain of production, distribution, consumption and disposal activities including the incentives that shape the system (i.e. property, liability and fiscal laws and regulations). Given the complexity of such chains and given the need for a pro-active approach such system changes will require the involvement of society as a whole and they will require an inspiring vision to mobilize all participants (see Figure 4). It is clear that such visions are likely to compete with one another, which can slow down the change, but this is not necessarily counter productive as competition is a driving force in itself. Furthermore, a change to more sustainable systems is only partially a matter of technology. Economic, socio-cultural and institutional change plays an equally important role. In fact, transformation can only be successful when the technological change is inherently coupled with a societal change.

These considerations and a wide international, multidisciplinary consultation provided foundations for the creation of the Industrial Transformation project (IT) of the International Human Dimensions Programme on Global Environmental Change (IHDP). The overarching goal of the IT research is threefold:

- To understand complex society-environment interactions;
- To identify driving forces for change;
- To explore development trajectories that have significantly smaller burden on the environment.

The IHDP-IT programme is based on the assumption that important changes in production and consumption systems will be required in order to meet the needs and aspirations of a growing world population while using environmental resources in a sustainable manner. This type of research has to be of a multi-disciplinary character. Industrial Transformation therefore builds on the foundations of a range of social science disciplines including economics, sociology, psychology, human ecology, anthropology, political science, geography, and history, as well as on the foundations of natural sciences such as physics, chemistry, biology, and technological sciences. To provide a framework for the co-operation required between various disciplines, a matrix was developed (Figure 5). The rows reflect the disciplinary research fields that each has a certain tradition (outlined in Vellinga 1999a), while the columns describe a set of human activities aimed at meeting specific human needs. Through this multidisciplinary approach, the Industrial Transformation Project strives to build on existing pillars of research and draw from expert communities while developing new research topics and radical approaches.

Figure 5: Tentative Framework for Industrial Transformation Research with research fields/disciplinary approaches in the rows and human needs/activities in the columns (Vellinga 1999b)



5. Why *Industrial* Transformation?

The word *Industrial* in the name of the project was selected to describe and indicate the need for a transformation of ALL human activities defined as a chain of interrelated economic activities aimed at providing a specific need for a society. Industrial Transformation was defined analogously to Industrial Metabolism and hence refers to all processes reflecting economic activity instead of those of the industrial sector alone. Industrial Transformation could also be called *Societal* Transformation but this word is confusing as it emphasizes changing norms, values and attitudes instead of transforming inputs into outputs (de Bruijn 1999). Looking at the history of how societies moved from agricultural to an industrial mode of subsistence, one could argue that many countries are past the industrialization process and therefore Industrial Transformation is over, *but* this is not what IT refers to. Current societies including the so-called post-industrial world are strongly based on the production of goods and services in ways that have a massive effect on environment (e.g. the energy and food sector as well as tourism and the health care sector). Industrial Transformation is therefore about transforming production and consumption based societies towards sustainability.

6. From chaos to convergence

Since launching of the IT Science Plan in the early 2000, a number of relevant research initiatives have been developed worldwide, many of which were supported by the IHDP IT programme. The aim of these activities has been firstly to better understand the complex society – environment interaction and the process of socio-technological transformations; secondly to use this understanding to inform policies and strategies to realize purposive transitions; and thirdly to better understand the different messages that Industrial Transformation carries throughout the world.

For example, the research group focussing on innovation theories based at Twente and Maastricht (The Netherlands) developed a "multilevel perspective on transitions" to help us understand dynamics of transformations. They distinguish three levels: niche, regime and landscape (Geels 2002):

- *Niche*: denoting a space where individuals, based on existing knowledge and capabilities develop new technologies or concepts that are geared towards problems of existing regimes. Niches provide space for learning processes and development of social networks, which support innovations. Innovations generated at this level are usually radical.
- *Socio-technical regime*: accounting for stability of existing technological development. Regimes refer to rules that enable and constrain activities within communities. If innovations are generated at the regime level- they are mainly incremental.
- *Socio-technical landscape*: encompassing the wider context of a regime in the form of socio-cultural and normative values, economic and broad political processes. The context of landscape is very difficult to change and if it does change, it takes much longer than in the case of regimes. (Geels, 2002).

A niche-based approach to sustainable development – the Strategic Niche Management that has been developed in conjunction with the multilevel perspective on system innovation advocates a deliberate stimulation and protection of the novel socio-technical niches to seed a transformation of the technological niches towards sustainability (Kemp, Schot, Hoogma 1998).

These findings gave foundations to a new approach – transition management which has been defined as an anticipatory form of multi-level governance that uses collective, normative visions as starting point for formulating long-term, collective innovation strategies (Rotmans et al 2003). This managerial approach advocates an evolutionary way of steering instead of command-and-control governance. It suggests that a transition takes place through a sequence of the following stages: a pre-development phase where there is very little visible change at the systems-level but a great deal of experimentation at the individual level; a take-off phase where the process of change starts to build up and the state of the system begins to shift because of different reinforcing innovations or surprises; an acceleration phase in which structural changes occur in a visible way through an accumulation and implementation of socio-cultural, economic, ecological and institutional changes; and a stabilization phase where the speed of societal change decreases and a new dynamic equilibrium is reached.

Critics of the approaches and taxonomy described above indicate that indeed traditional innovation may be explained in the terms niche innovation. However, changes required to reverse the trend of growing global environmental pressures are likely to be triggered only by institutional changes at the level of "regimes" or "landscapes". It is claimed that addressing energy, food and transportation systems and their effects on the global environment requires changes in the existing international incentive structure for these activities. Such changes should include some kind of internalisation of external cost of environmental resource use e.g. through taxes and/or through the allocation of resource use quota systems and the introduction of tradable resource use rights. The critics argue, however, that niche innovation can only come about after relevant changes have been made in the international "level playing field" (in evolutionary economics this is called the "selection environment"). In terms of transformation management: stimulation of niche innovation is only worthwhile when incentives at global scale are adjusted simultaneously (assuming the systems addressed are embedded in global markets).

Berkhout and Smith (2004) propose a taxonomy listing four different types of transitions: path dependent, reorientation of trajectories, emergent transitions and purposive transitions, each with its own pace and features. Berkhout argues that the normatively driven purposive transformations (such as those triggered by the desire to avoid irreversible damage to life support systems like climate, biodiversity and the water cycle) do not fit the typical model as described by Geels (Geels 2002) and the others mentioned above.

Historical analysis of technological innovations leads also to the conclusion that most innovation tends to be of an incremental nature but broad transitions do occur (Elzen 2003). Taking into account the fact that these transitions have not been planned and that there was no consensual vision about where the societies could transform to (either in more or less sustainable directions) the main challenge for research remains in gaining a better understanding of the dynamics of transitions so as to be able to suggest possibilities for inducing and stimulating the occurrence of transitions. It seems likely, however, that purposive transitions, taking place on mainly environmental grounds, will have different characteristics, may be more costly and therefore more difficult to implement (van de Kerkhof & Wieczorek 2003).

The road towards sustainability through the decoupling of economic development from its environmental burden proves to pose many challenges. There are many areas of human needs that need to be addressed such as food, fresh water, health, shelter, mobility and energy, to name only a few. There are also many dimensions in which sustainability needs to be achieved, including e.g., technical, socio-economic, cultural or spatial aspects. Achieving sustainability in the broad sense therefore appears to require a multitude of changes that have been referred to by analysts from different disciplinary backgrounds using a variety of concepts. *System innovation*, *regime transformation*, *industrial transformation*, *technological transition*, *socio-economic paradigm shift* are some of the best known (Elzen 2003).

The review of research carried out since the launching of the IT Science Plan in 2000 illustrates that transition research is still in its infancy with different schools of thought claiming the term (Vellinga & Wieczorek 2003a). This is mainly due to different disciplinary and interdisciplinary approaches to research and different attitudes regarding normative and non-normative aspects of research. Despite this variety of terms and the lack of well-established definition for a transformation, there is still convergence and a growing set of characteristic features of a transformation that scientists do agree about. They agree that:

- A Transformation is a major but gradual and long-term change in the way societal functions are fulfilled.
- Technological change is crucial in bringing about the change but its introduction is inherently coupled with high-level socio-cultural and institutional changes.
- Transformations involve a wide range of actors, including firms, consumers, NGOs, knowledge producers and governments.
- They are not caused by a change in a single factor but are the result of the interplay of many factors and actors that influence each other but they may also have their own trajectories of development.

The insights developed thus far also allow making policy suggestions that can inspire current attempts to define and implement various forms of transition policy. The challenge to realize transitions towards sustainability in a variety of domains can only be fruitfully tackled when near-future attempts to induce them are carried out in close interaction with work on furthering the understanding of the dynamic of transitions.

7. Understanding geographical differences

When studying historical transformations with the aim to fuel the policy process and envisage pathways towards sustainability, it is of utmost importance to take account of regional differences within the framework of global interconnectedness. This is not only due to various levels of economic development, but also because of different climatic conditions and topography and often very different cultural and socio-political patterns. For example, the challenge for the OECD countries is to continue economic development while reducing environmental burden (de-coupling of economic growth from its environmental burden). For the South Asian region a single challenge cannot be defined since differences among and within the countries in terms of production and consumption are too large to allow for such a simplification. The rapid change to natural gas busses in New Delhi or growth of kilowatts produced by decentralized renewable energy systems in India could serve as good examples of change for many OECD countries. But at the same time, the South Asian region is home to the largest number of poor and nearly half of the two billion people without access to energy (Wieczorek and Vellinga 2003b).

On the other hand, the industrializing East Asian mega-cities undergo a rapid transformation due to massive economic growth in the last few decades. This growth has been accompanied by increases in per capita income and significant declines in poverty and child mortality but also by tremendous increases in air and water pollution, resource degradation and escalating energy use. It has been widely recognized that this is due to policies failures and institutional weakness. On the other hand, evidence shows that incremental improvements in environmental regulatory policy were often overridden by the scale effects of increased production, consumption and resource use. Given this urban-industrial growth, the challenge for this region is therefore to shift to patterns of economic development that are significantly less energy, resource and pollution intensive (Angel 2000).

8. Conclusions

Global environmental change problems such as climate change, the loss of biodiversity and the overexploitation of water resources require major changes of the way energy, food, transport and water needs are met. In view of these global environmental problems and their irreversibility, there is an urgent need to explore development trajectories and implement strategies that have a significantly smaller burden on the global environment.

The activities causing global environmental change such as the production and consumption of (fossil fuels) energy, transport, food and water are deeply embedded in our societies. Therefore traditional command-and-control policy measures will not suffice in bringing about the required changes. System innovation offers a more promising approach. It advocates a reconsideration and innovation of the entire chain of production and consumption as well as the institutional and political structures that shape relations between the two.

The international community has developed a number of research concepts and tools to address the enormous challenge of global environmental change. There is a consensus that effective research approaches should include the analyses of technological, socio-economic and institutional change. Such multidisciplinary approaches are generally presented under the name of industrial transformation research.

Industrial Transformation research as described and promoted by the International Human Dimensions Programme (Vellinga and Herb 1999) brings the various research approaches together. This programme plays an important role in the generation and sharing of the knowledge required to initiate and guide international, regional, national and local efforts towards more sustainable production and consumption processes. The character of the most urgent global environmental problems legitimises the focus on the transformation of production and consumption of energy, transport, food and water and the technical, institutional and societal elements that shape these systems.

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SECTION A: Multi-Actor and Multi-Level Governance

Network Failures - How Realistic is Durable Cooperation in Global Governance?

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Introduction

The inclusion of civil-society in policy-formation and –execution has been discussed as a new strategy for global management of natural resources in the spirit of "sustainable development". If such a policy network is about to be build, the main question to be answered is, whether the planned network structure is able to guarantee durable cooperation for global governance or not. We want to answer this question from a theoretical point of view within this chapter. Three steps will be made in doing so:

Chapter 2 is a brief overview on social change and its influences on the management of natural resources. The central thesis is that *modernisation process forces social actors to cooperation in multi-actor multi-level policy networks* by revealing more and more the limitations of the dominant coordination modes "market" and "hierarchy". Furthermore, globalisation transfers the task of natural resource management from national to global level of policy. As a result, the guiding principle of sustainable development and its additional requests for social integration on time-, territorial- and target-dimension even increases the coordination problems associated with this task and the demand for multi-actor multi-level policy networks. Thus, policy networks are not only an outcome of social change but also a goal for global policy following the principles of sustainable development.

In chapter 3, some general remarks on *network theory* will be made to describe the functionality of multi-actor multi-level networks as institutions for governance. The key elements of networks as coordination mechanism and some findings on the preconditions of self-regulation will be presented.

In chapter 4, we discuss the chance to implement multi-actor multi-level networks on global level that promise to be an improvement to actual processes of global governance. The focus is set on "network failures" that hinder the coordination function of this regulative mode. They have to be handled by proper political institutions for to ensure functionality. Some examples for the needed mechanism on a global level will be given at last.

Finally, the central findings of this chapter will be summarised in chapter 5 and used to answer the question how realistic durable cooperation in policy networks is.

The Global Problem of Resource Management

As far as human beings' ability to produce goods for their own needs increased, the *usage of natural resources* becomes more and more an important variable in socio-economic development. During the last century, the rising demand for production proofed the insufficiency of natural resources available. Hence, the need for rational resource management has been recognised and it is becoming more and more a global task. Moreover, the importance of effective and efficient management emerged due to growing complexity of production. As a result of rationalisation and differentiation processes, the division of labour between different social actors revealed also the significance to coordinate individual action for reaching common goals.

This *coordination of action* between individual and/or collective actors occurs within the existing socio-cultural structures of a politically defined territory and is therefore embedded in social structures and processes of a given society (cf. Granovetter 1985). Moreover, it influences societies' capability of *social integration* (cf. Friedrichs & Jagodzinski 1999) and is therefore one of the most important sources for developing a *sense of community* (cf. Tönnies 1988). *Vice versa*, this sense of community is the source of "*positive solidarity*" (cf. Durkheim 1992: 166ff.) which always includes cooperation and is strongly associated with an *active forming of society by political interventions* producing "*positive integration*" (cf. Münch 2000: 206ff.).

According to Parsons (1985: 26ff.), the *key function of polity* is the protection of societal community and to ensure social integration as a permanent process by executing common norms and collective action. *Social institutions* within the political system (e.g. the principles of free election) are safeguards for this development. Hence, *policies* are cooperation processes to (re)produce social integration by using different modes for coordination of action within a given society. The *formation of nation states* in the 19th century (cf. Eisenstadt & Rokkan 1973, Tilly & Ardant 1975) and the emergence of democratic political systems to govern these unities have been up to now the most influencing and path-making result of social integration processes. Today, nation states and its governments are dominant actors not only within its own national context but also on the international political stage.

Coordination of Action through Market Exchange

Within capitalistic societies, *market exchange* has become the most important coordination principle and each kind of social action is more or less subordinated to this code. Hence, the prior function of *social institutions* in modern market societies is the protection of free trade and fair competition from egoistic manipulation of one or the other actor involved in this interaction. Beyond question, this kind of coordination and its supporting social institutions, like for instance the democratic welfare state, increased not only the "wealth of the nations" but also the welfare of its citizens. Globally seen, the economical dynamics are still unbroken, although the centres of growth shifted from the western states (North America and Western Europe) to other regions (especially East Asia). The ecologically determined global "*limits of growth*" (cf. Meadows 1972), heavily discussed as one outcome of the rising exploitation of natural resources in the seventies of the last century, are obviously not yet reached.

However, this does not mean that critical judgements on the problem solving capacities for ecological questions of the existing economical and political order, done by ecologists during public debates in Western Europe and the USA in the 1970s and 1980s (for an short overview see Meyer & Martinuzzi 2000), are *per se* wrong. While the discussion on basic conflicts between ecology and economy seems to be overcome (cf. for the development of public debates on ecology in the western hemisphere, especially in Germany see Huber 2001: 274ff.), some key problems for coordination of action, directly associated with market regulation principles, still remains unsolved (for an overview see Diekmann & Preisendörfer 2001: 77ff.).

To put the focus on only one topic here, the phenomenon described by Hardin (1968) as the "*tragedy of the commons*" seems to be well suited. If several different actors share a common resource, the risk of abuse is given on behalf of individual strategies to maximize personal benefits. Each actor tries to minimize investments for preservation of common resources while simultaneously he or she wants to get the most out of this resources for own advantages. As far as costs and benefits of common resources can not be individually allocated, this problem of exploitation can not be solved by market exchange. From the view of economic theory, common natural resources are highly demanded public goods which are not supplied on private market and due to this can not be traded – the reason for *market failure* (see for further details for instance Buchanan 1999). Moreover, the benefits of *global public goods* – like most natural resources – reach across boarders and sometimes even about generations (for the discussion on global public goods at the World Summit 2002 in Johannesburg see Gardiner & Le Goulven 2002). In other words: the globalisation of ecological risks even increases the public good problem associated with environmental topics (cf. Beck 1986).

Several strategies to overcome market failures and to integrate ecological topics into the economical system have been discussed in the last decades. In general, some economists suggested state intervention for public goods to adjust market failures (among the classical theorists especially Pigou 1998). A very popular example is the recommendation of taxes for a radical reform of international monetary system (cf. Tobin 1978), which became one of the main demands of attac, the first global social movement (cf. Grefe, Greffrath & Schumann 2002: 73ff.). In global environmental policy, the international emission trade system, probably the most important outcome of the "Kyoto Protocol" (cf. UN 1992, 1997), can be seen as another measure within this way of thinking. On national level, several trials to include ecological costs into the national accounting systems have been made by statistical offices (cf. for Germany Stahmer 1989; Cansier & Richter 1995; Rademacher & Stahmer1997). Finally, some efforts on the level of firms to include ecological aspects in cost management and controlling systems can be found (cf. Müller-Wenk 1978, for an overview Grießhammer & Eberle 1996). All these strategies aim on inclusion of environmental costs into economical system and to avoid externalities by measures of *state regulation* (even the creation of property rights like in the case of emission trade is finally dependent on state activities).

Regulation of Action through Nation States

This sets the focus on regulation systems of the *nation state* and its ability to solve environmental problems. In a global historical view, the *implementation of environmental policy* within the political system can be described as a story of success: between the late 60s and the beginning of the 90s of the last century, successively all OECD-countries established national environmental authorities and developed a more or less elaborated environmental regulation system, including national plans, laws and legislations on certain environmental issues (Kern, Jörgens & Jänicke 2000; 2001). Moreover, comparable institutions have been implemented both on supra-national (e.g. within the European Union, cf. Jeppesen 2002) and regional level (for German communes see Kern & Wegener 2002). Finally, the World Summit 1992 in Rio de Janeiro established environmental protection as a global policy and 178 nation states ratified the "Agenda 21" as a common political strategy.

In difference to the successful institutional implementation, the *effects of national environmental policies* are at least ambivalent. While some remarkable outcomes of political programs with sometimes impressive impacts on the ecological system can be referred to (e.g. the progresses in East Germany cf. Stockmann, Meyer et al 2001: 65ff.), many basic trends – especially those concerning the usage of natural resources – are still leading in the wrong direction (as mentioned for example by the Federal Environmental Agency in Germany cf. UBA 2002: 4ff.). In most cases, *executive problems* associated with the political measures used, can be blamed for poor regulative effects of national environmental policy (cf. Mayntz 1978, Gawel 1999, Wilson 2002). Especially the acceptance of state regulation within the stakeholder groups is an important problem – not only in environmental policy.

Due to social change, the decision-making capability of national governments is nowadays challenged from two sides. As Hanf & O'Toole (1992:166) mentioned, „modern governance is characterised by decision systems in which territorial and functional differentiation desegregate effective problem-solving capacity into a collection of sub-systems of actors with specialised tasks and limited competence and resources". Therefore, differentiation as an outcome of modernization increases the demand for *co-ordination between state and non-state organisations* within the national framework (cf. Mayntz 1994, 1996). Moreover, the inclusion of lobby groups with different member interests into policy forming processes often *raise* the problem to find a commonly shared solution and their power to influence government might even hinder any decision at all (or at least its implementation). The political discussions on health reforms in Germany can be used as an example (see Bandelow 1998; 1999; 2003a, b; Gerlinger 2003): several working sessions including members of all political parties as well as a great variety of non-state organisations (e.g. general medical council, pharmaceutical industry, health insurance companies, pharmacies etc.) developed a solution, which had been publicly blamed for its "bias" preferring some pressure groups' interests. Furthermore, the activities of several of the non-state groups involved have to be described as a blockade to strongly needed reforms. To sum it up: it is becoming more and more difficult for national governments to find proper solutions to societal problems and to make decisions that will be executed by civil society forces in the way they are supposed to.

Supplementing this intra-national development *globalisation processes* with its raising number of trans-national linkages in the economical as well as in the political system face the steering ability of centralized national governments from an inter-national perspective (cf. Zürn 1998, Beck 1999, Prakash & Hart 2001). Hence, globalisation as another outcome of modernization increases the demand for *co-ordination between national organisations* – concerning both state and non-state actors – on a trans-national policy level. The well-known problems of the European Union to find common positions and the inability of the United Nations to develop shared political strategies (actual examples reach from the climate change policy to the Iraq war) need not to be further outlined here.

Following these argumentations, *state failures* primarily occur as a result of coordination problems between autonomous actors which are at least partly not an constitutive element of the national political system. Nevertheless, the nation state is *forced to cooperate* because it has lost the ability to develop proper solutions and to impose the execution of its will. Modern democratic states are "weak states" (and they are still getting weaker) because they have to share power with civil society actors and international cooperation both in the political and the economical system. A return to pure national state governance (as some nationalist movements demand) is not possible and would lead to economical and political disasters. Therefore, both state and non-state actors are doomed to cooperation within *multi-actor and multi-level policy networks* - provided that they are interested to avoid political blockades leading certainly to ecological and economical ruin.

Sustainable Development as a New Challenge for Social Integration

Additionally, the use of *sustainable development* as a guiding principle makes the whole thing even more complicated. Since the World Commission on Environment and Development published the famous "Brundtland-report" in 1987, sustainable development is defined as a development 'that meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission 1987: 8). Although most authors refer to the Brundtland-definition of "sustainable development", specification problems associated with this definition are still unsolved in the initiated scientific discourse. To give an example, the debate on "weak vs. strong" sustainability should be mentioned here. Nevertheless, the integration of ecological, economical and social targets has been unfolded as another commonly shared aspect of sustainable development (cf. Minsch 1993). On the political arena, especially the World Summit in Rio de Janeiro 1992 and the Agenda 21 were important milestones on the new pathway of global policy. Although a lot of too optimistic expectations had been disappointed, this kick-off led to a bunch of activities on global, national, and local level of politics since than. Moreover, the Rio-slogan "think global – act local" emphasises the spirit of global integration which is still lasting in some of these activities.

By summing up these aspects, sustainable development can be recognised as a (demanded) *social integration process on three different dimensions* (Meyer 2002: 12):

- *Time integration*: As mentioned in the Brundtland-definition, sustainability should be the *integration of needs between different generations of human beings*. This means incorporation on the *time-dimension*, with the demand to include a long-term perspective into nowadays political decisions.
- *Territorial integration*: Following the spirit of Rio, local action for sustainable development has to be framed by national regulations, which itself have to be harmonized with global agreements. Therefore, decision systems integrating several territorial levels of political action have to be developed within the political system.
- *Target integration*: Finally, the scientific debate revealed the importance of target integration because sustainable development needs to be supported by different social groups with diverse interests. The *integration of ecological, economical, and social targets* offers the possibility to include environmental and social aspects in business decisions and *vice versa* to legitimate business action from a social and environmental policy view (cf. Minsch 1993:9).

According to the coordination problems described above, these three requests for social integration dramatically increases the need for cooperation of state and non-state actors on different policy levels – and the problems associated with these cooperation, which have to be solved by political action and institution building. *Time integration implies a lack of information* about the needs of future generations and the risks of optional pathways in consideration. These uncertainties open the floor for ideologies and political discussions which can not be decided by rational arguments or cost-benefits analysis. The fruitless scientific debate on "weak vs. strong" sustainability may only be the opening act for a new century of ideological battles within the political system. *Territorial integration implies intensive communication processes* between local, regional, national and supra-national levels of policy making, assuring a fair democratic representation of all interests involved. The European integration process and its problems to build up appropriate institutions ensuring adequate representation of interests, powerful translation of decisions into common action and support on the local level gives a first impression on the assumable difficulties. Finally, *target integration implies new modes of coordination of political action*, due to the increasing number of corporate actors which have to be involved in problem solving and therefore also in policy making. As a result, the political system has to open itself for non-political actors, while non-state actors have to allow political interventions in their own sphere of influence.

Therefore, multi-actor and multi-level networks are not only a "must" because of modernisation process but also a common goal of global policy in the spirit of sustainable development. This specific mode of coordination implies some particular characteristics and problems (compared to other coordination modes) that will be analysed from a theoretical point of view in the next chapter.

Is Network Governance the Solution?

Depending on the perspective of scientific discipline, the use of 'network' as an analytical concept varies considerably. Even if the focus is set on social sciences, several different understandings of the term can be found: among others economists analyse the interrelationship of formally independent enterprises, innovation research recognise networks both as important sources for developing innovations and tools for spreading innovations throughout a given social system, and in the view of organisation theory network is a hybrid mode of coordination between the poles "market" and "hierarchy" (for an overview on social network research see Weyer 2000). Here, only the last viewpoint is of certain interest because it refers directly to the steering capacities and problems of networks (see especially the contributions in Sydow & Windeler 2000).

The discussion on the *dichotomy of "market" and "hierarchy" as coordination principles* first occurred within economics. Basing on the pioneering work of Ronald Coase (1937), transaction cost theory set the focus on coordination principles for explaining organisational forms and the existence of firms (cf. Williamson 1975): under certain conditions (especially the costs of transaction), bureaucratic organisation (e.g. in firms) is in favour to market transaction, probably leading to an integration of these transactions into hierarchical organised framework. Further research on these issues revealed the importance of mixed or hybrid organisational forms between "market" and "hierarchy". To describe these forms, the term "network" had been introduced and some authors emphasize the specifics of this coordination mechanisms in difference to "market" and "hierarchy", justifying the classification as an own type (cf. Powell 1990).

In *political science*, the network approach has been introduced in several different theoretical contexts and used both as a quantitative or a qualitative analysis tool (for an overview see Börzel 1997). For a consensual, minimal definition, Börzel (1997: 1) suggested the understanding of *policy network* "as a set of relatively stable relationships which are of non-hierarchical and interdependent nature linking a variety of actors, who share common interests with regard to a policy and who exchange resources to pursue these shared interests acknowledging that co-operation is the best way to achieve common goals".

Therefore, the policy network approach offers a broad range of analytical utilities and *research on governance* represents only a small part within this context. Nevertheless, in the past decade a respectable amount of theoretical reflections and empirical studies on multi-actor networks and its contribution to governance had been published (c.f. Marin & Mayntz 1991; Jordan & Schubert 1992; Börzel 1997; Rhodes 1997; Marsh 1998; Koob 1999; Knill 2000; Dinter 2001; Hajer & Wagenaar 2003). As participants of such kinds of inter-organisational co-operations several different state-organisations (national and local government, legislative and administration, federal and regional agencies etc.) and non-state-organisations (multi-national, small and medium-sized enterprises, non-profit organisations, interest groups and associations etc.) have been recognised in empirical analysis on various policy fields at the local, regional, national and international level of policy making (e.g. from a comparative perspective for health policy Banting & Corbett 2002; for public policy in United Kingdom Richards & Smith 2002; further examples can be found in the work of the Max Planck-Institute in Cologne cf. Mayntz & Scharpf 1995a; Mayntz 2003).

Network Regulation and Coordination of Action

As a short summary, the following four key elements of "*network regulation*" can be identified (cf. Meyer 2003):

- *Trust*: Collective action is only possible, if trust in the reliability of each member to act in a co-operative way can be guaranteed (cf. Knill 2000: 119ff.). Cheating will destroy the cooperation (only Charlie Brown will try to kick the ball again) and break up the network.
- *Durability*: To produce trust, to avoid cheating and to overcome "prisoner dilemma"-situations, continuous (or as a minimum repeated) interaction between same actors is necessary (cf. the considerations of game theory Ordeshook 2003, especially on the importance of repeated interaction Axelrod 1984). Therefore, networks have to be stable constellations of actors at least to a certain extent and over a recognizable time period.
- *Strategic Dependency*: Continuous interaction between formally independent and voluntary participating actors leads to "strategic dependency" (Streeck & Schmitter 1996: 137f.) due to shared production of common goods. Therefore, the scope of action for each actor in every decision situation is reduced to cooperative alternatives because egoistic behaviour risks future support of partners.
- *Institutionalisation*: Especially for balancing power disparities between members (cf. Bachmann 2000: 108ff.) network rules have to be developed. Such an institutional framework regulates the modalities of participation, the process of decision-making, the distribution of commonly produced benefits and the possibility of access and exit to network (cf. Mayntz & Scharpf 1995b: 19ff.).

Problems of network coordination are to a certain extent identical with *general problems of collective action*: Neither the "invisible hand" of market exchange nor the threatening force of sanctions in hierarchical power relations is primarily relevant in this context. In contrary, "trust" as the central regulation principle has to be reproduced in every single cooperation situation and cheating is always possible. Hence, actors have to *invest in network maintenance* by waiving individual benefits with respect of the common output or the individual benefits of others with the expectation of comparable behaviour of the other actors now or in future situations. As far as social institutions controlling interactions are missing, the only potential sanction for a single actor is to leave the network (and this also the only threatening force to push its own will through). From a theoretical viewpoint, this will happen if individual costs to maintain cooperation exceeds the benefits of collective action. Although positive experiences in repeated interaction will increase trust, the risk of cheating still exists. Moreover, cheating is the best option, if expected benefits of further collective action are supposed to be lower than individual benefits available in the concrete situation. These are the well-known problems of collective action and theoretical considerations as well as experimental research have shown that sufficient institutions and measures are needed to avoid bargaining dilemmas and egoistic behaviour (Olson 2000, Heckelman & Olson 2003). Therefore, only social institutions regulating network activities like formal agreements and rules make the difference to repeated collective action that is not able to ensure stability of the interaction system by itself.

The implementation of *network rules* lead also to some kind of restrictions. They might, for instance, limit the exit opinion making an agreement on periods of notice. Comparable to rules within organisations, such network rules need to be developed, controlled and reformulated over time (cf. on the life history of organisational rules Schulz & Beck 2002). This might lead to some kind of closure of the network and probably even run into a process of organisation building. Especially for continuing cooperation including a clear-cut division of labour and a big number of members, hierarchic organisation has definitely advantages compared with networks (cf. Schimank 2002: 30ff.). Therefore, with increasing intensity and length of cooperation and/or number of members a shift from network to organisation (probably in form of associations) has to be assumed. Even private-public partnerships in policy networks can be formalised in some kind of association. To sum it up: *networks are instable constructions* which are tending either to disintegration or to establish formal organisation. As far as policy networks shall be long-lasting modes to coordinate individual action, they are in need of *suitable social institutions ensuring the durability of the regulation mechanism* network itself (this argument is quite similar to the problems of institutional framing of market exchange mentioned in chapter 2).

Governance through Policy Networks

From the viewpoint of *decision-making*, non-hierarchical forms have some visible advantages, especially in complex social environments. They have the capability producing more effective solutions because they are able to process more relevant information, to take a greater variety of values into account rising the acceptance of decisions by stakeholders, and to be more flexible in reaction on changing situations increasing the adaptability of solutions (cf. Scharpf 1993). Due to this, policy networks are creating innovative answers on complex questions and they are regarding the possibilities of execution. For doing so, they need to include all relevant interests in the decision-making process and to balance these interests during the negotiations. In other words: *policy networks have to beware their openness* and flexibility to discuss innovative suggestions, to develop balanced and practicable solutions, and to force execution in a changing social environment. Social institutions to regulate network activities have to guarantee this.

Three different types of *governance through policy networks* can be distinguished regarding the position of nation state within the decision-making process:

- *Neo-corporatist governance*: Any kind of direct collaboration of public authorities and private corporate actors in form of institutionalised negotiations can be subsumed in this category, as long as the power of decision lies still in the hand of national government. Although network negotiations between state and non-state actors might be open and equal, the administrative decision process remains untouched and the output of negotiations might be changed in further steps on its way to legislation. Especially strong interventionist states in Western Europe (among others Austria, Germany and Sweden) developed such kinds of institutions. A recent and obviously not very successful example in Germany had been the "Bündnis für Arbeit" ("cooperation for employment"; for further information on neo-corporatist institutions in the German labour market system sees Schroeder 2001).
- *Multi-level governance*: Following the principles of federalism, several different levels of policy-making (local, regional, national, and supra-national) are institutionally linked in a shared decision-making process. Within such kind of multi-level systems, the nation state is only one actor among others and it has to take the decisions (or at least a right to a say) of sub- and supra-national committees into account. The European Union is probably the most popular example for such a kind of institutionalised multi-level governance (cf. Marks et. al. 1996; although

several nation states – among others the USA and Germany – are organised in a comparable way). From an institutional perspective, the integration of civil society in the political arrangements of the EU is still very poor. However, the discussion on a better inclusion of civil society in European governance has been recently started with a "white paper" (cf. Commission of the European Communities 2001).
- *Self-regulation ("governance without government")*: Two different kinds of self-regulation through policy-networks should be mentioned here. On one hand, self-regulation is the dominant coordination mode of international institutions like the United Nations (cf. Rosenau & Czempiel 1992). Under these circumstances nation states are actors with more or less equal rights and governance is the direct outcome of negotiations. On the other hand, self-regulation describes policy networks without any political authorities involved in the decision process. In this case, private organisations overtake regulatory functions and act in public interest as so-called "private governments" (cf. Mayntz 2003, Streeck & Schmitter 1985). The nation state is not involved in decision-making and its role is reduced to legal framing of civil-society institutions.

The enormous amount of empirical literature on governance in these different types and its differentiated and sometime even contradictory results can not be mentioned in detail here. Only some of the main determinants for durability and effectiveness of network governance will be presented, following an actual summary of findings by Mayntz (2003).

- First – and most important in the context here – one has to recognise the *need of a "strong" (nation) state to ensure the functionality of self-regulation*: "If self-regulation remains ineffective, the state can step in and regulate by direct intervention… Self-regulation in the context of modern governance is always regulated self-regulation" (Mayntz 2003: 4). Thus, policy-networks often act "in the shadow of hierarchy" and powerful political authorities as "guardians of public welfare" are preconditions for effective self-regulation. If such kind of control mechanism is missing (most probably in international relations), effective governance through self-regulated policy networks proves to be very difficult.
- A second precondition of effective governance in multi-actor constellations, mentioned by Renate Mayntz, is "the existence of *a strong, functionally differentiated, and well-organized civil society*" (Mayntz 2003: 5). Therefore, most important parts of civil-society and policy-networks are corporate actors with professional communication management which are able to *integrate and aggregate the particular interests of citizens* and *to represent them for opinion-building within policy network* as well as *to produce common social responsibility* and *to organise collective action of its members in the sense of network decisions* (cf. Meyer 2003).
- Finally, a "*common identity*" of corporate actors involved in network management is needed to (re)produce social responsibility not only in the network but also in the memberships of the participating civil-society actors. Without at least a crude feeling of being "all in the same boat", the willingness to cooperate and to waive claims on common resources will not exist. Therefore, extensive communication both between and within network actors for developing a shared "sense of community" and to enable social integration independently from nation state is needed.

This short summary on research findings on policy network governance reveals the importance of *strong corporate actors with an extraordinary sense for common identity and the importance of appropriate institutions and rules to regulate the network itself*. To ensure the functionality of self-regulation, the threat of (state) intervention is needed. Representation of civil society's interests is only possible within a system of professional interest organisations which are able to communicate the positions of their clients. *Vice versa* they have to transmit social responsibility from policy network to their members. *Policy networks are costly and demanding regulative modes with high requests for the participating corporate actors as well as for the institutional framework.*

Network Failures and its Institutional Consequences

Obviously, the preconditions to ensure functionality and durability of policy networks mentioned in the last chapter are not given in a *global perspective*. The claims of social integration associated with the concept of sustainable development even increases the difficulties. There are at least three special problems facing *global governance through multi-actor multi-level networks*:

- *Competence for Governance:* If policy networks should be able to solve problems, they require the power to make decisions. Therefore, a transfer of this power from nation states to multi-actor policy networks is needed. Moreover, in multi-level policy networks a division of decision-making competences between the levels is essential. Hence, global reorganisation of power division is a premise for *decision-making competence* of multi-actor multi-level policy networks in the spirit of sustainable development. Additionally, the possibilities to include new options and expertise for developing proper solutions have to be guaranteed, if those who decide should get *problem-solving competence*. As a result, the policy networks have to be open for any kind of consultation and the entry of new civil-society actors. In a global view, this requires an enormous amount of flexibility and information processing within the network structure. The concept of sustainable development even requests more: if the needs of future generations have to be taken into account the results of rational long-term planning has to be integrated as basis of decision-making. Hence, *long-term planning competence* on a global level of governance means the transfer of information on complex and hardly predictable topics that have to be scientifically monitored and appropriate estimated.
- *Communication within corporate actors*: If private corporate actors and interest groups are getting involved in political decision-making and policy formation at least to a certain extent, they have to manage internal "bottom-up" and "top-down"-communication processes in a professional way. "Bottom-up"-communication refers to the problem of "*representation of interests*". Due to democratic principles, each member of the electorate must have the same right and possibility to get his or her interests represented by delegates within the political system (cf. Dahl 1998). In civil-society organisations, delegates get elected by *members* of the organisation. As far as membership is voluntary, members are not identical with the "*clients*", which should be represented by the organisation. Hence, legitimation of delegates is limited to a more or less large part of the group they should represent. Increasing heterogeneity of this "clients" group as well as a rising number of organisation members lead to more difficulties for its representation through one single organisation. At least, it is a challenge for internal communication, especially within civil-society actors (cf. Meyer 2003). Obviously, these problems can be found more often on the global than on the local level of politics and global actors have more problems to handle them. "Top-down"-communication within corporate actors involved in political negotiations is needed to ensure internal support for the resulting decisions of these negotiations. In other words, "*corporate social responsibility*" must be produced by communication tools within the participating organisations. Therefore, the problem of involving civil-society actors in political decision-making is *for them* connected with intra-organisational conflicts between *social and member responsibility*. If delegates from non-state organisations agree with common network decisions that provoke the members of their organisation, they might be voted out at the next election. If they try to push the opinion of their

organisation through the network decision process, they risk a breakdown of negotiations. Hence, the delegates have to transfer *responsibility for public goods* among the members of their organisation. If the national state shall be replaced in his function as a "guardian of public welfare", each civil-society organisation included in the political decision-making process has to internalise this task within its existing organisational and communicational structure. Again the problem rises with heterogeneity and number of people that have to be involved in this internal communication process.

- *Global Coordination of Action*: The number of independent and equally righted actors involved in decision-making increases the complexity and reduces the chance to find a commonly accepted solution. On global level with the claim of total integration of all interests either the number of actors in *multi-actor coordination* exceeds or only delegates of organisations on an exorbitant high level of aggregation can be involved in decision-making. However, limiting the quantity of negotiators by constant number of interests to be represented on one level of negotiations only shifts the problem to delegation and aggregation of interests on a lower level. Again the number of levels linked together in *multi-level coordination* increases complexity and reduces the possibility of a common statement. The more different interests should be involved in one decision process the higher the number either of actors within negotiations or levels of negotiation. Following the claims of sustainable development both numbers of actors and levels have to be maximised to include the interests of the whole world.

The mentioned problems of global governance through multi-actor multi-level network are not primarily associated with the coordination mechanism "network" but with the *inclusion of civil-society into (global) decision-making processes*. Moreover, most of theses aspects are even well-known as coordination difficulties of political actors in global policy and the inclusion of civil-society only increases these troubles to a certain extent and on some specific dimensions (e.g. the principles of democratic representation and legitimation, see Sørensen 2002 for more details on the implications of network governance for democratic theory). The existing institutionalised system of global politics is far away from being an effective measure for global governance. The limits of United Nations steering competence have been most recently revealed by the Iraq crisis – and even the more elaborated political institutions of the European Union failed to produce a common European position and to avoid different policies of their member states. As far as, on one hand, the inclusion of civil-society and the establishment of multi-actor multi-level networks are not *per se* solutions for these problems, they are, on the other hand, not definitely reasons for a significant increase of trouble under all circumstances. Whether multi-actor multi-level networks are able to improve global governance or not, is an open question that have to be answered with respect to the institutionalisation of its coordination mode.

Specific Problems of Network Coordination

A transfer of power from the United Nations to self-regulating civil-society networks may open the floor for more effective institutional solutions, but it will be confronted with the demands of effective network governance that are:

- Institutions that are able to subsidize the nation state as a "guardian of public welfare"
- Strong corporate actors representing civil-society in a proper way and being able to organise collective action of its members
- A common global identity overcoming cultural differences and national egoism.

Unfortunately, even if one is able to fit these requirements, there are still a couple of problems remaining, which are inseparably linked with the regulation mode "network". These "*network failures*" are associated with its structural elements. Due to the "hybrid" structure of "network" coordination, including both characteristic elements of "market" and "hierarchy", these poles have some forces of attraction destabilising the network mode:

- *Production of Trust (Openness vs. Oligarchy)*: The main advantage of "network as a cooperation mechanism compared with "hierarchy" is its *openness* for new members and ideas. While formal organisations are "closed shops" with an own corporate identity, "networks" are flexible constructions being able to adapt much better to changes in their social environment. However, openness is not only a precondition for innovation but also a threat to *trust*. As far as repeated interaction within a network is needed to develop trust into the behaviour of others, free entrance and exit of members makes this production of trust at least more difficult. The main source for "trust" is, as mentioned above, the *positive experience of cooperation*. People who worked together several times and demonstrated each other the willingness (and ability) to produce common benefits instead of maximizing individual outcomes prefer this proved partnership for cooperation. This "team-building" process may also lead to some kind of closure against third parties supposed to hinder successful cooperation. In other words, "*mistrust in others*" is often a result of "*trust in companions*". Following the argumentation of Scharpf (1996: 518), such a dichotomy of "insiders" and "outsiders", companions and competitors, as a radical cognitive simplification is needed to reduce complexity of cooperation situations. Therefore, the production of trust within a given network can cause enclosure. Moreover, following Michels (1987), this is a "must" because of the "*iron law of oligarchy*". Due to the extensive communication in policy networks, the interpersonal relationship between delegates even may lead to estrangement from the organisation they are representing and result in clique-building. Thus, trust is important for the stabilisation of network negotiations but it is also a source for oligarchic tendencies that excludes even the members of corporate actors from network benefits.
- *Durability of the Network (Integration vs. Disintegration)*: The relationship between stability and change in networks is unclear both from theoretical and empirical perspective. On one hand, networks need to be stabilized for ensuring the development of trust between participants. As a result, network members as well as formal and informal rules of interaction have to remain more or less constant over time because any change would challenge the balance needed for successful cooperation. On the other hand, to protect the network both from internal and external takeovers, an institutionalisation process with on-going changes of rules and agreements is necessary. Furthermore, modernisation process demands for the possibility to include new actors. "Networks" as regulative modes seem to be fragile constructions, tending towards bureaucratic closure ("hierarchy") or dispersal of cooperation ("market"). Therefore, the capability of "network" cooperation for *social integration* seems to be limited to a certain extent. The positive ability of networks to integrate new members and ideas endangers the existence of the network itself. Innovation networks (e.g. in industry or in research) have, in most cases, an institutionalised limitation of existence. In contrary, policy networks are seldom defined as periodical constructs. As durable solutions, networks have the risk to be transformed to organisation or to an oligarchy.
- *Strategic Dependency (positive vs. negative coordination)*: Scharpf (1996: 512ff.) distinguished two different modes of self-coordination of actors that can be interpreted as contrary modes of strategic dependency. While *positive coordination* points on the goal to maximize the common output of activities, *negative coordination* emphasise the minimal consensus to avoid individual disadvantages as a result of common activities. Following Scharpf (1996: 523), perfect correspondence between net-

work members is improbable due to the increasing variability of interdependence relations. Moreover, one can assume that some actors who have to cooperate for successful positive coordination in a specific coordination situation are not members of the network. The capability for positive coordination is restricted by the chance to produce homogenous interests within the network and, additionally, by the chance to include external actors into cooperation that are commonly needed in specific cases. In other words, positive coordination leads to strategic dependency of actors that can be described as *internal homogenisation of interests* and *instrumentalisation of social integration with respect to shared network interests (collective egoism).* In contrary, negative coordination stresses the individual interests of each actor and therefore the heterogeneity of interests within the network. According to this coordination mode, agreements with "significant others" are needed to minimise the threat for individual action. If this significant others are not yet members of the network, they have to be integrated for egoistic reasons of single members despite the integration problems resulting for network community. Thus, negative coordination leads to strategic dependency of actors that can be described as *internal heterogenisation of interests* and *instrumentalisation of social integration with respect to individual actor interests (individual egoism).*

- *Institutionalisation of rules (network restrictions vs. individual freedom)*: As mentioned above, network institutions and rules are needed to stabilise networks and to produce trust as its key coordination mechanism. Therefore, the institutional framing of networks is of prior evidence not only for its functionality as a coordination mode but also for its capacity for social integration. From the perspective of actors, formalisation of inter-actor relationships within networks requires self-commitment and results in some *restrictions of his or her individual freedom to act.* As far as corporate actors are involved, the increasing demand of network institutions may even lead to incorporation and is therefore a threat for the independent existence of the own organisation. Therefore, *the institutionalisation process of networks can result in building a new formal organisation* that is – from the perspective of network – the most extreme form of social integration of actors and institutionalisation of coordination. At this severe end of scale, the networks itself as well as its corporate actors lose their existence and shift to another form of coordination of action. Below this level, social integration of corporate actors within network is guaranteed by social norms, juristic proceedings and contractual commitments. Such kind of "integration by constitution" can be called *political integration* and is associated with the problem of legitimisation of common norms by the members of the unit (cf. Fuchs 1999: 167ff.). For corporate participants of networks, legitimisation of network institution and rules is a product of a social process that occurs within the organisation. Moreover, social integration is of course also an important task for corporate actors, which have to ensure the support for their own target by their members. As far as network rules are limitations of corporate actors' activities and the network goals are not absolutely identical with actors' goals, some problems for internal integration have to be assumed under the condition of free choice for membership. In other words: *the capacity for social integration of corporate actors is dependent of the degree of freedom to act for its own targets.* The absence of network rules maximises this capacity but also leads to disintegration of the network (approach towards "market").

Additionally to this general "network failures", at least one other aspect has to be mentioned for *governance through policy networks*:

- *Governance through networks (effectiveness vs. efficiency of decision-making)*: Despite the question, whether multi-actor policy networks are effective modes for decision-making and problem-solving, they are for sure not very *efficient* compared to "market" and "hierarchy". While competition at the "market" proofed to be an effective *and* efficient way to co-ordinate exchanges of goods and services, bureaucratic rationality in hierarchies offers an optimised way to handle routine tasks fast (assuring a minimum of communication and coordination expenses) and productive (assuring the involvement of exact those actors needed to produce the common good). Compared to these co-ordination modes, "network" is rather inefficient because of the amount of informal and non-task-related communication (necessary for the production of "trust). Furthermore, effectiveness of coordination is as well associated with communication: a growing number of actors require higher expenses for communication to reach an identical solution. Under given circumstances (actors involved, interest constellation, decision-problem, etc.), a rise in effectiveness call for more or intensified communication. As far as communication is the most important factor of costs in this coordination mode, an *increasing effectiveness may generally result in decreasing efficiency and vice versa.*

Consequences for Network Institutions

Following these theoretical considerations, some consequences for network institutions can be derived. The functionality of institutions has to be controlled by a *third party* that is not directly involved in network negotiations or dependent on one of the actors. This party has to act as "guardian of public welfare" protecting common interests both against individual and collective egoism of network members. It has to guarantee the right to participate (and equal chances in doing so) of each relevant (defining this is probably the most difficult part of this task) stakeholder organisation to avoid oligarchic tendencies. Furthermore, for the protection of trustful interrelationship of network members, sanctions for cheating and effective measures for punishment have to be developed to shun "free-rider" behaviour. The functional relation of this instance is comparable to the relation of political system and jurisdiction.

A common identity of network members and shared responsibility for network decisions must be assured to support integration processes. Additionally, adaptation to changing social environments and rational rules development is necessary. As far as stabilisation of the network as coordination mode is seen as one of the most important tasks for institutional regulation, two aspects of *communication within the network* have to be mentioned. First, purposeful communication between members is needed to ensure progress in negotiations and to attain common goals. Second, the implementation of observation and evaluation of changes in social environment of the network is necessary regarding adaptation and integration of improvement. For internal management of negotiations as well as for monitoring external development, at least one *specialist and independent unit within the network structure* must be implemented overtaking these "administration" tasks. Institutions have to guarantee a clear-cut assignment of responsibilities for this "network office".

Probably the most difficult mission is the regulation of inter-actor dependencies within the network. Balancing power differences and establishing mediation capacities for conflict management are at least some of the tasks that are difficult to handle for people or organisations who are involved in network relations and negotiations. Therefore, institutions have to regulate the inclusion of *external experts of mediation* if they are needed for optimizing communication between network actors. Moreover, it is an important task to avoid inequalities within the network relations. Although the "third party" is able to control the misuse of power, the task of social intervention should not be given in the same hands. Not every conflict situation is in need of a "court" but requires "fire brigades" to get the things under control again.

Finally, the development of network rules is neither a task of "network office" nor of the "third party", it still remains an important duty for network actors and their negotiations. However, for more effective work a special "*rules committee*" has to be implemented and the integration of delegates from outside the network may be useful to optimise communication between the network and external actors. This last aspect points on the problem of closure: openness can only be ensured by external forces involved in rules development.

These four aspects are only first hints about the institutional framework guaranteeing the functionality of multi-actor multi-level policy networks for global governance of sustainable development. For sure, a more systematic analysis of existing policy networks is needed to develop a theoretical model of network regulation in this context. Nevertheless, social institutions governing policy networks have to cause poor attention for implementing new functional solutions for global resource management and sustainable development governance.

Conclusions

„Sustainable Development“ as a guiding principle offers an answer to the pressing question how natural resources should be globally managed. This solution requests

- the consideration of the needs of future generations for time integration,
- the linkage of policies on all kind of levels for territorial integration, and
- the inclusion of civil-society actors for target integration.

In other words, "sustainable development" is the still utopian idea of "one world" solving its problems in free political discourse, including all people and giving them equal rights to decide with respect to the needs of their children and by acknowledging claims of the ecological system.

From a political point of view, such kind of global governance can not be realised without fundamental changes in the recent political system that is dominated by nation states and their particular interests. The demanded inclusion of civil-society actors on global level will result in multi-actor multi-level policy networks. Moreover, these networks are not supposed to be only "think-tanks" for policy formation, leaving decision-making within existing political structures and legislative processes. Global governance in the spirit of "sustainable development" implies the transfer of power for decision-making from national governments to global multi-actor multi-level policy networks. This step is needed to integrate the growing executive power of civil-society actors and to use it for problem-solving.

This chapter discussed how realistic such kind of durable cooperation in global governance is. By doing so, four key elements of policy networks have been derived from theoretical literature on coordination of action. According to this, cooperation in networks can be described by

- production of trust between network actors to ensure collective action,
- durability of network constellation to enable the production of trust,
- strategic dependency between formally independent actors guiding individual action towards common goals, and
- institutionalisation of cooperation by developing rules to protect the network against external takeover or individual egoism.

A lot of empirical work on the praxis of various kinds of policy networks can be found. As a result, some preconditions for self-regulation through policy networks have to be mentioned:

- Strong nation state is needed as "guardian of public welfare", enabling self-regulation of the civil-society "in the shadow of hierarchy";
- Strong civil-society organisations are also needed, ensuring the integration, aggregation and representation of particular interests as well as the production of

social responsibility and the organisation of collective action within its own sphere of influence;
- A common identity of all actors involved in network management is needed to ensure general acceptance and willingness to cooperate with each other.

According to these aspects, several problems for global governance through multi-actor multi-level networks have to be assumed. Some of the difficulties are directly associated with the *global level* of governance and therefore well-known in international politics. The *inclusion of civil-society actors* increases these difficulties in some special parts. We referred to:

- Problem-solving competence requires the inclusion of varying civil-society actors with different perspectives and innovative ideas. This – in addition with the demand for long-term planning - increases the amount of information that has to be processed;
- Internal communication within corporate actors involved in policy network is challenged both by the duty of representing the interests of its clients and the task to transfer responsibility for network decisions and activities to its members. Obviously, there are inequalities of capacities between actors (and their territorial origins);
- The increasing number of actors involved in network negotiations hinders the possibility to find commonly acceptable solutions and a limitation of actors in multi-level structures raises new problems for aggregation of heterogeneous interests on the lower level.

Even more relevant are specific "*network failures*", comparable to the problems of handling externalities described as "market failures" or the limitation of execution as one key element of "state failures". We emphasised the dualistic pressures from both "market" and "hierarchy" on the coordination principle "network" as the main source of "network failures" that can be associated with the key elements of network regulation mentioned above:

- Closure tendencies of networks are leading to "organisation-building" if they are not counterbalanced by measures to protect openness. Additionally, openness may result in dissolution of network structure in direction of "competitive market" if trials for stabilisation fail;
- Networks – as any mechanism to coordinate action of various actors – produce social integration that stabilises their social structure. While "trust in companions" goes along with "mistrust in others", it may lead to durable exclusion of non-members;
- Maximisation of common outcome requires "positive coordination" between actors and leads to "collective egoism". In contrary, maximisation of individual benefits is in need of "negative coordination";
- Finally, network regulation by appropriate institutions and rules has to balance formalisation for ensuring cooperation and the individual freedom to act. The more formalised rules exist, the less freedom remains for single actors – and *vice versa*.

According to this, we described four key elements of institutions to regulate multi-actor multi-level networks:

Considering these institutional ideas being only first hints that have not shown empirical evidence, the lack of proper institutions has to be seen as the most important reason why durable cooperation in multi-actor multi-level networks needed for global governance to manage national resources still seems to be not very realistic.

- A "third party" replacing nation states in its function as a "guardian of public welfare", controlling the functionality of networks and its rules;
- A "network office" managing the communication within network actors and observing external development to ensure adaptation to social environment;
- The "inclusion of external experts" at special points for mediation of conflicts, for development of the relations between single actors and for optimizing communication between actors within the network;
- A "rules committee" with the power to develop new network rules and institutions for to optimize communication between the network and external actors as well as to give them the possibility to participate within the network.

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Private Environmental Governance and the Sustainability Transition: Functions and Impacts of NGO-Business Partnerships

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1. Introduction

Industrial transformation research seeks to understand complex society-environment interactions. It aims at identifying driving forces for change as well as developing possible trajectories towards a sustainable future. Meeting the needs and aspirations of a growing world population while using environmental resources in a sustainable manner will require not only better process efficiency and greener products, but also rather a range of new institutions to manage the profound challenges ahead. The emerging trend of private governance, and, more specifically, the formation of rule-setting NGO-business partnerships, may be interpreted as such a necessary institution for industrial transformation.

As far as rule-making is concerned, studies in global environmental politics have primarily focused on international regimes and organisations designed to address trans-boundary problems. Only recently have non-state actors and their influence on the international political process become a major topic of environmental policy research (Arts 1998; Keck and Sikkink 1998; Reinalda and Verbeek 2001; Raustiala 1997; Rowlands 2001; Tamiotti and Finger 2001; Weiss 1996). Although scholars have studied in detail the role and function of different non-state actors in agenda-setting, lobbying governments, and implementing international agreements, still rather little is known about rule-making by private institutional arrangements that do not emanate from or primarily address the international political system.

Until very recently, the debate about non-state actors and their new roles in environmental governance has been limited to public-private partnerships and global public policy networks (Börzel and Risse Forthcoming; Witte, Reinicke, and Benner 2000). It has neglected far reaching institutionalisations among private actors without the involvement of governments, government agencies or intergovernmental organisations. But it is precisely this evolving trend that poses new questions with respect to some fundamental political concepts, such as public interest, authority, and legitimacy.

The emerging private institutions are no longer primarily concerned with influencing the international policy cycle, but increasingly begin to agree upon, implement, and monitor different forms of self-regulation, including general codes of conduct, management standards, and certified product labels. As a result, the impact of private actors on global politics has changed as well. They have developed from being an intervening variable of the international system to establishing rules that exist mainly outside of it. Consequently, private authority is considered to be different from public authority, because the latter derives mainly from the possibility of coercion, whereas the former is based on persuasion. As a result, private authority most likely takes the form of market or moral authority (Hall and Biersteker 2002; Hall 1997). As Cutler, Haufler and Porter conclude, "[a]uthority involves a surrendering of individual judgement, an acceptance of its dictates based not on the merits of any particular pronouncement but on a belief in the rightness of the authority itself" (Cutler, Haufler, and Porter 1999b: 334).

The chapter attempts to draw a preliminary picture of private rule-making and its functions in the field of environmental politics by developing a conceptual framework of private transnational governance institutions. It captures the essence of new forms of self-regulation and co-regulation by analysing them as mechanisms of global governance different from more traditional international or hybrid public-private regimes. The different functions of private governance institutions are assessed by taking a close look at one of the most prominent private rule-making bodies, the Forest Stewardship Council (FSC).

2. The Concept of Private Governance Institutions

The attempt to develop a concept to capture empirical phenomena of trans-sovereign global politics in general and private rule-making in particular is grounded on theoretical considerations often referred to as 'global governance debate' or even 'global governance theory'. Therefore, it is necessary to first mark the conceptual and empirical boundaries of this debate before further clarifying what a private governance institution is and how it can help making more sense of many current phenomena in global environmental politics.

Modes of Global Governance

Recent debates about the growing political influence of non-state actors, multiple interconnected policy levels, and new functional mechanisms of steering beyond the nation-state, can all be subsumed under the headline of *global governance*. Although there is neither an uncontested definition of global governance, nor a common understanding of what the term refers to in terms of structure and processes, the aforementioned and highly controversial debate highlights some empirical observations that go beyond traditional accounts of international relations, especially in the field of environmental politics.

Global governance is generally believed to encompass different systems of rule on different levels of human activity as an organising social principle beyond hierarchical steering and the sovereign authority of nation-states. As James Rosenau notes, "global governance is the sum of myriad - literally millions of - control mechanisms driven by different histories, goals, structures, and processes" (1997: 27). It therefore includes "the activities of governments, but it also includes the many channels through which 'commands' flow in the form of goals framed, directives issued, and policies pursued" (Rosenau 1995: 14). What follows from this perception are two different 'geographies' of global governance. One being considerably wide, encompassing those actions of states and non-state actors on the international level that involve non-hierarchical modes of steering, like intergovernmental or inter-organisational bargaining, and the other being more restricted, only including non-hierarchical modes that involve at least one non-state actor, such as global public policy networks. I take a middle ground, arguing that different modes and actor-constellations are positioned along a continuum from more traditional inter-state negotiations, which already involve non-state actors in the process of rule-making, to hybrid public-private partnerships, and fully private co-operations, institutions, and organisations.

These modes of governance differ according to the purpose and actor-constellation involved. Public forms of governance include the provision of services and implementation of international norms through comprehensive or issue specific international organisations, as well as rule-making in international negotiations. Public actor-constellations therefore may include international organisations, governments and government agencies. Hybrid forms of governance are often labelled with the general term public-private partnership (PPP), but include many distinct cooperative arrangements between public and private actors, involving governments, government agencies, subnational political authorities, international organisations, transnational corporations, global advocacy networks, and non-profit organisations. The third mode of governance is purely private in nature, involving firms, business associations, advocacy networks, think tanks, and non-profit organisations in the establishment and maintenance of global public goods through service provision, rule-making and its implementation.

Private Policy-Making in Global (Environmental) Governance

Partnership between various non-profit organisations, transnational corporations or global interest associations is not an entirely new phenomenon. But the fact that these co-operations often lead to independent institutions and organisations that apply new forms of governance, and thus bypass traditional ways of political influence, makes it a noteworthy phenomenon. To further clarify the concept of private governance institutions in environmental politics, I discuss various approaches to private policy-making in the following section. The focus is on how the concept of private governance institutions draws upon or departs from three prominent concepts addressing private governance, namely private sector international regimes, private organisations, and certification institutions.

The term *private sector international regimes* was first established in the field of industrial relations and commercial activity to denote institutionalised responses to state or market failure. As Virginia Haufler argues, a "mis-match between markets and politics in terms of governance" is responded to by the construction of private international regimes in many industry sectors (2000: 122). These private inter-firm regimes, understood as formal and informal norms, principles, rules, and decision-making procedures exercise a "form of self-regulation or rule-setting in the absence of an overarching global political regime" (Haufler 2000: ibid). Whereas the traditional debate on international regimes, by definition, has focused on the cooperation of states only, the concept of private inter-firm regimes broadens this narrow view to incorporate formal and informal institutions that are the source of governance for an economic issue area as a whole (Cutler, Haufler, and Porter 1999a: 13). Private inter-firm regimes differ from other forms of cooperative business-arrangements, such as industry associations, production alliances, and cartels, in terms of the breadth of their activity, often incorporating less institutionalised forms within their scope (Cutler 2002: 28-29). Consequently, private governance institutions incorporate private regimes within their scope, focusing explicitly on the rule-making function of these social institutions, but going beyond transnational business as the main driver of institutionalisation.

The second concept competing with private governance institutions, *private organisations*, starts from the assumption that the failure of states and markets to create stable environments for commercial and social transactions leads to the establishment of alternative governance mechanisms through private organisations (Ronit and Schneider 1999: 244), an argument resembling much of the theorised causes for the construction of private regimes. According to Ronit and Schneider, private organisations include *inter alia* the following: multi-national corporations, business associations, federations of trade unions, standardising associations, learned societies, think tanks, religious orders, sporting organisations and environmental groups (2000: 1). But research has been largely limited to global business actors, such as the International Chamber of Commerce (ICC), the International Federation of Pharmaceutical Manufacturers Association (IFPMA) or the Ecological and Toxicological Association of Dyes and Organic Pigments Manufacturers (ETAD) (Ronit and Schneider 1999).

In sum, the concept of private organisations aims at developing a "new and all-encompassing theory which integrates all private actors active in global politics," (Ronit and Schneider 2000: 7) not only focusing on those actors participating in the global policy cycle, but also incorporating organisations that assume responsibility for problem-solving through standard setting and self-regulation. Although the concept of private organisations is a substantive step forward towards understanding the complex structure and nature of private actors in global politics and remedies much of the conceptual impreciseness of the frequently used term 'non-governmental organisation', it still falls short of capturing the diversity of institutional settings and procedures that characterise private rule-making in the field of global governance.

In contrast, the proposed concept of private governance institutions differs from the concept of private organisations in five distinctive ways: first, it includes less formalised co-operations not qualifying as an independent organisation; second, it focuses on rule-making institutions only, thus excluding sufficiently debated issues of non-state actors' involvement in policy-making or rule-implementation on the international level; third, it highlights alternative actor-constellations within institutions and organisations; forth, it acknowledges the network character of many institutions; and fifth, it overcomes sharp distinctions between the profit and non-profit sector of society, focusing on their joint efforts to create and sustain global public goods instead.

The third rival concept to private governance institutions, *certification institutions*, contains two principal components: first, a set of voluntary norms and rules; and second, a reporting or monitoring mechanism (Garcia-Johnson 2001). Certification institutions are not typologised according to the actors and interests involved, as in the case of private governance institutions, but according to a more instrumental approach that highlights the distinct way of ensuring verification. Ideal types range from first-party certification, wherein organisations generate rules internally and report conformance themselves, to second-party certification, wherein firms and organisations work together to generate rules and report compliance, and third-party certification, wherein independent bodies set the standards and others report conformance (Garcia-Johnson 2001: 2). Although the concept of certification institutions adds to out general understanding of private governance by stressing the importance of reporting and compliance management, it does not offer a comprehensive concept of private-rule-making as a mechanism of global governance for two reasons: first, the concept of certification institutions emphasises the verification of compliance at the cost of the standard setting process; second, the concept does not distinguish the institutions according to the distinct societal actors involved in its formation and maintenance.

Turning back to the initial aim of clarifying the concept of private governance institutions with respect to other approaches proposed in the literature, a comprehensive definition can be offered, which covers different types of institutions as well as different instrumental approaches. Accordingly, a private transnational governance institution is a self-coordinated network of two or more private actors operating in more than one country (involving the non-profit and/or the profit sector of society), engaging in the establishment, implementation and monitoring of voluntary norms and rules (general codes of conduct, management standards or labels) directed towards a specific issue area, not being primarily profit-orientated. Nevertheless, the market provides the mechanism through which authority is, at least partially, allocated to distinct private institutions. It is the consumer, producer, trader, and retailer who legitimise a certain rule-making system.

NGO-Business Cooperation as a Private Governance Institution

Multi-stakeholder partnerships represent the most challenging type of private rule-making because they involve both the logic of the market and that of civil society. As a result, they align types of non-state actors that are perceived as strongly antagonistic. As Murphy and Coleman notice,

"'[p]artnership' is not the first word that usually comes to mind when one thinks about business and NGOs. Over the past three decades, most relationships between the commercial sector and civil society have been founded on conflict" (2000: 207).

The term *partnership* has predominantly referred to profit-making relationships between individuals, but in recent years gained prominence as a more general inter-organisational idea, including relations between various transnational actors, international organisations and states. Two events are generally believed to have triggered the transformation from confrontational strategies to those of partnership in the field of environmental politics, namely the public debate about Shell's involvement in the Ogoni case in southern Nigeria and the disposal of the Brent Spar offshore oilrig. After widespread public protest and consumer boycott, Shell's Chief Executive Officer Herkstroter highlighted the positive aspects of the Greenpeace campaign, and a partnership approach in general:

"We took decisions, which in retrospect were mistakes. We now realise that alone we could never have hoped to reach the right approach - that we should have discussed them in a more open and frank way with others in order reach acceptable solutions… In essence, we were somewhat slow in understanding that environmental groups, consumer groups and so on were tending to acquire authority" (Heap 2000: 3).

In more general terms, the concept of partnership refers to four important aspects that apply for local and global co-operations, whether public-private or private-private. First, partnerships have shared goals that are beyond profit-making, thus excluding purely market-coordinated relations or other private interactions to maximize profit. Second, partnerships can involve actors from different sectors of society; third, they have institutionalised relationships; and fourth, partnerships engage in rule-making and/or implementation, facilitating outcomes that would not be possible in absence of the specific partnership (Harding 1990; Kouwenhoven 1993; McQuaid 2000). Critical scholars have pointed to the fact that the term partnership represents a policy paradigm (Richter 2003: 9) based on the assumption of trust, shared benefits, and an underlying win-win situation, concealing the fundamentally different goals and power resources of the actors involved. This paper uses the concept of partnership as a value neutral term, equivalent with co-operation.

It is the concept of *green alliances* that addresses these unusual partnerships with respect to the idea of policy arrangements. The term policy arrangement "refers to the temporary stabilisation of the content and organisation of a policy domain," including policy programmes and discourses as content, and actors and their coalitions as organisations (Arts 2002: 4). These policy arrangements are influenced by the macro-societal process of reflexive modernization (Beck, Giddens, and Lash 1994) that effects the policy domain at the meso-level and forces actors to adopt to the changing environment. The debate about green alliances, defined as "collaborative partnerships between environmental NGOs and business that pursue mutually beneficial ecological goals" (Arts 2002: 2) highlights four important elements of 'private environmental policy arrangements' (Arts 2002: 4) that are relevant in the context of private-private governance institutions: the specific form that coalitions take, the internal power relations, the 'rules of the game' and dominant discourses (Arts and Tatenhove 2000).

In sum, the discussion of green alliances leads to a valuable understanding of transnational NGO-business partnerships as a distinct type of private governance institutions. Accordingly, cooperative arrangements between different sectors of society qualify as a private environmental governance institution, when they (a) aim at regulating a specific environmental issue area by voluntary norms and rules, including environmental management standards, labels and general codes of conduct, (b) can be considered a self-organising network of at least two transnational private actors, (c) represent both the profit and non-profit logic, and (d) reach some degree of institutional permanence over time.

3. Do Private Governance Institutions Matter? The Case of the Forest Stewardship Council (FSC)

Although, by definition, governance institutions are involved in the establishment of voluntary norms, rules and standards, they perform a wide range of additional functions, from facilitating a solution to a wide range of different interests to brokering knowledge, to constituting a learning network of individual and organisational actors.

Making the Rules

The idea of rule-making seems self-evident in most domestic and international contexts, but if we talk about rule-making by private institutions on the global scale, what do we refer to? From the perspective of regime theory, rules occur as four different types: (1) principles (beliefs of fact and causation); (2) norms (rights and obligations); (3) regulations (pre- or proscriptions for action); (4) procedures (decision-making rules) (Krasner 1983: 2). Principles and norms provide the basic characteristics of an institution, whereas regulations and procedures may change without altering the substantial content of a regime. To capture this important difference, some scholars have argued for distinguishing between constitutive rules on the one hand, and regulative rules on the other (Arts 2003; Giddens 1984). As a result, a change in the constitutive rules is understood to alter the institution as a whole, whereas a change in the regulative rules only implies a transformation of existing procedural, structural or substantive rules, such as a tightening of certain product standards or introducing additional aspects of environmental management.

Accordingly, standard setting in the context of private governance institutions is conceptualised as the act of agreeing on regulative rules. Standard setting, as opposed to the more general process of establishing and maintaining constitutive regulations, is consequently defined as the making of voluntary, expertise-based structural, procedural or substantive regulation (Kerwer 2002: 298). Standards can take the form of management schemes, labels or general codes of conduct. Although private standards are voluntary in nature, some degree of compliance is necessary to qualify as private regulation.

In sum, the concept of rule-making by private institutions includes both constitutive and regulative rules. But whereas the former are considered to be an important prerequisite for enhanced cooperation between different actors, the latter are understood as the functional output of governance institutions. Private standards in global environmental politics therefore include product as well as process standards. They are applied above the national level and, as voluntary regulations, include management standards, codes of conduct as well as labels. But regulative rules set by private governance institutions in the field of environmental politics not only contain prescriptions of behaviour directed towards the environment. They also define who accounts for the compliance with management standards, codes of conduct or labels, and under what rules. As discussed in section two, governance institutions employ three basic types of reporting compliance with their voluntary standards: first-party reporting (self-assessment), second-party reporting (joint assessment), and third-party reporting (independent assessment).

To better illustrate the rule-making function of private governance institutions, I now turn to the FSC as an empirical example of a multi-stakeholder partnership within the wider context of global environmental governance and industrial transformation. The Forest Stewardship Council was founded in 1993 by a general assembly of interested parties in Toronto, Canada. Among the 126 participants from 26 countries were concerned individuals and representatives from a wide range of organisations, including WWF, Greenpeace, Friends of the Earth, retailers, trade unions, and indigenous interest groups. Although consultations among forest producers, retailers, and environmental and social interest groups had been going on since 1990, it was not until 1994 that the founding members of FSC agreed upon the "FSC Standards and Principles," the substantive basis of FSC's work with regards to definition and implementation of sustainable forestry (FSC 2000).

The General Assembly (GA), a tripartite body that represents business, social, and environmental interests within three chambers, governs the FSC. Each chamber has equal voting power; internally they have a 50% quorum for north and south representation as well as a limitation of individual votes to 10% of the respective chamber. The GA elects a board of directors that mirrors the principal governance structure. Each chamber sends three members to the board for a three-year term. The representation of northern and southern countries alternates between four and five, changing every three years. The board decides on all issues of major importance, from approving national representatives and initiatives of the FSC, to allocating the annual budget, to approving new standards. The operational work of the FSC is handled by the FSC international secretariat located in Bonn, Germany, and supervised by the Executive Director who is appointed by the board. Whereas the day to day operations of the FSC are in the responsibility of the international secretariat and its executive director and questions of major importance are decided by the board of directors, only the general assembly is authorised to change the fundamental "standards and principles" as well as the statutes of the FSC.

As a private institution, the FSC produces three different basic types of standards, which constitute the regulative outcome of the institution. First, global forest management standards that form the basis for national and regional standards development; second, chain of custody standards prescribing detailed rules along the production chain; and third, standards for accreditation. The standards are developed and drafted by the standards and policies unit within the international secretariat and later approved by the board of directors. The standard setting procedure involves consultations with all relevant stakeholders. Explicit provision shall be made to ensure "that stakeholders whose interests are often marginalized are empowered to take a full and active part in the development of standards" (FSC 2003: §9). Often technical committees are formed to include the expertise of forest managers and producers along with the normative guidance of non-profit actors. For example, recent debates about percentage based claims included technical experts on paper production and representatives from environmental NGOs to ensure the technical feasibility of producing paper out of recycled raw material and FSC certified timber as well as the acceptable decision on how much the FSC timber must be included in a certain product to carry the FSC trademark.

But the FSC does not only establish regulative rules on sustainable forestry, but also substantive 'rules of the game', from formal regulations on governance structure, voting rights, and complaint procedures to informal norms, such as appropriate behaviour in conflict situations, style of communication, and self-recognition.

Facilitating a Solution

By bringing together many different actors and interests within one forum, by verifying these commitments, and by providing a model for other actors and other issue areas, the FSC provides an institutionalised solution to global environmental problems.

The FSC provides different types of fora to its members and stakeholders through which discussion processes are enhanced and consensus on diverse issues can be reached. The central forum is the general assembly that comes together physically every three years but is frequently asked to decide on various issues by mail or E-Mail. Next to the international GA there are currently 31 national initiatives (NI) that provide institutional space for discussions on the national and regional aspects of standards and principles, as well as on specific areas of concern. The recent decentralisation of the FSC's geographic structure has resulted in the creation of four regional offices, Europe, Africa, Latin America, and Asia, that organise regular meetings of all national initiatives within a region, thus enhancing cooperation among national initiatives as well as among the stakeholder groups and individuals. The fourth type of forum for close stakeholder contact is provided by expert involvement in the development of rules and standards. The technical and standard committees for example involve many relevant interests in the process of standard setting by providing an open-access Internet forum for direct stakeholders and the general public.

Next to providing a forum for discussion and consensus building on technical and practical aspects of forest certification, the verification of fundamental commitments is an important prerequisite for providing an institutionalised solution to the forest problem. Ensuring compliance with the forest management and chain of custody standards is essential to the effective operation of FSC because transparency, reliability, and neutrality constitute the basis of FSC's credibility. Demands in this respect are highly divergent. For forest owners and managers it is highly important that FSC enforces comparable standards in every country and region, so as not to distort market competition. Retailers are interested in a transparent standard that is easy to communicate to consumers, whereas environmental NGOs demand environmentally accurate performance by forest managers and timber producers.

The FSC seems to have found a credible solution to all these different demands regarding the verification of standard compliance. The central idea is to accredit certifiers on the basis of FSC standards, which then issue certificates to forest management units or producers. The accreditation business unit of the international secretariat carries out this process of accreditation. Accreditation is defined as "the procedure by which an accreditation body gives written assurance that a certification body conforms with the requirements of an accreditation system" (FSC 2002b: Glossary). The accreditation body conducts and administers the accreditation system and formally grants accreditation. In case of the FSC, accreditation is proposed in a final accreditation report, which is filed by the accreditation body, and than approved by the board of FSC.

In sum, the mechanism of accrediting independent certification bodies ensures that all major demands of stakeholders regarding constant verification and compliance management are met. The importance of FSC's credibility and neutrality is also underscored by the current debate over outsourcing the accreditation business unit to further enhance its independence from FSC. In addition, an independent accreditation unit would also meet the ISO requirements for accreditation bodies, another prerequisite for enhanced credibility.

The third pattern through which the FSC institutionalises problem solving in global environmental politics is providing a model for successful cooperation for other actors and within different issue areas. Consider the close organisational resemblance between the FSC and the Marine Stewardship Council (MSC). Both institutions are private-private co-operations between non-profit organisations and business actors, and are involved in standard setting, accrediting certifiers, and granting labels for products and production chains. The WWF was a key player in the establishment of both the FSC and MSC. Already in 1997, WWF and Unilever launched the MSC as a close private-private partnership. As a result, the governance structure is markedly different from that of FSC, because both partners decided not to include other stakeholders in the negotiations of standards and principles. Further, the MSC is not a membership organisation, but is governed by a board of trustees appointed by the two founding institutions. Stakeholders are represented in the Stakeholder Council along a public interest and a commercial/socio-economic category (Marine Stewardship Council 2003).

But nevertheless, the specific model of stewardship provided by the FSC, combining expert standard setting with independent third-party certification, proves to be successful in the field of marine resources as well. As a formally independent institution, the MSC today certifies seven highly valuable fisheries worldwide; 13 are currently in the process of full assessment. The certification/stewardship model won further support in 2001 when, after publishing its core standards, the Marine Aquarium Council (MAC) became the second private governance institution modelled after the FSC. Although the FSC cannot claim to have invented the idea of environmental and social certification, its individual success transfers the model of normative standards setting and economic incentives to other issue areas. As a result, the scale and scope of private environmental governance increases, whereas traditional forms of public environmental governance seem to be on the retreat.

In sum, the FSC can be understood as a solution-facilitator in global environmental politics through three inter-related mechanisms: first, the FSC brings together many divergent actors in institutionalised fora to negotiate standards and procedures and to build general consensus on important issues; second, verification of compliance is ensured through an independent third-party mechanism, which raises the FSC's acceptance within all stakeholder camps; third, the successful application of expert standard setting and independent monitoring constitutes a model for other actors and issue areas, providing a solution beyond the narrow realm of forest politics.

Brokering Knowledge

Next to providing an institutionalised solution to a complex environmental and social problem, the FSC acts as a knowledge-broker for many different interests. Most obvious is the aspect of producing and disseminating information. As I have argued above, standard setting is, by definition, based on specific expertise. Agreeing on regulative rules in such complicated issue areas as chemical substances or marine biodiversity requires not only substantial theoretical knowledge, but also a great deal of practical experience. These substantive and organisational prerequisites allow private actors to take a leading role in standard setting, precisely because most public actors lack the necessary theoretical and practical resources. In contrast to public actors, the network character of private governance institutions and the resulting close incorporation of relevant experts in the process of rule making produces very detailed standards, outperforming many international regulation. The aforementioned FSC standards and principles for sustainable forestry currently cover more than 43 million hectares of forest in 73 countries, whereas the intergovernmental negotiation process under the auspices of the United Nations fell short of producing considerable results. The very diverse and broad knowledge base that the FSC is able to draw upon can partially explain this difference. As noted above, a standard setting process usually involves not only technical experts and NGO representatives, but also concerns practitioners and the wider public. I addition, the specific, decentralised structure of the FSC makes it easy to integrate local and national knowledge whenever appropriate.

But whereas the FSC has been rather successful in creating information and communicating this information to members and stakeholders as well as to specific segments of the market, FSC's record is rather weak on influencing public opinion on the problem of deforestation and forest degradation in general. This weakness in raising public awareness can mainly be attributed to the specific governance and stakeholder structure of the FSC, which supports an effective outsourcing of awareness-raising campaigns to other actors, especially the environmental NGOs within the FSC. They run regular campaigns on the forest problem and consequently advertise the FSC as the only viable solution, thus contributing to a rise in the overall knowledge on FSC. But business actors also take over public information functions from FSC, when, for example, retailers inform their customers about the problems of deforestation in order to promote themselves as environmentally sensible corporations.

Learning in Networks

The institutional structure of FSC facilitates two types of learning processes. The first could be described as intra-organisational learning and includes processes of self-evaluation and resulting organisational restructuring. This topic has been extensively covered within management science, especially in the literatures on economic history, industrial economics, and the theory of the firm (Dodgson 1993: 375). Although the concept of organisational learning is highly contested (Fiol and Lyles 1995) and there is no commonly accepted definition of what the concept refers to in terms of outcome and process, I propose the following minimal definition: organisational learning can be described as the way an organisation builds, supplements, and organises knowledge around its activities, resulting in a change in organisational structures and procedures.

One example for organisational learning within the FSC is the self-evaluation process conducted by the so-called 'Change Management Team' (CMT). Established by the former executive director Maharaj Muthoo in 2000, the six-member team conducted numerous interviews with stakeholders and staff members to identify internal and external challenges as well as possible strategic directions of the FSC. The CMT presented a report that the board adopted in 2001. It recommended eight steps to ensure FSC's future success in its mission of promoting environmentally appropriate, socially responsible, and economically viable forest management, such as empowering national and regional initiatives, improving the recognition of the FSC brand, and moving the headquarters to an international setting (FSC 2002a). Further priorities to ensure a healthy future for the FSC were suggested, inter alia: professionalising the communication activities, separating accreditation and standard setting functions, and securing an independent financial basis through enhanced fundraising efforts. Many of these recommendations are currently in practice. For example, FSC's communication services have substantially improved since the year 2000, today offering standardised communication templates, comprehensive fact sheets for quick information as well as a more service-orientated web site. In addition, the strategic relocation of FSC headquarters to an international setting has been completed with moving to Bonn in 2002 as well as the envisaged decentralisation, which was finalised by the establishment of the fourth independent regional centre, located in Africa.

These observations suggest that organisational learning is taking place within the FSC. Although the described process is quite formalised and was imposed by the FSC leadership, organisational learning drew on the many individual resources of staff members and stakeholders in order to change the organisation's procedures and practices in key areas. From this perspective, organisational learning in the case of the FSC is not only the result of a management decision, but also an outcome of the specific organisational structure and culture of the FSC, which supports flexible knowledge production and stakeholder involvement as important prerequisites for effective organisational learning (Fiol and Lyles 1995: 804-805).

The second type of learning could be labelled inter-organisational learning, involving very different types of actors. From this perspective, the FSC constitutes the institutional core of a wider learning network, including members, first and second order stakeholders as well as the general public. A learning network can be defined as an inter-organisational network combining the voluntary efforts of autonomous organisations in order to overcome complex challenges through the formal and informal exchange of knowledge. Such inter-organisational networks are characterised by three distinct features: first, inter-organisational networks operate as rather abstract conceptual systems that enable organisations to overcome complex problems; second, networks evolve around shared visions, purposes, and goals; and third, inter-organisational networks rest on horizontal organising principles rather than centralised power (Chisholm 1998: 6). Learning is facilitated by these features of inter-organisational networks for two reasons: first, horizontal structures and the lack of central power are important prerequisites for the exchange of information within a network; second, mutual visions and a shared perception of problems and possible solutions enable communication between very divergent organisations.

The FSC constitutes a learning network that includes very different organisational actors. This organisational diversity, both in structure and content, seems to facilitate effective learning processes. Consider the example of leading retailers of wood products. It was the specific structure of the FSC as a network of local, regional, and global organisations that has led to successful learning. Only the involvement of local and regional experts, forest managers, and producers enabled retailers to learn about the many unnecessary intermediate traders participating in the business. The result was a cheaper product for the retailers and at the same time a higher profit margin for local producers and managers. But network learning processes within the FSC do not only occur because dissimilar organisations learn about possible win-win situations, but also because similar organisations learn from dissimilar procedures. The general assembly and other formal or informal meetings between stakeholders provide opportunities for learning that would not exist in absence of the network. Social organisations, such as trade unions or indigenous peoples associations, meet with environmental NGOs to exchange strategies and substantive information. As a result, organisations often enrich their strategic toolkit as well as their general organisational culture. For historic reasons, the environmental chamber of the FSC has been the best organised in terms of resource mobilisation, shared visions and resulting policy motions. But business and social interests are catching up as a direct result of learning processes within the FSC network.

In sum, the FSC can be considered a learning institution in two ways: first, the FSC shows distinct features of intra-organisational learning, mobilising the very different experiences of its staff members and stakeholders and turning them into effective organisational restructuring; second, the FSC is an inter-organisational learning network of many diverse actors that facilitates effective learning processes exactly because of the organisational dissimilarity of its members.

4. Conclusion

In this contribution I have argued that we can make sense of many emerging phenomena in global environmental politics by applying the concept of private governance institutions, to denote changes in both the structure and impact of private policy-making. The current institutionalisation of cooperation between divergent private actors, including corporations, environmental non-profits and social interest organisations, is a noteworthy trend in global politics because the resulting transnational rules transcend our understanding of international relations. Although some literatures do address private institutions as important factors in global governance, the phenomenon still lacks a coherent and encompassing approach, which unifies competing views to improve our theoretical and empirical knowledge under one conceptual framework.

Therefore, global governance has been introduced as the appropriate lens to analyse basic trends that separate the study of contemporary global environmental politics from more traditional accounts of international relations. Next to intergovernmental negotiations and public-private partnerships, private actor-constellations take up the function of rule-making in global environmental politics. In contrast to other, rival concepts of institutional partnership put forward in the literature, such as private sector regimes, private organisations or certification institutions, the concept of private governance institutions joins together the three key features of the phenomenon in question: first, the private nature of the respective body, distinguishing it from hybrid private-public partnerships; second, the distinct mechanisms of rule-making, clearly excluding forms of rule-implementation or service provision by private actors; and third, the institutional character, allowing for both highly formalised organisations and less formalised initiatives. The detailed analysis of the Forest Stewardship Council has shown that private institutions in global environmental governance perform various functions. Next to standard-setting, these functions include: providing an institutionalised solution to global environmental problems, producing and disseminating knowledge to a wide range of stakeholders, and providing an arena for learning, both inside the FSC and among a network of independent organisations.

What can be learned from the analysis of private institutions in global environmental politics with respect to the specific questions of the conference and Industrial Transformation research in general? I believe the following three observations to be the most important: first, industrial sectors, such as the forestry sector, are currently being transformed by private actors, with the effect that the 'rules of the game' within one sector no longer necessarily emanate from the international system alone. Second, important changes to certain production and consumption systems originate from co-regulation between antagonistic actors, such as transnational corporations and environmental organisations. And finally, the market, as one of the principal modes of governance next to hierarchies and networks, occupies a prominent role in the allocation of impact and the resulting success of private governance.

Although future research has still to assess the precise impact of private institutions as mechanisms of global governance and their respective effectiveness in solving environmental problems, the results of this contribution indicate that the analysed new private institutionalism in environmental politics could contribute to the much needed sustainability transition. The perennial question thus is not if private partnerships can help to transform the current industrial system into a sustainable one, but rather how their valuable contribution can be integrated into a democratic and legitimate governance of global environmental affairs.

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Could Too Little and Too Much Turn Out to be Just Right? – On The Relevance of Pioneering Environmental Policy[1]

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1. Introduction

Frequently a national "going-ahead" of environmental policy is proposed, e.g. by the German Council of Advisers on the Environment (SRU 2001). This request for a stricter environmental policy is often rationalized by the proposed prospect of advantages for national enterprises, resulting in higher domestic employment and output (Porter 1991; Porter, van der Linde 1995). Politicians take up this argument to promote environmental regulation. An opposing view holds that stricter environmental policy deteriorates competitiveness and induces capital flight. This position implies a rational for eco-dumping.

The prospects of an environmental policy designed to improve international competitiveness and welfare of a country have been investigated in the theory of strategic environmental policy (Fees, Taistra 2001). While a negative effect on national welfare of a stricter environmental policy can be easily explained, a positive effect seems to be much less straightforward. Various theoretical models have been developed though, which show the possibility of welfare increases of stricter environmental policy.

A number of empirical studies - surveyed in Scholz and Stähler 1999 – can be identified which have looked for evidence of the impacts of environmental policy on international competitiveness. These studies did not find a strong positive or negative effect of environmental policy on international competitiveness. The question of whether environmental policy is actually used in an attempt to improve international competitiveness has remained unresolved, however. This is particularly true for the case of stricter environmental policy.

[1] We are indebted for helpful comments to Susanne Droege and Klaus Jacob. All remaining insufficiencies are ours.

The present chapter looks for evidence of the existence of pioneering environmental policy, i.e. strategic environmental policy which is designed stricter than in other countries in order to gain advantages for national enterprises.. For this purpose we screen a series of case studies. We find that evidence of pioneering environmental policy is elusive. We explain this result by the restrictive nature of the conditions for the success of pioneering environmental policy as identified in different attempts to find a rational for such policy in economic theory . We show that these conditions are actually not given in any of the case studies. We conclude by arguing that pioneering environmental policy may still be welfare enhancing as it may be instrumental to overcome the well known prisoner's dilemma in international environmental policy.

In the following section we present a definition of pioneering environmental policy and propose operational criteria for the presence of such policy. We then list the criteria for a successful pioneering environmental policy derived from the theoretical literature. Next we present the evidence from the case studies. Finally we present our argument for the welfare enhancing effects of pioneering environmental policy.

2. Definition and Criteria of Pioneering Environmental Policy

Pioneering environmental policy is understood to set national environmental standards in excess of their optimal level.[2] Such policy imposes a cost on society. It has been suggested, however, that this cost is more than offset by advantages gained by national economic agents on international markets (Porter 1991).

The state of the environment can be targeted in a multitude of ways. Basically we can distinguish between non-restrictive and restrictive policies. Among the former ones are subsidies for environmental R&D, for example. The latter ones comprise command and control policies of all kinds as well as environmental taxes and permit schemes. The debate around pioneering environmental policy relates to the apparent "puzzle" that more restrictive policies can be advantageous. Therefore we look at restrictive policies only.

Detecting pioneering environmental policy is difficult, because the optimal level of environmental policy – determined by marginal costs and benefits - is usually not known. Instead, objectives of environmental policy are derived from scientific reasoning, sometimes modified by cost and distributional considerations. Often environmental policy does not even address the state of the environment directly, but targets environmental pressures in a way which is only indirectly related to the actual state of the environment.

Therefore a precise benchmark for identifying pioneering environmental policy is not available. Nevertheless we can use a set of criteria to look for the presence of such policies. For the purpose of the present chapter we look for environmental policies

- which restrict the use of the natural environment,
- which - in comparison to environmental policy of other countries at the same time - impose more severe restrictions on agents, thus raising their costs,
- which politicians rationalize by international offsets.

3. Evidence of Pioneering Environmental Policy

Looking for empirical evidence of the existence or non-existence of pioneering environmental policies we screen a series of in-depth case studies. These are part of an interdisciplinary research project titled *Policy-Frameworks for the Development of Interna-*

2 Sometimes such policy is termed excessive environmental policy (Feess, Taistra 2001: p.1).

tional Markets for Innovations of a Sustainable Economy - from Pilot Markets to Lead Markets[3], *which* looks at the conditions for the establishment of lead markets for environmental friendly innovations. A country (or region) is defined as a lead market for a specific technological solution

- if it is the place where this technology is developed and adopted in an early phase (a pilot market) and
- if it is in a position to shape the world markets such that this technology diffuses internationally.

One focus of the case studies is the mixture of policy instruments which has been implemented in each country to foster the generation and (international) diffusion of specific technologies. The technologies which were more closely investigated include[4]

- technologies with potential to substitute paper by electronic media
- fuel cells for mobile applications
- fuel cells for stationary applications
- technologies for emission reduction in Diesel powered cars
- paints with VOC (Volatile Organic Compounds)-free or VOC-reduced solvents
- technologies for paper recycling
- photovoltaic energy conversion

In the case study which deals with technologies with potential to substitute paper by electronic media environmental policy instruments do not play any role at all as the application of these technologies is motivated by non-environmental concerns. Therefore this is not a case of pioneering *environmental* policy.

Fuel cells for stationary applications and especially for mobile applications are in an early stage of product development without any broad commercial market penetration. It seems to be not yet decided which of the numerous alternative designs may become dominant in the future. The direct policy instruments involved are therefore mainly R&D-related. R&D is motivated by future strict clean air requirements. Environmental policy instruments thus have more an indirect impact defining the long-term framework conditions for these technologies. For the time being this does not restrict competitiveness of the national (local) industry. California being the region with the strictest regulation with respect to mobile fuel cells is unlikely to pursuit strategic objectives as it is not home of a strong automotive industry.

In the case study about emission reduction in Diesel powered cars, on the one hand, a prominent role is taken by clean air regulation in Europe and the US and market-oriented instruments like fuel taxes and tax exemptions . On the other hand technology-forcing and the strategic behaviour of multinationals are important. The strategic R&D behaviour of a competitor (Peugeot) created a technological breakthrough, however, this was not the result of strategic environmental policy.

The case of paints with VOC-free or -reduced solvents is characterized by a variety of product -related instruments, ranging from command-and-control, market-oriented

[3] The research project is sponsored by the German Federal Ministry of Education and Research as part of the research program on *Frameworks for Innovation towards Sustainability (RIW)* (Grant number 07RIW1A). For intermediate results of the project see Beise et. al. 2003.

[4] Beside this a number of a literature based case studies were also screened for information concerning pioneering environmental policy; the technologies under investigation include fuel-efficient passenger cars, wind energy, substitutes for CFCs as coolant in refrigerators for private households, chlorine reduced pulp production, introduction of the catalytic converter for cars and black liquor gasification.

instruments to labelling and voluntary agreements. The number of internationally applied instruments has increased significantly since the beginning of the Eighties. The additional cost for users increase only marginally as a consequence of these regulations and a strategic orientation can not be identified.

The amount of paper recycling is strongly influenced by regulation on waste paper recovery. While some countries have more restrictive recovery requirements the costs are mainly borne by private households. Therefore, the competitiveness of firms is not affected. Also no strategic objectives of environmental policy are presented to justify the environmental regulation.

The photovoltaic energy conversion case has to be seen in the context of climate change protection. The promotion of renewable energy is one strategy to reduce CO_2-emissions. Different instruments like R&D-subsidies, environmental taxes and guaranteed prices for energy from renewable resources (so called renewable energy feed tariffs (REFIT)) are used to increase the installed capacity of this technology. The case of Japan deserves some closer attention. The commitment to comparably demanding CO_2 reduction goals in the Kyoto protocol could be viewed as imposing more severe restrictions on domestic actors than on actors in foreign countries. While in Germany REFIT´s have induced a large increase in wind energy production (and to a lesser extent of photovoltaic capacity)[5], Japan has decided to bet on the development of photovoltaic energy conversion.[6] Japan used a variety of instruments to promote photovoltaics[7]. Beise 2003 argues that the decision in favour of photovoltaics was to a large extent motivated by the expectations about the future success potentials for Japanese exporting firms on the world market. Given the already established competitive semiconductor industry in Japan the future gains on the world market looked more favourable for photovoltaics than for other equipment markets for the production of renewable energy. At least this could be viewed as an example of policy in the line of strategic environmental policy. Although in this case there exists a clear strategic orientation of environmental policy, cost increases for domestic companies are avoided. Instead the cost of this policy is broadly distributed to all taxpayers.

Table 1: Presence of Criteria of Pioneering Environmental Policy

Cases	**Environmental Policy**	**Restrictive, cost inducing, competitiveness impeding**	**Strategic orientation**
Technologies with potential to substitute paper by electronic media	-	-	-
Fuel cells for mobile applications	(X)	-	-
Fuel cells for stationary applications	(X)	-	-
Technologies for emission reduction in Diesel powered cars	X	(X)	-
Paints with VOC (Volatile Organic Compounds)-free or VOC-reduced solvents	X	(X)	-
Technologies for paper recycling	X	(X)	-
Photovoltaic energy conversion	X	(X)	X

5 By using this instrument only grid-connected systems were promoted, while there is strong indication that the world market for photovoltaic systems will be dominated by the demand for stand-alone/non-grid systems.

6 The natural conditions for wind energy and for photovoltaic in Japan are said to be comparable – not favouring one of the two alternative technologies.– From an international comparative perspective they are not really good for both technologies.

7 Governmental and public institutions were urged to install units; photovoltaic systems were declared as building material opening up tax benefits. See Beise 2003, p. 5

The table demonstrates that it is difficult to identify examples, in which – compared to other countries at the same time- a stricter regulation is imposed, which negatively affects the costs of companies. Costs are usually broadly spread over to private households or taxpayers. Indications of a strategic motivation of environmental policy seem to be very rare.

4. Why Evidence of Pioneering Environmental Policy is Elusive

A rationale for a pioneering environmental policy is given by the Porter hypothesis (Porter 1990, Porter, van der Linde 1995). It states that environmental regulation does – regularly - not reduce the profits of firms. Instead it exerts pressure, leading firms to realize previously undiscovered advantageous innovation opportunities.

At a first glance this proposition seems to suggest that firms systematically overlook profitable investment opportunities. There is a number of explanations of such behaviour.[8] For example, economic models can produce this result as second best outcome in principal-agent constellations under asymmetric information (Holmström, Tirole 1987). If the cost of compliance is more than offset by cost savings through innovation, the environmental policy stimulating such innovation creates a cost advantage relative to foreign competitors, but only as long as environmental policy abroad does not follow.

1. Complete Offsets

If the cost of compliance is more than offset by cost savings through innovation, pioneering environmental policy is advantageous as long as environmental policy abroad does not follow.

However, many economists have remained sceptical that this is generally the case (Palmer, Oates, Portney 1995). Then the question arises if independent of such inefficiencies a pioneering environmental policies can be successful in increasing the share of domestic companies in international markets and increase national income and employment[9] (Stähler 1998)[10].

Game theory-founded environmental economics supports the view that under incomplete competition strict environmental policy implemented in advance of other countries – even while increasing costs to regulated companies – can improve the competitiveness of domestic enterprises under certain conditions (Ecchia, Mariotti 1994; Feess, Muehlheusser 2002 (emphasizing the profits of suppliers of environmental technologies as a justification for a pioneering environmental policy); Feess, Taistra 2001; Scholz, Stähler 1999; Taistra 2000; Ulph 1996; Ulph, Ulph 1996, Ulph 1999)[11].[12]

8 Besides plain inefficiency and manager-owner conflicts there may be bounded rationality leading to local search, incomplete information on the benefits of an innovation, a prisoners' dilemma among firms because of spillovers or asymmetric information of customers.

9 The welfare effects for the national economy comprise producer rent, consumer rent, government revenues and domestic environmental quality. If firms produce for third markets only, the consumer rent becomes irrelevant from a national perspective.

10 The market share of domestic companies in international markets is an indicator of sectoral competitiveness. It does not necessarily imply an increased competitiveness of the overall economy. Using this indicator corresponds to the view of strategic environmental policy as a form of industrial policy. See Scholz, Stähler 1999.

11 Under certain conditions maximization of national welfare requires eco dumping instead of a pioneering environmental policy (Barett 1994).

Different Mechanisms Are Suggested As Being Able To Explain This Result:

Strict environmental policy can incite companies competing simultaneously in prices on oligopolistic international markets (Bertrand competition) to behave more aggressively.[13] Strict environmental policy increases the costs of domestic firms, firms increase their prices, and foreign firms react by increasing their prices as well: companies in both countries move towards monopoly. This increases producer rent. However, domestic overall welfare increases only if production is sold to foreign countries.

2. Rent Shifting

We state that pioneering environmental policy may be advantageous under simultaneous price competition on oligopolistic international markets if polluting firms export most of their output.

A strict environmental policy may induce innovations of polluting firms which c.p. reduce their unit costs.[14] Without strict policy the innovation is not a credible strategy. If the cost advantage of the innovation exceeds the additional costs of the pioneering policy (higher environmental taxes), firms can choose an aggressive strategy in quantities. Foreign firms – if not supported by their governments – will then reduce their production in order to avoid having to accept lower prices. In addition, foreign firms may reduce their innovation efforts.

3. Strategic Innovation

If innovation is feasible for polluting firms, innovation is a strategic component in competition, but the innovation is not a credible thread, the scope for the possibility of a welfare enhancing pioneering environmental policy is expanded to competition in quantities. Note that a diffusion of the policy could nullify the advantage of the domestic firms.

A stricter environmental policy chosen in a country may be advantageous if learning of polluting firms reduces unit costs. If then the environmental policy diffuses to foreign countries, domestic firms can gain market share. At this moment foreign companies have to adopt the new technology which is initially more expensive, while domestic companies, due to learning, have much lower costs. It is important that foreign environmental policy neither follows too early, i.e. before learning has become effective, nor too late, in which case domestic enterprises will bear higher costs than their foreign competitors over an extended period.[15]

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12 This corresponds to a general result of game theory: restricting the options of a player can be advantageous if this influences the decisions of other players in a way favourable for this player.

13 Contrary to Barret 1994 Feess and Taistra 2001 suggest that pioneering environmental policy may be justified under Cournot competition if polluting industries are export-oriented.

14 A similar effect arises if pollution is an inferior input, i.e. emissions decrease with output. This is the case if there are economies of scale in abatement. Greaker 2003 shows that the environmental agency then should choose excessive standards if two firms simultaneously compete in quantities.

15 There must also be some uncertainty about the following of the foreign environmental policy, because otherwise foreign firms anticipate the following and adopt the innovation

4. Learning

A pioneering environmental policy can increase welfare if domestic polluting firms display learning effects and a diffusion of the environmental policy is induced not to early and not to late.

If a domestic industry producing clean technologies (or tradable services) exists which displays increasing economies of scale, e.g. through learning effects, the authorities may set strict standards in order to increase the domestic demand for clean technologies.[16] This happens if the reduction in output of the polluting industry through higher standards is less important than the increase in avoidance effort per unit of output. Unit costs of the industry producing clean technology decreases and it can gain profits from selling its products to foreign polluting firms. A similar argument holds if the technology can be effectively protected by patents. These gains are higher if the strict policy is also introduced in the foreign country. If there are spillovers, foreign firms could benefit from a second mover advantage. In order to be welfare enhancing, foreign demand for output of the domestic polluting industry which has to bear the higher cost of strict regulation must have a low price elasticity.

5. Advantage for Environmental Industry

A pioneering policy is justified by welfare gains if strict environmental policy increases the demand for clean technology produced by a domestic industry which displays increasing economies of scale or is able to protect its innovation by patents, and if this industry can export its products to foreign markets while the export performance of polluting firms is not impeded.

There is a number of general considerations which cast doubt on the relevance of the hypothesis that a pioneering environmental policy enhances national welfare. In particular, firms could relocate if environmental policy is tightened. Also, for innovation they could seek international co-operation. Then advantages can not be attributed to one nation only. Similarly, if multinational firms are affected, it is difficult to see how welfare of a nation is affected. In addition, it is generally assumed that in reaction to a pioneering environmental policy counter measures are not taken in other countries.

We conclude that there are a number of models in which a pioneering environmental policy - while increasing costs to regulated companies – can enhance domestic welfare. However, the conditions under which this holds are rather restrictive. Generally, precise information on whether these conditions are given is not available. Some conditions are even ambiguous: sometimes a diffusion of environmental policy to foreign countries is required, sometimes it is harmful. This may explain the hesitation of governments to actually implement pioneering environmental policies.

From a more general perspective some of the necessary prerequisites for engaging in pioneering environmental policy seem to be potentially present in the case studies.

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immediately.

16 It is important that increased demand leads to innovations of *domestic* firms which can subsequently be exported. This is the core of the Lead Market Hypothesis. See Beise et al. 2003.

About 40 items, organized in a common analytical framework, are used to characterize the specifics of each of the case studies. Broader dimensions which were used for characterization include

- involved actors
- characteristics of the underlying environmental problem
- types of policy instruments
- country and market specifics
- characteristics of innovation
- impact and characteristics of (environmental) policy measures

Looking for factors which have been identified frequently in the case studies as being relevant it can be noticed that

- integration into the world market and
- technological competence

of the lead market countries are viewed as decisive factors in most cases. The relevance of technological competence is underlined by the fact that the demonstration effect of a domestic application of new technologies is considered as important for the international diffusion of the innovation. It should be noted, however, that additional incentives for exporting do not play any important role for the policy measures identified in the case studies.[17]

At the same time countries with lead market potential often have the image of environmental frontrunners. The international diffusion of environmental regulation, e.g. the diffusion of specific instruments between countries, from a frontrunner country to followers, has also been identified as a common pattern in many case studies.

While at a more general level the conditions for pioneering environmental policy seem to be potentially present in many case studies, a closer look shows that this actually often not the case.

If we look at the possible (theoretical) mechanisms which make strategic environmental policy advantageous from a national perspective, namely

1. complete offsets
2. rent shifting
3. strategic innovation
4. learning
5. advantage for environmental industry

the first four mechanism relate to advantages for polluting firms (as adoptors of enforced new environmental technologies) and only the last mechanism relates to the technology producing industry.

However, in almost all of the case studies the relevant mechanism which could possibly create an advantage for domestic firms is an internationally successful environmental industry.

[17] Due to WTO rules direct incentives for exporting are generally problematic, so that direct measures might be avoided, perhaps sometimes substituted for by softer forms of indirect measures.

Table 2: Potentially Advantageous Economic Mechanisms

Cases	**Mechanisms**
Technologies with potential to substitute paper by electronic media	not applicable
Fuel cells for mobile applications	Environmental Industry
Fuel cells for stationary applications	Environmental Industry
Technologies for emission reduction in Diesel powered cars	Environmental Industry
Paints with VOC (Volatile Organic Compounds)-free or VOC-reduced solvents	Environmental Industry and/or learning
Technologies for paper recycling	Environmental Industry and/or learning
Photovoltaic energy conversion	Environmental Industry

Above we have identified theoretically the conditions for an environmental industry to be successful in international markets and in overcompensating disadvantages for the regulated polluting industries:

- the existence of a domestic environmental industry[18]
- increasing economies of scale or patent protection as prerequisite for international competitiveness of the environmental industry
- chances to export to foreign markets induced e.g. by policy diffusion
- unimpeded competitiveness of polluting firms.

The following table demonstrates that it is doubtful that all necessary conditions – as required by theoretical models – are satisfied simultaneously. Therefore politicians can not be sure that pioneering environmental regulation will benefit domestic companies. In addition it should be noted that multinational enterprises are involved in all cases under consideration and that their presence makes the idea of national advantages by means of pioneering environmental policy ambiguous.

[18] In two cases (clean air regulation for mobile fuel cells applications in California, regulation on VOC-free paints) strict regulation is enacted without the existence of a (strong) domestic industry.

Table 3: Necessary Conditions for a Successful Environmental Industry

Cases	Domestic en-vironmental industry	Increasing economies of scale or patent protection	Export chances/ Policy diffusion	Unimpeded competitiveness of polluting firms
Technologies with potential to substitute paper by electronic media	n.a.	n.a	n.a	n.a
Fuel cells for mobile applications	-		?	-
Fuel cells for stationary applications			-	?
Technologies for emission reduction in Diesel powered cars			?	?
Paints with VOC (Volatile Organic Compounds)-free or VOC-reduced solvents			?	
Technologies for paper recycling		?	-	
Photovoltaic energy conversion			?	-

n.a.: not applicable
? : doubtful
- : missing

5. Can Pioneering Environmental Policy Still Be Welfare Enhancing?

The conditions under which strategic environmental policy benefits national economic agents through the mechanisms described above are rather restrictive and therefore unlikely to hold. Still such policy could be welfare enhancing.

In case of international or global environmental problems a country which maximizes national welfare has an incentive to set lower environmental standards than would be rational from an international perspective. Part of the damages arise abroad, i.e. they are external effects from the perspective of that country. Equivalently the situation may be characterized as a prisoners' dilemma in which it is rational for each country not to participate in any effort to solve the problem. In such situations the nationally efficient level of environmental standards is low or even zero. [19]

Coordinated policies of a number of nations could make all of them better off, justifying environmental standards stricter than the nationally efficient level. It may be difficult to agree on cooperative standards, however, as any one nation which goes ahead is likely to be worse off - unless losses are offset by gains from strategic environmental policy. Moreover, of individuals behaviour according to the principle of reciprocity has been observed: sometimes individuals behave against their self-interest if they observe others to do so. By this behaviour prisoners' dilemmas can be overcome to the benefit of all. If nations states "behave" in a similar way alleged advantages from strategic environmental policy would enable politicians to go ahead and incite other nations to follow. Even if the conditions for advantages from strategic environmental policy are not fulfilled, society would finally be better off.

[19] Other authors have expressed a positive view of symbolic environmental policy. Böhringer/Voigt (2003: p.249) conclude from their assessment of the Kyoto-Protocol that it is almost ineffective and thus represents symbolic policy only. They explain this as an attempt of rational governments interested in their re-election which want to satisfy a public sensible to climate change. They regard it as a success, however, that climate issues have thus been put on the international agenda. A similar view is held by Weimann, J., ibid. p. 234. Taistra (2001: p. 257) emphasizes the role of a pioneering policy as a step towards a later cooperative solution.

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Local Sustainability Measurements and Determinants: Investigating Industrial Stress, Economic Performance and Local Governance at Piracicaba Basin (Brazil).

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Introduction

The chapter focuses on measurements and determinants of local sustainability in the Piracicaba river basin in Brazil. In particular, we investigate industrial stress, economic performance and local environmental governance as the main drivers in achieving or preventing this sustainability.

The investigations and measurements of the main drivers of local sustainability have a significant impact on industrial transformation research, as it helps to identify the local patterns of economic activities, environmental burdens and governance. It can also provide local stakeholders with tools to identify critical trends and institutional and political barriers that affect local efforts to promote industrial transformation.

Our aim is to apply and test methodologies that measure the different dimensions of the sustainability, facing the challenges of aggregating and producing comparable data from many different sources, produced at different scales, collected at different periods and which vary in coverage. In this perspective, this chapter can be seen as part of a broader effort to provide better quality data and statistical analyses for local environmental decision-making. Quality data is crucial to industrial transformation. Despite the increasing efforts towards industrial transformation, the understanding of the relationships between society, economic activities and the environment usually rely on very little information. The provision of firm and reliable information to support decision-making has been a major challenge for a good assessment of the efforts to reduce environmental burdens coming from economic activities.

Piracicaba Basin has been chosen for the numerous possibilities it presents for the analysis and study of sustainability drivers. The Basin has a large protected area within Brazil's Atlantic Forest. It has the most important iron-steel industrial complex in Latin America, mining areas exploited both industrially and on small-scale basis, an expanding Japanese-Brazilian cellulose industrial complex, enormous areas of eucalyptus monoculture plantations, and a rapid growing urban system that includes major regional urban centers.

The first part of the chapter seeks to track progress toward local sustainability in the 26 municipalities of the basin through the construction of a set of local sustainability indexes. These indexes combine measures of environmental quality, human welfare, institutional capacity and local governance, industrial stress, urbanization stress and agricultural stress. By comparing the performance of the 26 localities in each of these different aspects of sustainability, we measure the degree of local sustainability in a comprehensive and synthetic way. The sustainability index set also allows for the measurement of the local governance driver. The results show a clear trade-off between environmental quality and economic performance in the Piracicaba basin, indicating an urgent need of industrial transformation.

The second part of the chapter attempts to measure the industrial stress driver within the studied area according to different methodologies. We measure the environmental stress posed by the major industrial plants in the area through modeling water effluents emission and water consumption.

The concluding part of the chapter brings together data from the first and second parts to statistically investigate three major drivers of environmental change at the studied area: industrial stress, economic performance and local environmental governance.

Piracicaba Basin: The Studied Area

The Piracicaba Basin was chosen as the study area due to the numerous possibilities it presents for the analysis and study of key environmental problems and sustainability drivers.

The Piracicaba Basin has the most important iron-steel industrial complex in Latin America with iron and gold mining areas, exploited both industrially (iron and gold) and on small-scale basis (gold), an expanding Japanese-Brazilian pulp industrial complex, enormous areas of eucalyptus monoculture plantations, and a rapid growing urban system that includes major regional urban centers.

The Basin has a large protected area of Brazil's Atlantic Forest, the Parque Estadual do Rio Doce - PERD, which is the biggest preserved rainforest area in Minas Gerais State. PERD has 35.976 hectares and is the richest Brazilian Atlantic Forest Park in both biodiversity and presence of endemic species (PAULA et all, 1997)

In this way, the Piracicaba basin is a rich mosaic of environmental problems, concentrating on a relative small area (see figure 1) a highly significant mix of economic activities with a strong potential of environmental impact. The rapid urbanization process and the perspectives of expansion of the local industrial plants magnify the scenario described above.

Figure 1: Localization of study area

The main urban center at Piracicaba Basin is the "Steel Valley", a metropolitan region composed by 4 municipalities: Ipatinga, Timóteo, Coronel Fabriciano and Santana do Paraíso. Ipatinga and Timóteo are the industrial core of "Steel Valley", hosting two iron-stell plants - Usiminas and Acesita, respectively. Coronel Fabriciano is a rapidly growing commercial center. Santana do Paraíso, the only municipality at the "Steel Valley" with relevant rural activities, functions as a displacement area, receiving industrial and urban solid waste for treatment and disposal.

João Monlevade and Itabira are also important urban centers; the former hosts an iron-steel plant – Belgo Mineira – and the later hosts an important iron mining complex – Companhia Vale do Rio Doce (the biggest mining company in Brazil).

Caratinga and Nova Era are traditional commercial centers that hosts small-scale industrial plants. Marliéria and Santa Bárbara have a large share of their area protected for environmental reasons (Parque Estadual do Rio Doce and Parque do Caraça, respectively). The other municipalities are small towns with agriculture activities, mainly the monoculture of Eucaliptus to provide Cenibra, a pulp plant located near the "Steel Valley", with raw material.

Cenibra is one of the largest producers of short-fiber bleached Eucalyptus pulp in Brazil. Founded on 1973 as a Brazil-Japan joint project, under the stock control of Companhia Vale do Rio Doce (CVRD) – at that time a Brazilian Government owned company - and Japan Brazil Paper and Pulp Resources Development Company (JBP)[1]. In 2001, after the privatization of CVRD, JBP took the 100% ownership of Cenibra. Cenibra is located in the county of Belo Oriente, near the "Steel Valley". Its annual output reaches 800 thousand tons. From this total, over 90% is directed to the foreign market, serving mainly Japan, Europe, the United States, as well as other countries in Latin America and Asia.

Usiminas is one of the leading Brazilian steel companies, producing and commercializing flat steel products, like heavy plates (low-carbon and low-alloy steels), hot-rolled steels, cold-rolled steels and coated steels. Founded in 1962, the company was controlled by Brazilian Federal government since 1991 when it was privatized. Its annual output reaches 4,080,000 tons of steel.

Acesita and Belgo Mineira are controlled by Arcelor, an European steel-making group with the world highest steel production. Acesita, the sole manufacturer of flat stainless steels in South America, also produces carbon and micro-alloyed steels and also silicon steels. Founded in 1944, it was owned by the Brazilian Federal Government until its privatization in 1992. The present capacity is 850,000 tons of steel per year. Belgo Mineira was founded in 1923. The present capacity is 1,200,000 tons of steel per year.

3. Tracking progress towards local sustainability

This section seeks to track progress toward local sustainability in the 26 localities of the Piracicaba basin through a set of sustainability indexes and indicators, which combines measures of environmental quality, human wellbeing, local governance and environmental stress. We use the indexes to compare the relative performance of the 26 localities in the different aspects of sustainability and measure the degree of local sustainability in a comprehensive and synthetic way (BRAGA et all, 2003).

[1] JBP was is controlled by the Japanese companies Oji Paper Co., Itochu Corporation and Japanese Bank for International Cooperation.

The river is seen as a life witness of the environmental quality in its basin and as the main methodological tool to integrate and compare information from multiple sources under different methodologies and disciplinary approaches.

The index set combines 36 variables, rolled up into 14 indicators and 4 core indexes: the Environmental Quality Index, the Human Wellbeing Index the Environmental Stress Index and the Local Governance Index. The variables and indicators were chosen through an extensive literature review, combined with assessment of available data and conclusions drawn from previous experiences of environmental index building. In particular, we draw inspiration from the sustainability matrix of the "Biodiversity, Population and Economy" research project (PAULA et all, 1997) and from the ESI - Environmental Sustainability Index (ENVIRONMENTAL, 2002).

The indexes and indicators presented are a relative measure of local sustainability. Due to the lack of scientific knowledge to specify precisely what levels of environmental quality are good enough to be sustainable, we were not able to establish benchmarks for all variables, which is why the index was built as a comparative measure between the municipalities at the studied area.

The Environmental Quality Index measure the quality of the environmental system by taking the water quality at selected points at the Piracicaba River as a proxy of the health of the local ecosystem. It includes both a biological index that measures the diversity of fish and inland water plankton and a physical-chemical index that measures parameters as dissolved oxygen, electrical conductivity, temperature, suspended solids, phosphorous concentration, turbidity, among others. As the variables for this index, we used data produced by BARBOSA (1997) and BARBOSA (2002) through extensive field research at few points along Piracicaba River.

The Human Wellbeing Index measures the life quality within the municipality relating it to indicators of health, education, income, security and housing quality. The Environmental Stress Index measures the burdens posed to the local environment by industry, agriculture and urbanization. The Political Institutional Capacity Index measures local capacity to respond to sustainability challenges through the strength of its institutions and the quality and accountability of its decision-making processes. The variables used in these indexes were calculated by aggregating information from a wide range of data sources as the Brazilian Census Bureau, the National Health Agency Database, the Local Governance Database, electricity companies, environmental state agencies and local governments.

The variables were chosen observing three main criteria: i) relevance - extent to which the variable corresponds to the phenomenon; ii) meaning for local context - extent to which the variable's main drive remains under local responsibility; iii) availability - coverage and recency of data. Proxies were applied when direct measures of the phenomenon were not available. We statistically tested the set of variables, through bivariate correlation and principal component analyses. At that point, few variables were dropped out of the indicators. Table 1 show the variables used to compose the indicators and core indexes.

We make the variables comparable, by trimming the tails of the variable distribution and converting them to a standardized value (z-scores). We tested the theoretical choices of the variables for each indicator through principal component analyses (we find a value for the second component over 0.70 for all indicators). The indexes were calculated by taking the unweighted average of the indicators converted from the z-score scale to a standard normal percentile scale.

We calculated the indexes for year-base 1991 and for year-base 2000. The Human Wellbeing Index and the Environmental Stress Index were built for the 26 municipalities for both year-base. The Political and Institutional Capacity Index was build for the 26 municipalities for 2000, but was not build for 1991 because of insufficient data. The Environmental Quality was build for 9 municipalities in 1991 and for 4 municipalities for 2000, according to data availability, as it depends on extensive field research and collection and analyses of water samples at selected points along the river.

Considering their key role on measuring the drivers of sustainability and identifying relationships that are crucial to industrial transformation, we now have a close look at the Environmental Stress Index and the local governance index.

The Environmental Stress Index measures the pressures posed on the environment by human activities, covering both pollution and exploitation. It ranks localities at the studied area by the potential burden they pose on the adjoining environment, focusing on pollution potential, speed of growth and degree of concentration of polluting activities.

Our aim with the Environmental Stress Index was to build a comprehensive and sensible pressure index using publicly available data. In order to do so, we had to use proxies to measure most of the indicators due to the lack of direct and reliable data on pollution and exploitation levels for the whole basin.

We took energy efficiency as a proxy for industrial stress. Consumption of energy is (in many cases) the main source of atmospheric emissions from industry. We can also assume that companies that are more efficient on the use of energy also use cleaner technologies.

To measure agricultural stress we combined data on growth of agricultural land with data on density of agricultural land (SAWYER, 2000), energy efficiency and conversion of natural forest into planted forest. Increasing agricultural land is a major driver of land conversion and ecosystem losses, putting strong pressure on the regional environment.

We took household density and population growth, vehicles *per capita* and domestic energy consumption as proxies for the urban pressure. Vehicles are the main source of atmospheric pollution in urban areas, energy consumption is a good proxy for general consumption level, while household density and population growth have a direct correlation with urbanization degree and pressure on adjoining areas for land conversion.

We used a vegetation indicator as an inverse measure of environmental stress, since localities with higher vegetation shares are less vulnerable to the negative effects of anthropogenic pressure.

The Local Governance Index measures the local capacity to respond to sustainability challenges through the strength of its institutions and the quality and accountability of its decision-making processes. It ranks localities at the studied area by the effectiveness of their governance patterns.

Our aim with the Local Governance Index was to use publicly available data (National Census on Sub-national Governance - IBGE) to build a comprehensive and sensible governance index that takes in to account two main trends – the broadening of the spectrum of actors involved on the decision making process and the gaining of importance of the local level on the policy making process.

We took "fiscal autonomy" and "electoral weight" as proxies for political autonomy. Fiscal autonomy is seen as the proportion of locally based revenue to the revenue coming through federal/state transfers. It is a key driver of the overall political power of a sub-national level in a federal country. It influences the degree of political independence relative to the higher levels of power - the Union and the State. The electoral weight is seen as the ratio of voters to the total population. It is also a determinant factor of power of the local government, as a locality with a high electoral weigh can influence the elections for the upper levels of power by helping to elect candidates committed to local interests.

"Staff qualification", "information systems" and "participation in the public policy decision making process" are the proxies for Institutional Capacity. The first two measure the quality of the human resources and the information technology resources of each local government. The third ranks localities according to the effectiveness of participation in the public policy decision making process by evaluating the broadness of the spectrum of actors involved in the processes and the existence of decision making tools (as participatory budget and policy funds managed by community boards).

"Participation in the environmental policy decision making process" and "area under legal protection" were taken as proxies for Environmental Governance. The former rank localities according to the effectiveness of participation in the environmental policy decision making process. It does that by evaluating the broadness of the spectrum of actors involved in the processes and the existence of decision making tools as local environmental funds managed by community boards. The later rank localities according to the actual municipal area under legal environmental protection (given through local legislation).

"Environmental NGOs", "electoral participation" and "press" were taken as proxies for the Capacity of Debate. The environmental NGOs indicator ranks localities according to the number of nationally accredited environmental NGOs with local branches per capita. The electoral participation indicator measures the proportion of registered voters that actually voted at the most recent municipal elections. The press indicator ranks localities according to the number of local newspapers and radio stations per capita.

Table 1: Indexes, indicators and variables

Index	Indicator	Variable
Environmental Quality	Water quality	Biological quality
		Physical-chemical quality
Human Wellbeing	Environmental Health and Security	Child death from respiratory diseases*
		Death from intestinal infectious diseases*
		Homicides*
		Death from car accident*
	Housing quality	Squatters percentage*
	Sanitation	Improved water Supply
		Improved sewage
		Improved waste collection
	Wellbeing	Municipal Human Development Index – Health
		Municipal Human Development Index – Education
	Income	Municipal Human Development Index – Income
Environmental Stress	Vegetation	Land covered by natural forest*
	Industrial Stress	Energy efficiency*
	Urban Stress	Household density
		Population growth
		Vehicles per capita
		Domestic energy consumption
	Agricultural Stress	Density of agricultural land
		Growth of agricultural land
		Energy efficiency*
		Conversion of natural forest in to planted forest

Local governance	Political Autonomy	Fiscal autonomy
		Electoral weight
	Institutional Capacity	Staff qualification
		Information systems
		Participation in public policy decision making process
	Environmental Governance	Participation in environmental policy decision making
		Area under legal protection
	Capacity for debate	Environmental NGOs
		Electoral participation
		Press (newspapers and radios)

Note: * inverse variables – the highest the variable value, the lowest the indicator.

We present the results of the calculations of the four core indexes for the years 1991 and 2000 in Tables 2 and 3, grouping municipalities through cluster analyses. These results are also mapped in Figure 2. Although the results have being fairly consistent, the index set is considered as an open project, subject to further review and methodological refinement.

The cluster analyses allow us to identify a sole group with a clear development pattern. Cluster 1 shows a clear unsustainable pattern, combining high human well-being, high environmental stress and strong local governance. The municipalities on this cluster are the industrial cities at the region, showing that economic performance and industrial stress are major drivers of environmental sustainability in the region and showing an urgent need of industrial transformation.

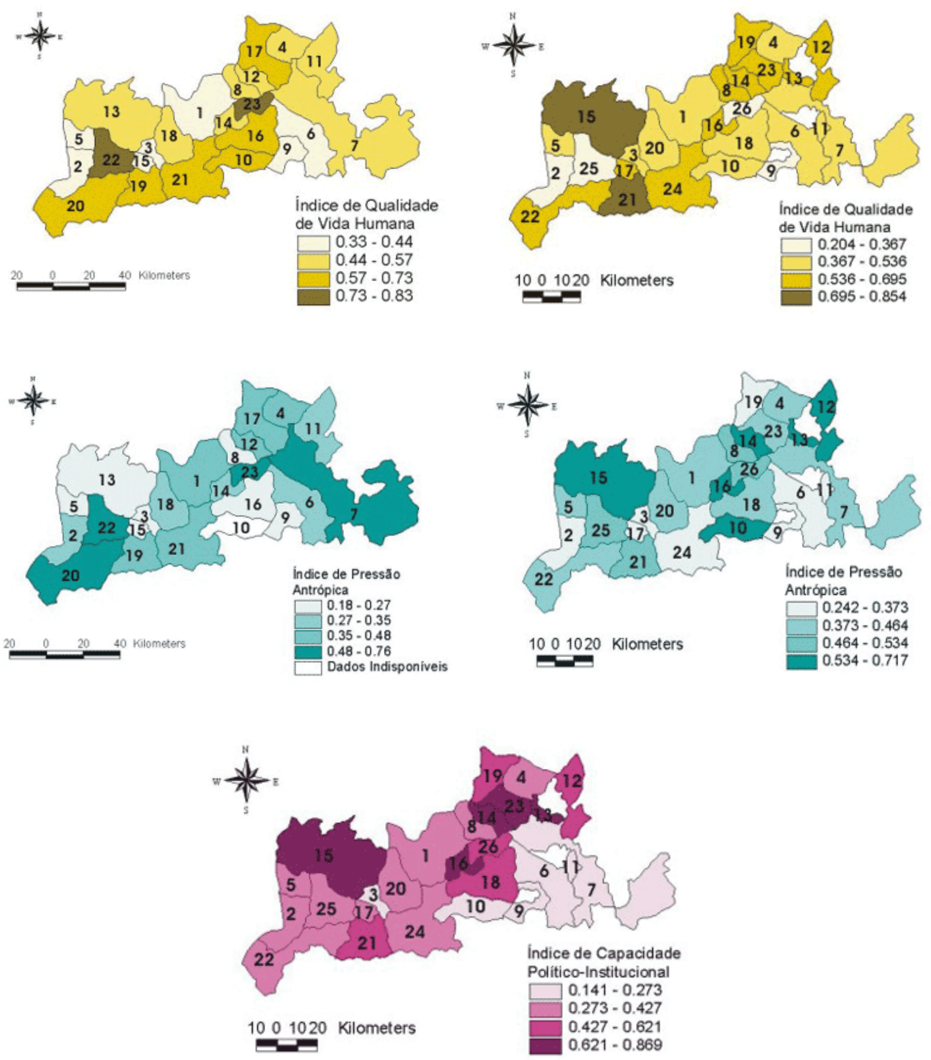
Table 2: Human Wellbeing Index, Environmental Pressure Index, Environmental Quality Index, 1991

Municipalities	Human Wellbeing Index	Environmental Stress Index	Environmental Quality Index	Cluster
Coronel Fabriciano	0.69	0.39	0.88	1
Ipatinga	0.73	0.68	0.00	1
Itabira	0.64	0.48	0.66	1
João Monlevade	0.83	0.76	0.64	1
Timóteo	0.81	0.58	0.88	1
Antônio Dias	0.42	0.23	-	2
Barão de Cocais	0.66	-	0.09	2
Bela Vista de Minas	0.51	0.31	-	2
Belo Oriente	0.53	0.40	1.00	2
Dionísio	0.57	0.27	-	2
Jaguaraçu	0.54	0.29	-	2
Mesquita	0.39	0.18	--	2
Rio Piracicaba	0.62	0.23		2
Santa Bárbara	0.67	0.41	0.93	2
São Gonçalo Rio Abaixo	0.50	0.35	-	2
Bom Jesus do Amparo	0.33	0.39	-	3
Bom Jesus do Galho	0.35	0.35	-	3
Caratinga	0.41	0.22	-	3
Córrego Novo	0.49	0.39	-	3
Iapu	0.44	0.23	-	3
Marliéria	0.39	0.31	-	3
Nova Era	0.49	0.62	0.66	3
São Domingos do Prata	0.53	0.23	-	3

Table 3: Human Wellbeing Index, Environmental Pressure Index, Environmental Quality Index, 2000

Municipalities	Human Wellbeing Index	Environmental Stress Index	Environmental Quality Index	Local Governance Index	Cluster
Barão de Cocais	0.67	0.65	0.00	0.52	1
Ipatinga	0.64	0.66	0.22	0.87	1
Itabira	0.66	0.72	0.36	0.80	1
João Monlevade	0.85	0.65	-	0.72	1
Timóteo	0.68	0.67	-	0.80	1
Bela Vista de Minas	0.66	0.31	-	0.34	2
Caratinga	0.51	0.42	-	0.62	2
Coronel Fabriciano	0.67	0.35	-	0.53	2
Entre Folhas	0.53	0.44	-	0.43	2
Nova Era	0.76	0.53	-	0.47	2
Rio Piracicaba	0.66	0.46	-	0.37	2
Santa Bárbara	0.69	0.41	1.00	0.75	2
São Domingos do Prata	0.62	0.37	-	0.40	2
Bom Jesus do Amparo	0.44	0.45	-	0.38	3
Bom Jesus do Galho	0.36	0.33	-	0.32	3
Córrego Novo	0.45	0.24	-	0.26	3
Dionísio	0.44	0.42	-	0.34	3
Iapu	0.54	0.45	-	0.30	3
Ipaba	0.46	0.32	-	0.14	3
Jaguaraçu	0.48	0.44	-	0.27	3
Marliéria	0.60	0.51	-	0.31	3
Mesquita	0.37	0.32	-	0.16	3
Santana do Paraíso	0.50	0.64	-	0.19	3
São Gonçalo do Rio Abaixo	0.43	0.35	-	0.21	3
Antônio Dias	0.22	0.52	-	0.39	4
Belo Oriente	0.20	0.49	0.50	0.55	4

Figure 2: Sustainability indexes, Piracicaba Basin, 1991 (left) and 2000 (right)
Note: Human Wellbeing Index, Environmental Stress Index and Political and Institutional Capacity Index, from the top to the bottom.



Figures 3 and 4 compare the performance of the 26 municipalities on the Environmental Pressure and Human Wellbeing indexes by adapting to the studied reality the sustainability barometer proposed by PRESCOTT-ALLEN (1995). The horizontal axe shows the human system and the vertical axe the environmental system. We chose the Environmental Pressure Index instead of the Environmental Quality Index to compose the environmental axe since it was built for all municipalities in both year-base, allowing a broad comparison.

Figure 3: Human Wellbeing versus Environmental Stress, 1991

Environ-mental Stress	Human Wellbeing				
		Low (0 - 0,42)	Fair (0,43 - 0,52)	Medium (0,53 - 0,64)	High (> 0,65)
	Low (0 – 0,22)	Caratinga, Mes-quita			
	Fair (0,23 - 0,34)	Antônio Dias, Marliéria	Bela Vista de Minas, Iapu	Dionísio, Jaguaraçu, Rio Piracicaba, São Domingos do Prata	
	Medium (0,35 – 0,39)	Bom Jesus do Amparo, Bom Jesus do Galho	Córrego Novo, São Gonçalo do Rio Abaixo		Coronel Fabriciano
	High (> 0,40)		Nova Era	Belo Oriente, Itabira	Ipatinga, João Monlevade, Timóteo, Santa Bárbara

Figure 4: Human Wellbeing versus Environmental Stress, 2000

Environ-mental Stress	Human Wellbeing				
		Low (0 - 0,42)	Fair (0,43 - 0,52)	Medium (0,53 - 0,64)	High (> 0,65)
	Low (0 – 0,34)	Bom Jesus do Galho, Mesquita	Córrego Novo, Ipaba		Bela Vista de Minas
	Fair (0,35 - 0,44)	São Gonçalo do Rio Abaixo	Dionísio, Caratinga	São Domingos do Prata	Coronel Fabriciano, Santa Bárbara
	Medium (0,44 – 0,52)	Antônio Dias, Belo Oriente	Bom Jesus do Amparo, Jaguaraçu	Entre Folhas, Iapu, Marliéria	Rio Piracicaba
	High (> 0,53)		Santana do Paraíso	Ipatinga	Barão de Cocais, Itabira, João Mon-levade, Nova Era, Timóteo

Results once again clearly show a trade-off between environmental quality and human wellbeing at Piracicaba basin. The municipalities that rank higher in the Human Wellbeing Index were the same to rank higher in the Environmental Pressure Index, what indicates that increasing human wellbeing in the region was achieved by relaying on a high degree of burden on the environmental system. Nevertheless, a few municipalities were able to break the link between environmental burden and economic development, achieving a more balanced performance and suggesting that it is possible to face and overcome the trade-off and pursue a more sustainable path.

Measuring industrial stress

The aim of this section is to measure industrial stress at Piracicaba Basin. We do it by modeling the environmental damage caused by the four main industrial plants at the region and estimating the economic cost of these damages.

Industrial stress is a major hurdle to the achievement of sustainability at Piracicaba Basin, as demonstrated in section 3. The study region is specialized on primary transformation of raw natural resources – pulp and steel industries - and these industrial activities are not only resource intensive, but also energy and water intensive.

The pulp industry is a capital, energy, water and resource-intensive industrial sector. The iron-steel industry is a capital and resource-intensive industrial sector. Depending on technological pattern adopted, iron-steel plants can also be energy and water-intensive. Water intensive industries are the ones in which more than 15 per cent of the activity's total water intake is consumed. The iron-steel plants at Piracicaba basin fall in to this consumption range, being water-intensive. Both industrial sectors contribute to various emissions to air, especially sulphur dioxide (pulp and iron-steel), nitrogen oxides (pulp) and particles (iron-steel) and have historically been the source of acute air pollution problems.

We understand environmental damage as the losses on human wellbeing, ecosystem health and man-made capital resulting from environmental degradation caused by over-exploitation of the environmental services for productive purposes. The cost of environmental damage can be considered as the economic value of potential production or revenue that was not realized due to environmental damage, or as the economic value of the negative changes in the environmental quality.

Although incurring some degree of environmental damage is almost inevitable, given the particular characteristics of our economic system and current technological standards, a measure of the degree of current damage and its economic value is a powerful tool to identify critical trends and help the development of better management processes.

Measurement the extent and degree of environmental damage is not an easy task and there is no consensual methodology to do it. In this chapter we used the Environmental Resources Consumption Method (KHACHATUROV, 1993; MIKHAILOVA, 2002).

Given the difficulty to measure all the losses associated with environmental damage, most of the current efforts on environmental damage measurement focus on particular aspects of specific productive activities as proxies of the overall damage. In this chapter we measure the damage on the water media caused by the four major industrial plants - Cenibra, Usiminas, Acesita and Belgo Mineira - as a proxy of the environmental damage at the Piracicaba Basin. We then use the results to estimate the economic cost of the damage.

The Environmental Resources Consumption method estimates the environmental damage by modeling the consumption of environmental resources needed for the absorption or dispersion of the pollutants and bring the concentration levels back to a baseline level. For example, it is possible to model the volume of pure air needed to dilute the atmospheric emissions of a industrial plant and bring it back to a baseline (for example, the maximum level of concentration allowed by environmental legislation). The amount of air that was consumed, or used, to reach the maximum level of concentration is a proxy of the atmospheric damaged caused by the industrial plant. In the same way, it is possible to model the hydrological environmental damage. In this in case it is necessary to estimate the volume of water needed to dilute the water effluent launched until reaching the permissible maximum concentrations.

Environmental Damage Equation

$$D=\sum_{i=1}^{n}\frac{E_i}{P\max_i} \qquad (1)$$

Ei – emission of pollutant i, in year/ton;
Pmax.i – maximum level of concentration, in ton/m^3;
D – environmental damage, in m^3.

The first step was estimating the yearly volumes of water effluents of main pollutants for the four firms using available data. In the case of the Cenibra - Table 3 - we used data on water effluents published by the company. For the iron-steel plants - Table 4 – there is no published data on water effluents, which is why we used estimated data produced by RIO PIRACICABA (2003) using the methodology developed by PAULA et all (1997).

The second step was estimating the amount of water needed to dilute the emissions in order to reach the maximum concentrations allowed by legislation using data from tables 4, 5 and 6. The results are on tables 7 and 8.

Table 9 show the estimated costs of the environmental damage using as water value the effective water costs on water supply incurred by the studied firms - R$ 2,118 per m^3, charged by Copasa, the state owned water supplier at Minas Gerais State[2].

Table 4: Emissions of water pollutants, Cenibra (year/ton)

Pollutant	1999	2000	2001
Total Suspended Solids	2977.50	2290.90	1505.50
Chlorinated halogenated organics (AOX)	339.60	229.10	213.90
Phenols	15.70	8.20	7.90

Data source: RELATÓRIO AMBIENTAL CENIBRA, 2001

Table 5: Emissions of water pollutants, Usiminas, Acesita, Belgo - 2000 (year/ton)

Pollutant	Usiminas	Belgo	Acesita
Total Suspended Solids	39139	4967	8341
Phenols	67	0.05	1
Cyanide	29	6	3
Ammonium	167	3	4
Fluoride	21	15	6
Heavy oils	1549	205	781

Data source: RIO PIRACICABA (2003)

Table 6: Maximum concentration allowed by environmental legislation

Pollutants	Maximum concentration allowed by environmental legislation (mg/l)
Total Suspended Solids	60
Phenols	0.2
Cyanide	0.2
Ammonium	5
Fluorides	10
Heavy oils	20

Data source: PAULA et all (1997).

Table 7: Water resources needed to dilute Cenibra emissions (hundreds m^3/year)

Pollutant	1999	2000	2001
Total Suspended Solids	49620	38180	25090
Chlorinated halogenated organics (AOX)	13580	9160	8560
Phenols	7850	41000	39500
Total water consumption	141700	88340	73150

Data source: table 4

[2] R$ is the Brazilian Currency (Reais). In November 2003 the exchange rate was R$ 2,9 for 1 US Dollar.

Table 8: Water resources needed to dilute Usiminas, Acesita, Belgo emissions (hundreds m^3/year), 2000

Pollutant	Usiminas	Belgo	Acesita
Total Suspended Solids	652300	82800	139000
Phenols	335000	250	5000
Cyanide	145000	30000	15000
Ammonium	33400	600	800
Fluorides	2100	1500	600
Heavy oils	77400	10200	39000
Total	1245200	125350	199400

Data source: table 5

Table 9: Economic Cost of Environmental Damage, 2000

	Water resources needed to dilute emissions (million m^3/year)	Economic Cost of Environmental Damage (R$ million)
Cenibra	73.15	154.93
Usiminas	1245.20	2637.33
Belgo	125.30	265.39
Acesita	199.40	422.33

Data source: tables 6, 7 and 8.

The economic cost of environmental damage of the studied firms is very high. Taking Cenibra, the firm with the lowest cost, as an example, the cost of environmental damage on water media is very close to the average net profits of the company in the past three years (R$ 229 million in 2000, R$ 92 million in 2001 and R$ 120 million in 2002)[3]. Taking Usiminas, the firm with the highest cost, as an example, the cost of environmental damage is close to the company average revenue (R$ 2395 million in 2000, R$ 2942 million in 2001)[4]. These results indicate a clearly unsustainable pattern and a need for industrial transformation.

Table 10 show data on water intakes, water consumption and water efficiency for the three iron-steel plants. We used two different measures for water efficiency: water efficiency 1 is measured as ton of iron-steel produced per unit of water intakes, while water efficiency 2 is measured as ton of iron-steel produced per unit of water consumed.

Table 10: Water intake, water consumption and water efficiency, 2000

	Water intakes (m^3/month)	Water consumption (m^3/month)	Production (ton/month)	Water efficiency 1 (ton/m^3)	Water efficiency 2 (ton/m^3)
Belgo	326169	326126	100000	3.26	3.26
Usiminas	5140800	1079568	340000	15.12	3.18
Acesita	1080000	356400	70830	15.24	5.03

Data source: RAVISK (2002).

The pattern observed for water intakes and water consumption is similar to the one observed for environmental damage. Usiminas is much more intensive on water consumption and water intakes then the other two. The difference here is that for water intakes Acesita is much more intensive than Belgo, while they perform more similarly for water consumption and environmental damage.

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3 Data available at www.cenibra.com.br

4 Data available at www.usiminas.com.br

It is interesting to stress the fact that Belgo uses 100% of the water they take in from the Piracicaba river, recycling and making it return to the production process, while Usiminas and Acesita use respectively 21% and 33% of the water they take in, releasing most of it back to the river (RAVISK, 2002). The water Usiminas and Acesita give back to the river, used for cooling purposes during the production process, has a higher temperature then the river, causing disturbances to the river's environmental health and losses on aquatic biodiversity (PAULA et all, 1997).

The fact described above has a great impact on water efficiency and we can clearly see two different patterns. Water efficiency 2 (consumption) shows a pattern where Belgo shines compared to Usiminas and Acesita, being much more efficient. A different pattern can be observed for Water efficiency 1 (intakes), where Usiminas is the most efficient, performing very close to Belgo, and Acesita has a poorer performance.

Within the iron-steel plants, Belgo presents the lowest stress levels according to all indicators, as shown in table 11.

Table 11: Industrial stress

	Cenibra	**Usiminas**	**Belgo**	**Acesita**
Environmental damage (water, thousands of m^3)	73.150	1.245.200	125.300	199.400
Water consumption (thousands m^3)	-	1080	326	356
Water efficiency 1 [intakes] (m^3/tons)	-	3.18	3.26	5.03
Water efficiency 2 [consumption] (m^3/tons)	-	15.12	3.26	15.24
Cost of environmental damage (R$ thousands/year)	154.930	2.637.330	265.390	422.330
Environmental Stress Index (host municipality)	0,49	0,66	0,65	0,67

5. Drivers of environmental change

As a conclusion, we statistically investigated three major drivers to environmental change in the investigated area: industrial stress, economic performance and local environmental governance.

The relationship between sustainability and economic performance lies at the heart of major political debates and are of key importance to the environmental decision-making process. On the one hand, economic performance is a source of environmental stress and there are significant trade-offs between environmental performance and economic performance. On the other hand, sustainability, at least at national level, seems to benefit from improvements in economic development. Industrial stress is seen as a major barrier to achieving sustainability. Governance, at least at national level, is pointed out as a major driver of sustainability, since strong and democratic institutions are seen as necessary conditions to move towards sustainable paths. (Environmental, 2002; Esty and Porter, 2002; Dasgupta et all, 1995).

These three can also be considered important drivers of industrial transformation. The existence of a high industrial stress is itself the main reason for industrial transformation[5]. A positive and growing economic performance is seen as a condition for industrial transformation as it means that economic resources will be available for

5 Industrial transformation is defined as a change in the system of economic activities that is able to break the links between economic activities and environmental burden (Jacob, 2003). We also consider it to be the transformations needed to invert the existing trade-offs between industrial growth and environmental sustainability and allow the two to coexist.

technological changes and environmental protection. Good governance has been stressed by the literature as one of the main conditions to achieve industrial transformation.

In order to explore empirically the relationships between local sustainability, local governance, industrial stress and economic performance for the investigated area, we statistically tested the correlations between them through linear regression and bivariate correlation. We use selected variables in the index set in section 3 and the measures of industrial stress in section 4 to quantify the drivers and the degree of sustainability.

We took the inverse of the Environmental Stress Index calculated on part 3 - henceforth called Environmental Quality - as a proxy for local sustainability. The inverse of the "industrial stress indicator" calculated on part 3 - henceforth called Reducing Industrial Stress - was taken as a proxy for industrial stress. We took average household income and municipal gross product as proxies for economic performance. We took the Local Governance Index and the environmental governance indicator calculated in part 3 as proxies of local environmental governance.

The results show significant positive correlations, except for the case of municipal gross product and reducing industrial stress.

Table 12: Correlations

Variables	**Bivariate correlations**					
	(1)	(2)	(3)	(4)	(5)	(6)
Municipal Gross Product (1)	1.00	0.648	0.671	0.445	-0.463	-0.332
Average household income (2)	0.648	1.00	0.841	0.704	-0.575	-0.538
Local governance (3)	0.671	0.841	1.00	0.843	-0.625	-0.502
Environmental governance (4)	0.445	0.704	0.843	1.00	-0.543	-0.503
Environmental quality (5)	-0.463	-0.575	-0.625	-0.543	1.00	0.809
Reducing Industrial Stress (6)	-0.332	-0.538	-0.502	-0.503	0.809	1.00

Note: correlations between 0.4 - 0.5 are significant at 0.01 level; correlations higher 0.5 are significant at 0.05 level.

Clearly, economic performance can be considered a significant positive driver of local governance, suggesting a strong relationship between economic power and political power and institutional strength.

Economic performance can also be considered a significant negative driver of sustainability, mainly when we took the relative wealth variable - average household income as the economic performance measurement, showing once again the unsustainable development pattern at Piracicaba Basin being characterized by a strong trade-off between economic performance and environmental quality.

The evidence of a significant negative correlation between local governance and sustainability is quite surprising, but it can be statistically understood if we consider the strong correlation between governance and economic performance. There are two possible reasons for this negative correlation. The first one is that, as governance is a driver of sustainability in the long term, the correlation currently observed is due to a temporal gap and would possibly change in the future. The second one is that even when the local authorities succeed on improving governance tools, the power that comes from that is used rather to foster economic performance than to support the improvement of environmental quality.

The regression lines on figures 5 and 6 provide an interesting perspective on how each locality performs. At figure 5, the regression line shows a political and institutional strength above and a political and institutional weakness bellow. At figure 6, the regression line shows more sustainable path above and a less sustainable path bellow.

Nevertheless, the wide variations in environmental quality among localities at similar levels of relative wealth and the absence of a continuous relationship over the entire range of income show that the relationship between economic development and sustainability, although existent, is neither obvious nor definite.

Figure 5: Relation between Local Governance and Average household income

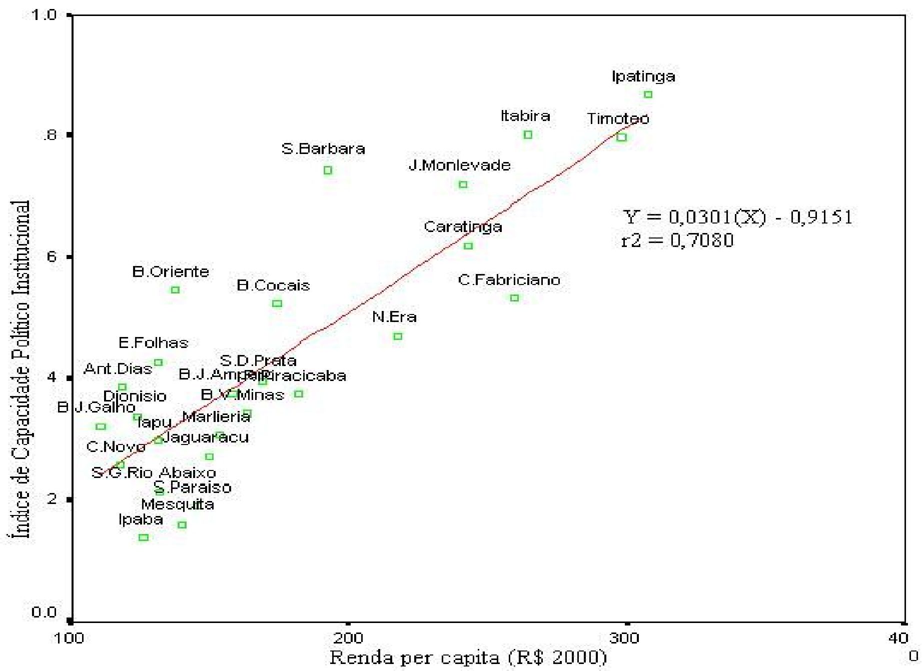
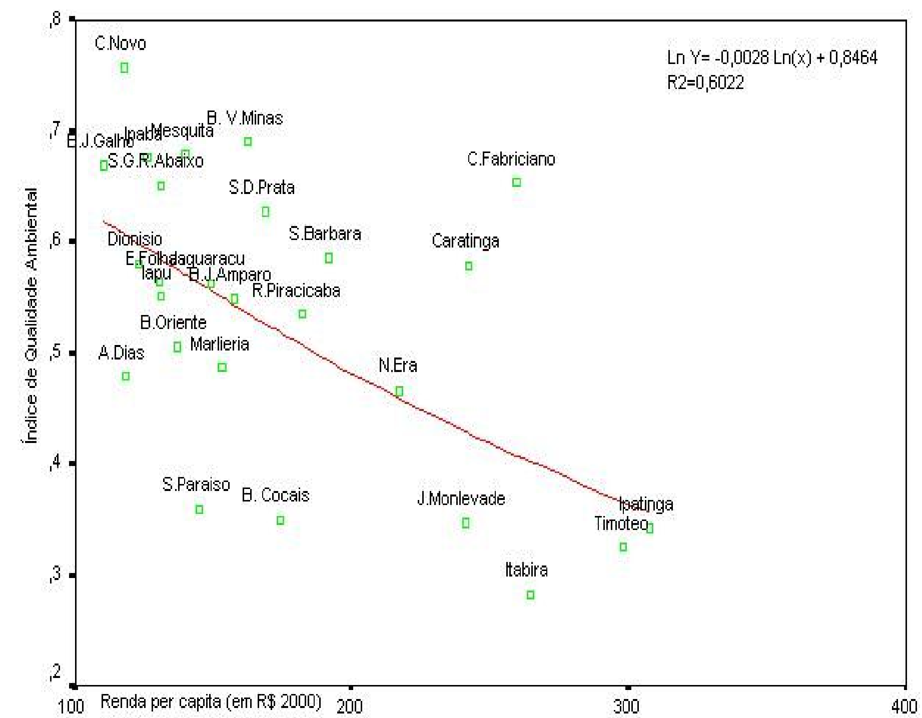


Figure 6: Relation between Environmental Quality and Average household income



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Innovation Systems and Policy-Making Processes for the Transition to Sustainability

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1. Introduction

The interactions between 'technological systems' and 'institutional systems' and the innovation processes occurring within them are a key factor in transitions to more sustainable socio-natural systems. Such transitions will be greatly influenced by how policies and regulatory frameworks (within the policy-making process) affect innovation in these systems, and, in turn, how innovation processes affect policy and governance frameworks. This chapter describes initial results from a research project being undertaken by the authors, under the UK ESRC Sustainable Technologies Programme, which is investigating the interaction between the policy-making process and the innovation process. The project is undertaking theoretical and empirical analyses of the interactions between policy-making processes and innovation systems in two case study areas - *low carbon innovation in the UK* and *alternative technologies for energy sources in vehicles at the EU policy level*. From these analyses, together with experience of direct involvement in producing policy advice for these two areas, a set of process guidelines will be developed for improving sustainable innovation policy processes, contributing to the design of a better mix of policy instruments for promoting innovation towards sustainability.

Section 2 of the chapter develops a framework for analysing interactions between innovation systems and policy-making processes, based on the interactions between technological systems and institutional systems. Section 3 reviews recent theoretical and empirical work describing innovation as a systemic, dynamic, non-linear process. Section 4 describes recent work which points to an improved rationale for sustainable innovation policy, based on ideas from innovation systems theory. Section 5 describes initial findings from the two project case studies, drawing out the implications for sustainable innovation policy processes. Section 6 concludes by presenting some emerging hypotheses, which draw on the previous theoretical and empirical work, for improving policy-making processes for promoting sustainable innovation.

2. A Framework for Analysing Interaction Between Innovation Systems and Policy-Making Processes

Until very recently, in the UK and many other countries, innovation policy and sustainability policy have been pursued separately. This is now changing as a result of greater understanding of innovation processes and recognition of their importance for sustainability. Recent theoretical and empirical advances paint a richer picture of innovation as a systemic, dynamic, non-linear process, involving a diverse range of actors, giving rise to both positive and negative feedback (see e.g. Kemp, 1997; Grubler, 1998; Hemmelskamp *et al.*, 2000; and Foxon, 2003 for a review). The new picture emphasises the roles of knowledge flows between actors; expectations about future technology, market and policy developments; political and regulatory risk; and the institutional structures that affect incentives and barriers. A similarly complex picture exists of the paradigms, principles and frameworks underlying the policy-making process (see Majone, 1989; Kingdon, 1995; Gunningham and Grabosky, 1998; John, 1998).

We are developing a framework for analysing the interaction between innovation systems and policy-making processes. This framework draws on previous work investigating the relation between environmental policy and innovation (Kemp *et al.*, 2000; Ashford, 2000; Janicke *et al.*, 2000), but develops a more explicitly systems based approach. There are two elements to the framework. The *first element* (see Figure 1) shows the broad overview of the transition from the current socio-natural system to a more sustainable one. The socio-natural system is composed of a number of interacting sub-systems. This study focuses on two of these subsystems -'technological systems' and 'institutional systems' - and their interactions.

The *second element* (see Figure 2) provides the methodological framework for the project. It illustrates two key interacting subsystems of institutional and technological systems, which may be involved in the transition of these systems towards greater sustainability. These are the 'policy-making process', within institutional systems, and 'sustainable innovation systems', within technological systems. The policy-making process may create opportunities for the innovation of technologies towards sustainability, by influencing the rate and direction of innovation. The sustainable innovation system may provide potential scope for improved policy targets and measures. For example, stringent targets for technology performance to meet certain social or environmental standards may be set if it is believed that the innovation system can deliver technologies meeting those targets.

This dynamic interaction between policy-making processes and sustainable innovation systems gives rise, at any point, to a particular mix of policy instruments for promoting sustainable innovation. As these instruments are implemented and experience of their effectiveness gathered and assessed, this feeds back – more or less effectively - into the further development of these processes and systems.

There are two parallel aspects to the analysis using this framework:

- The theoretical analysis of each process and the interactions between them.
- The empirical analysis of the two case studies - *low carbon technologies*, focussing on UK innovation systems and policy processes, and *alternative energy sources in vehicles*, focussing on policy-making and implementation processes, institutions and innovation at the EU level.

The case study analysis is drawing on stakeholder experience, through workshops and interviews. A report on the first stakeholder workshop, held in January 2003, is available on the Sustainable Technologies Programme web site (Foxon *et al.*, 2003); the second workshop on 'Improving policy-making for sustainable innovation: Learning from experience' was held in October 2003, with stakeholders from the business, policy-making, NGO and academic communities. A third workshop, which will explore a set of guidelines for developing better policy mixes, was held in June 2004.

Figure 1: Overview of the transition towards a sustainable socio-natural system

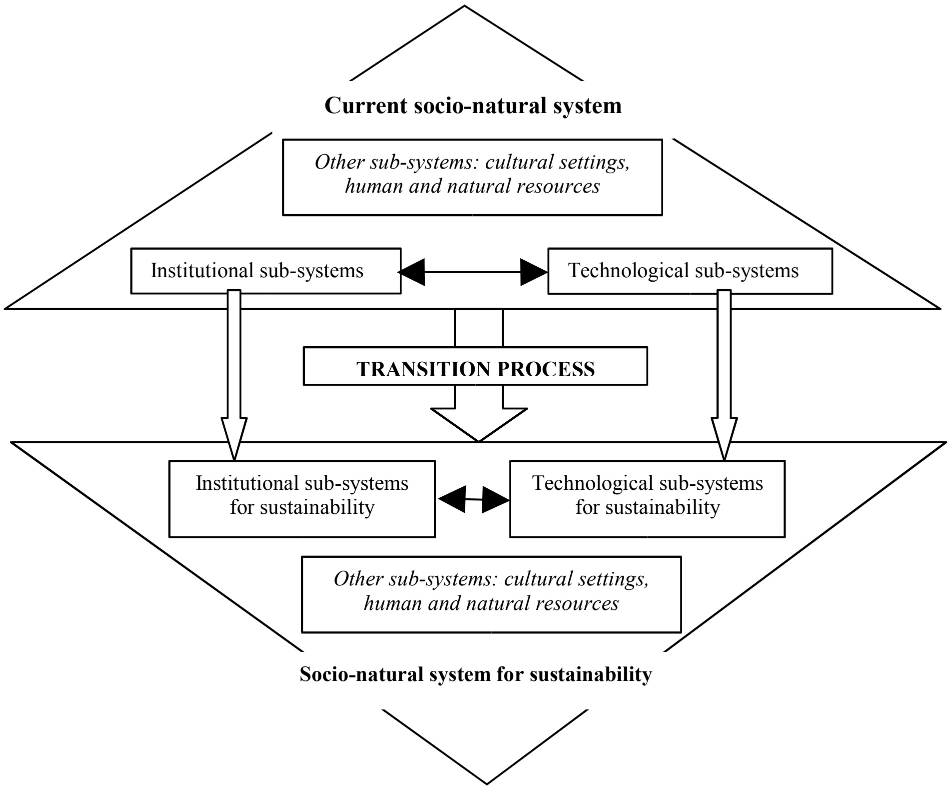
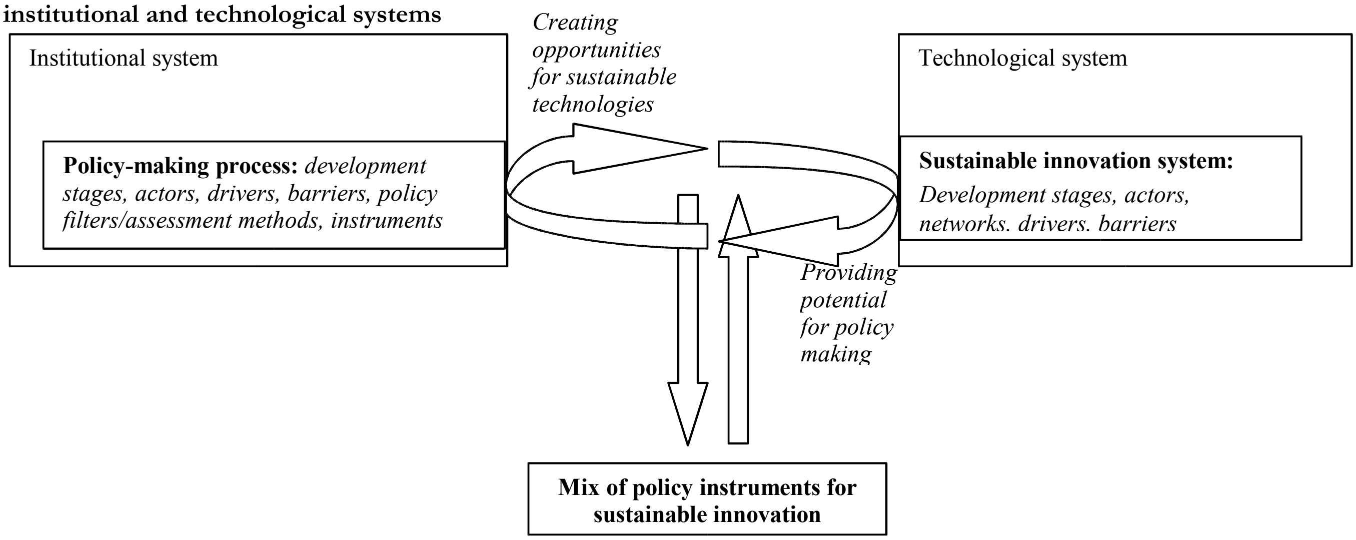


Figure 2: Interaction of the policy-making process and the sustainable innovation system within the institutional and technological systems



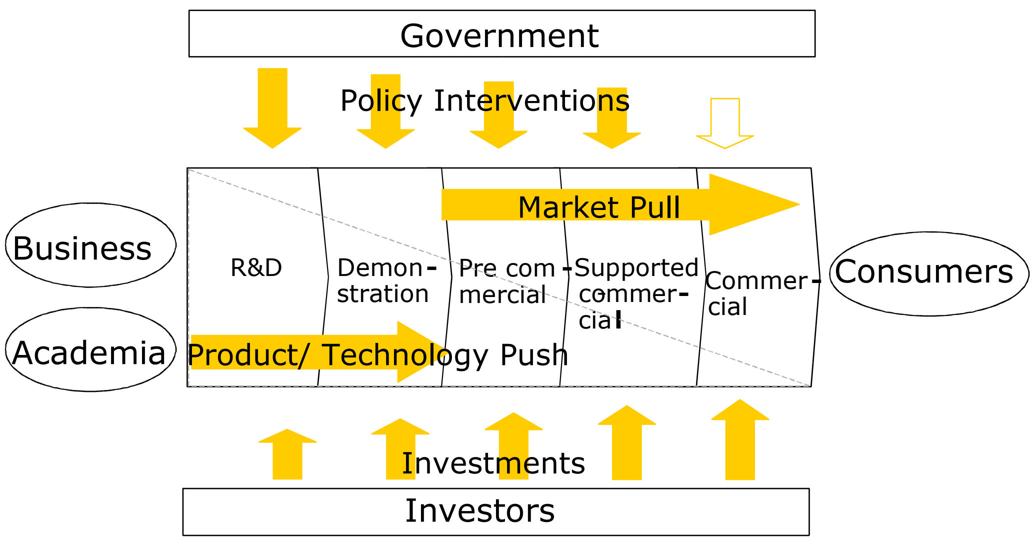
3. Understanding Innovation Processes

From the theoretical and empirical analysis undertaken so far in the project, we draw out a broad message that policy making, in the UK and at the EU level, has failed to take into account fully the complexity and dynamic nature of innovation processes. A range of recent work has enhanced our understanding of the richness of the innovation process, in relation to tackling environmental problems (see e.g. Kemp, 1997; Grubler, 1998; Hemmelskamp *et al.*, 2000; and Foxon, 2003 for a review), but, as described in Section 4, this understanding is not yet widely reflected in the rationale for or design of policy instruments.

The Innovation Chain

Rather than being categorised as a one-way, linear flow from R&D to new products, innovation is now seen as a process of matching technical possibilities to market opportunities, involving multiple interactions and types of learning (Freeman and Soete, 1997). There are a number of clearly identifiable stages (shown in Figure 3) in the development of new technology: R&D, demonstration, pre-commercial (large scale demonstration), supported commercial (under generic support schemes) and commercial (Carbon Trust, 2002; Foxon et al., 2004). However, knowledge flows in both directions, for example, as information from early market applications feeds back into further product research. This means that the conventional drivers of *technology push*, from R&D, and *market pull*, from customer demand, can be reinforced or inhibited by *feedbacks* between different stages and by the influence of *framework conditions*, such as government policy and availability of risk capital. Thus, the dynamic nature of the innovation process is emphasised, with feedbacks between different stages, which can either amplify or inhibit the basic technology push and market pull drivers.

Figure 3: Stages of the innovation chain (Source: adapted from Carbon Trust (2002)



The 'Chain Linked' Model

An early attempt to represent the systems feedbacks within the innovation process was made by Kline and Rosenberg (1986) in their 'chain linked' model. This was used as the conceptual framework in an influential report by the OECD (1992) on 'Technology and the Economy: The Key Relationships'. This model represents the feedback loops between: (i) research; (ii) the existing body of scientific and technological knowledge; (iii) the potential market; (iv) invention; and (v) the various steps in the production process. The model is shown in Figure 4.

Figure 4: An interactive model of the innovation process: The chain-linked model (Source: Kline and Rosenberg (1986))

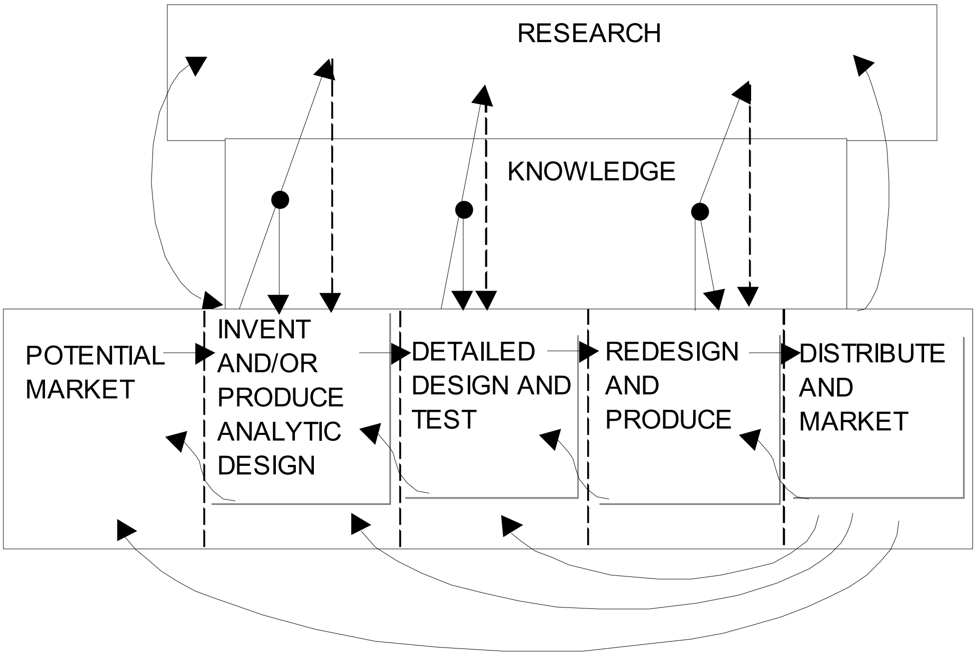


Figure 4 combines two different types of interaction. The first (in the lower part of the model) relates to the processes occurring within a given firm (or a network of firms acting together). The second expresses some of the relationships between the individual firm and the wider science and technology system within which it operates.

At the level of the firm, the innovation chain is represented as a process that starts from the recognition of a potential market opportunity together with a potential design for a new product or process to meet that opportunity. Building on existing scientific or technological knowledge and, where necessary, research to add to that knowledge, an 'analytic design' is produced. This leads to development, production and marketing, but there are feedbacks between each stage and, crucially, feedbacks between the product users and the design and production phases. A key feature is the uncertainty and unpredictable nature of both technological capabilities and user needs.

National Innovation Systems

To apply this type of model, researchers initially focussed on individual and comparative analyses of the innovation systems in different countries, across a range of technologies, as it was argued that key institutional drivers would be found at the national level.

The concept of a 'national system of innovation' was first developed by Chris Freeman, working at SPRU, in a pioneering study of the then successful Japanese economy in the late 1980s. Freeman (1988) defined a national system of innovation as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies." Freeman stressed the positive role of government, working closely with industry and the science base, to create a *vision* and provide *long-term support* for the development and marketing of the most advanced technologies; the *integrated approach* to R&D, design, procurement, production and marketing within large firms; and the high level of general *education* and scientific culture, combined with thorough practical *training* and frequent up-dating in industry.

Two major studies in the early 1990s by Lundvall (1992) and Nelson (1993) analysed national innovation systems in more detail. Lundvall (1992) defined a national system of innovation as constituted by "the elements and relationships which *interact* in the production, diffusion and use of new, and economically useful, knowledge … either located within or rooted inside the borders of a nation state." He stressed the role of interactions between *users* and *producers*, facilitating a flow of information and knowledge linking technological capabilities to user needs. Because of the fundamental *uncertainty* of innovation, these interactions go beyond pure market mechanisms, and rely on mutual trust and mutually respected codes of behaviour.

Nelson and collaborators (1993) conducted a major empirical study and comparison of the national innovation systems of 15 countries. They concluded that "to a considerable extent, differences in innovation systems reflect differences in economic and political circumstances and priorities between countries." Again, these differences reflected the differences in the institutional sub-systems between different countries, including systems of university research and training and industrial R&D, financial institutions, management skills, public infrastructure and national monetary, fiscal and trade policies.

The concept of national innovation systems has been taken forward and used extensively by the OECD (2002), following these early studies. The innovation process is seen as characterised by the different actors and institutions (small and large firms, users, governmental and regulatory bodies, universities, and research bodies), the interactions and flows of knowledge, funding and influence between them, and the incentives for innovation created by the institutional set-up.

Based on a review of innovation systems approaches, Johnson and Jacobsson (2001) identified a set of basic functions that need to be served in a technological innovation system, if a new industry surrounding that technology is to develop successfully. The five basic functions to be served in a technological system are identified as:

- To *create and diffuse 'new' knowledge*;
- To *guide the direction of the search process* among users and suppliers of technology, i.e. influence the direction in which actors deploy their resources (including providing recognition of growth potential, expectations of development, and choice of specific design configurations);
- To *supply resources*, including capital, competencies and other resources;
- To *create positive external economies* through the exchange of information, knowledge and vision;
- To *facilitate the formation of markets*.

Applying this approach to renewable energy technologies, Johnson and Jacobsson (2001) identify a number of mechanisms that induce or block the development of effective functions for particular technology systems. *Inducement mechanisms* may include government policy (e.g. R&D funding, investment subsidies, tax incentives), ease of firm entry, and feedback from market formation, and *blocking mechanisms* may include uncertainty, lack of support, poor connectivity of networks, opposing behaviour of established firms, and disincentives created by other government policies.

4. Rationale for Sustainable Innovation Policy

In this section, we argue that the above picture of innovation as a dynamic, systemic process has considerable implications for policy making that aims to promote more sustainable innovation.

The traditional economic argument for policy measures relating to sustainable innovation has been based on correcting for two principal market failures:

a) Firstly, because knowledge can easily be copied once it has been created, innovators cannot appropriate the full benefits of their investment in the creation of that knowledge, i.e. social returns to innovation exceed private returns, giving rise to a disincentive for private firms to undertake socially efficient levels of innovation (Arrow, 1962). This positive externality is the underlying rationale for public support for research and development (R&D) and for measures such as patent systems.
b) Secondly, the existence of negative externalities, for example, unpriced environmental impacts. This provides the rationale for economic instruments to internalise those externalities, such as environmental taxes or emissions trading schemes.

These arguments and measures remain valid, but we argue that they are insufficient, because they are explicitly or implicitly based on a conceptual framework with an inadequate representation of the innovation process. This sees innovation as a unidirectional process, with more R&D at one end naturally leading to more commercialisation of new products at the other end, with information about technical possibilities and user needs being easily available. Thus, these two types of intervention focus on the two ends of the innovation chain, shown in Figure 3, correcting for perceived market failures at the R&D and commercialisation stages, but neglecting the complexity of the innovation process, including the motivations of actors involved in the process.

Applying the concept of innovation systems, a number of authors have argued for the need to move to a notion of 'systems failure' as a rationale for policy interventions. For example, Edquist (1994, 2001) argues that, because of the evolutionary characteristics of innovation processes, a simple notion of 'market failure' as a comparison between conditions in the real world and an ideal or optimal system is no longer valid. Instead, he advocates concrete empirical and comparative analyses, using innovation systems concepts, to identify systems failures that can be rectified. He identifies two conditions that must be fulfilled for public intervention to be justified in a market economy:

1) a *problem* must exist, i.e. a situation in which market mechanisms and firms fail to achieve socially-defined objectives;
2) the state and its agencies must also have the *ability* to solve or mitigate the problem (i.e. the issue of potential government and bureaucratic failure must be addressed).

Smith (1991) and Metcalfe (2002) also stress that policy making should take an adaptive approach, and look for design and formulation of institutional arrangements that promote business experiments and generate a greater connectedness between organisations generating knowledge, e.g. universities, and those applying such knowledge, e.g. firms.

Previous work by the authors and collaborators (Anderson *et al.*, 2001; Gross and Foxon, 2003) has set out the case for appropriate levels of direct policy support for innovation to achieve environmental ends, including market development policies and financial incentives, as well as support for R&D. The case is based on four interrelated arguments: *The problem of time lags*; *Risks and uncertainties of costs and benefits*; *Value of* *creating options*; *Positive externalities of innovation*. For example, in the energy sector in addition to measures such as emissions taxes and pollution abatement regulation, the case is made for supporting innovation directly, so that environmental problems can be solved sooner, realising economic benefits given by option values and positive externalities.

These ideas can be used to inform debates about appropriate levels and mechanisms for policy support for more sustainable innovation, including conditions under which technologies should no longer receive support, i.e. 'exit strategies'. However, they do not provide simple formulas, and need to be supplemented by empirical data, and judgements about social acceptability of different technology and policy options, in order to be put into practice.

5. Some Lessons from the Case Studies

This section describes initial findings from the two case studies for our research project on 'Policy drivers and barriers for sustainable innovation'.

(1) Low Carbon Innovation in the UK

The first case study is analysing the innovation of low carbon technologies in the UK, focussing on renewable energy technologies. A complex mix of policies has arisen in recent years to support the development of renewable technologies, principally for electricity generation. A target of 10% of electricity to be generated from renewables by 2010 was put in place in 2001, together with a specific policy instrument designed to achieve this – the Renewables Obligation (DTI, 2003). This is an obligation on electricity suppliers to supply an annually increasing proportion of electricity generated from renewable sources, reaching 10% by 2010. This has a number of interesting features:

- It is a long-term measure: remaining in place, at a minimum 10% level, until 2026;
- It has an additional economic incentive: Renewables Obligation Certificates (ROCs) are tradable, as a means of satisfying the obligation;
- There is a 'buy-out price': instead of achieving their targets, suppliers can choose to pay the buy-out price of 3 p/kWh, with the funds being recycled to other suppliers who have met their obligation.

Other relevant measures include a short-term programme of capital grants for offshore wind, biomass energy crops and solar PV; support for renewables R&D; exemption of renewable electricity and good quality CHP from the Climate Change Levy (business energy tax); and a strategic framework for support of offshore wind, including licencing arrangements.

However, concerns have been expressed that current and foreseeable levels of investment will not be sufficient to reach the 10% target by 2010. In particular, many in the renewables industry argue that, in order to secure long-term power purchase agreements with electricity suppliers at rates justifying investment, a renewable generation target of 20% by 2020 is needed (Renewable Energy Report, 2003). This is despite the recent Energy White Paper (DTI, 2003), which set an 'aspiration' of renewable generation of 20% by 2020, together with a long-term goal of reducing the UK's CO_2 emissions by 60% by 2050. Such political aspirations are not regarded as sufficiently 'bankable' by the investment community (Grubb, 2003). In partial response to these concerns, the UK government announced, in December 2003, that the level of the Obligation would be further increased in annual steps beyond 2010 to a level of 15% by 2015.

The case study is also drawing on work by the authors and colleagues for the UK Department of Trade and Industry (DTI) (ICEPT/E4tech, 2003; Foxon *et al.*, 2004), which analysed current UK innovation systems for six new and renewable energy technologies. This work combined expert knowledge and interviews with stakeholders who are active in these innovation systems. The study identified systems failures in moving technologies along the innovation chain at two key stages, and made recommendations for overcoming these failures:

a. Moving from demonstration to pre-commercialisation: There are obstacles to companies seeking to move from the first one or two demonstration projects to more substantial (though still small scale) levels of deployment. The incentives offered by generic measures, such as the Renewables Obligation, cannot attract investment into technologies that are in their early stages of development, and so are high risk, high cost and confined to small niches. These problems may be addressed as follows:

- Policy incentives to create early niche markets are needed, for example, through dedicated capital grants or a 'feed-in' price premium. Costs per unit may be high, but the total numbers installed and total costs, are small.
- Encouragement is needed for the involvement of larger players with the finance and skills base to fund and support larger scale installations.
- Technologies which fail to make it over this gap in a reasonable time period should no longer attract R&D support.

b. Moving from pre-commercial to supported commercial: Several types of risk are hindering the large-scale deployment of pre-commercial technologies (such as offshore wind and biomass). Other energy policy measures associated with liberalization are often focussed on maximising short-run (price) competition. In the electricity generation industry, the resulting fierce market competition has led to price falls, very low profit margins for some producers, and increased risk for long-term investment. At the same time, the rewards, in terms of potential markets, may not be large enough to incentivise long-term investment, particularly where the future market relies on regulatory measures to internalise externalities, which are seen as subject to political risk, as policy priorities or governments change:

- The potential for policy incentives to improve risk/reward ratios should be investigated. This may mean additional funds, e.g. larger capital grants. However, there is scope for regulation to provide for much larger potential long term rewards, such that the private sector is prepared to bear a more early stage risk.

Expectations of the continuity or durability of policy frameworks are exceedingly important. In order to attract sustained investment, rewards from the full range of instruments must be seen to be stable over a sufficiently long timeframe. Innovation succeeds through the 'perseverance' of innovators, and perseverance is also required in policy. It is important that a shared vision for the future of each area of technology between government, industry and the research community is developed.

Within a strategic approach, key priorities should be to ensure:

- Perseverance of policy frameworks – policy measures to support innovation should be stable over the long-term and be insulated from short term political changes.
- Regulatory consistency and synergy – measures should add to the functioning of innovation support as a strategic whole, by augmenting and not disrupting existing measures.
- Continuity of policy measures – measures should 'join up' across the stages of the innovation chain, so that a successfully performing technology can progress smoothly towards commercialisation in self-sustaining markets, which exist without policy support.

However, it is recognised that there will always be a tension between the creation of stable policy frameworks and the need for policy learning, which arises as experience is gained in the implementation of policies, and the potential is created for new ways of achieving policy ends by the development of novel techniques and technologies.

These issues are being further investigated in the case study, including analysis of the policy-making processes which gave rise to the current mix of instruments to promote renewables innovation in the UK.

(2) EU Directives Relating to Alternative Energy Sources in Vehicles

The second case study examines at the EU-level the role of policy-making processes, policy frameworks (e.g. integrated product policy), and policy assessment procedures (e.g. *extended impact assessment*, *comitology*, *regulatory impact assessment*) in promoting or inhibiting innovation of more sustainable technologies and techniques. The particular focus is on alternative energy sources for vehicles, and the main regulatory instruments considered are the Batteries Directive and the End-of-Life Vehicles (ELV) Directive.

If sustainable innovation policy is an ultimate goal, then:

- The policy-making process (including policy frameworks and assessment procedures) should have the goal of "sustainable innovation" itself in-built. This is partly achieved by considering the interaction between the policy-making process and innovation systems, and analysing the different 'windows of opportunity' in which they interact and can influence each other. A main objective of the second case study is to investigate whether this is indeed the case as regards European Community environmental policy-making processes.
- A mix of policy instruments combining legislation (command-and-control), economic instruments and voluntary agreements needs to be considered, within a more integrated strategic framework. It is submitted that instrument mixes are a key means of moving the sustainable innovation agenda forward, and that European Community institutions are sensing that stakeholder responsibility is an important way of achieving this.

The Integrated Product Policy (IPP) framework at EU-level is an example of a more integrated, systemic policy framework, aiming to improve environmental performance at all phases of a product's life cycle. It seeks to establish principles and boundaries within which product policies would be designed and implemented. However, many of the proposals in the Green Paper have been eliminated or made not legally-binding in the final IPP Communication adopted by the European

Commission (EC, 2003). The case study is analysing the causes and consequences of this, particularly, the extent to which the promotion of sustainable innovation has been attenuated, especially in relation to the Batteries and ELV Directives.

The Extended Impact Assessment (ExIA) methodology is a new policy assessment procedure, and the Batteries Directive will be the first legislative instrument to which it will be applied. This is in line with the Commission and the Council's Better Regulation Action Plan (EC, 2002). The case study will examine the potential for ExIA to advance environmental protection and sustainable innovation, as it seeks to marry cost-benefit analysis, social impacts and environmental impact assessment in novel ways.

The systemic nature of the innovation process requires a combination of policy instruments that will deal with a range of different aspects, in order to achieve environmental protection targets. There are at least two ways that a mix of instruments aimed at one policy goal might evolve:

a) Through a conscious decision of DG Environment, a group of policy analysts could deliberately construct a strategy for promoting, for example, new technologies in alternative energy vehicles, by drawing upon a large number of disparate individual initiatives, which when taken collectively, all aim at promoting these technologies.
b) Combining command-and-control instruments, economic instruments and voluntary agreements within a single legislative framework. This alternative comes closest to approximating a mix of instruments at the European Community level to date.

At present, the Batteries Directive (91/157/EEC) is in the midst of a European Commission-led consultation process (BDC, 2002). This consultation process is of particular interest because:

a) It is entirely possible that in part, a combination or mix of instruments will be agreed for implementing the revised Directive, including voluntary instruments (e.g. legally-binding new waste stream monitoring techniques and technologies, as well as collection targets to be implemented by firms), economic instruments (e.g. a charging system to determine battery company contributions to the scheme) and more traditional command-and-control measures (e.g. to punish free riders or non-compliant parties).
b) There are two key principles that the revised Batteries Directive will codify, which are in direct interest of sustainable innovation: the *substitution principle* and the *producer responsibility principle*.

The choice and balance of instruments will have an effect on sustainable innovation. For example, a ban on cadmium (being considered under the new revision) would temporarily end European companies' electric car production, as nickel-cadmium (NiCd) is the only battery technology in European mass produced electric vehicles. This could have at least two effects on alternative energy vehicle production compared to other technologically locked-in internal combustion engine and lead-acid battery production. In the short and medium term, locked-in technology market share will not significantly fall, and electric vehicle demand may not be stimulated. However, a vacuum in the electric vehicle market may provide a stimulus for emerging technologies, including other battery technologies (e.g., lithium ion and nickel metal hydride) and fuel cells, to press ahead more rapidly.

The substitution principle is arguably the single greatest legally binding mechanism in the service of sustainable innovation policy as promulgated by the European Community. If applied in a flexible manner, this principle allows for regulators to effectively phase out and ban certain locked-in technologies and techniques in the service of environmental protection provided that such a decision is based on sound science. It is anticipated that this principle will be applied to battery chemistries with dangerous substances in favour of emerging technologies. In relation to the key role of stakeholders, it is noteworthy that the Battery Directive consultations have not, so far, featured any lobby or stakeholder group that is seen to be acting in the interest of sustainable innovation.

The objective of the End of Life Vehicles Directive (2000/53/EC) is to prevent waste from vehicles and to foster reuse, recycling and recovery as alternatives to the disposal of vehicle-based waste, hence removing 8-9 million tones of waste annually. Though it is not directly articulated, the Directive features the substitution principle, as it seeks a prohibition on the use of certain substances (lead, mercury, cadmium and hexavalent chromium) in existing vehicle technologies to the extent that this is permitted by scientific and technical progress. Hence, more environmentally sustainable technologies and techniques must be invented to allow substitution of these materials at the car design stage, the so-called "conception phase".

The Directive also serves sustainable innovation policy by suggesting that the design and production of new vehicles must take account of dismantling, reuse, recycling and recovery of vehicles, their components and parts. This provides the ideal opportunity for the car industry to implement the European Commission's evolving policy on integrated product policy so that design stage decisions are consistent with the highest standards of waste management strategy and implementation.

This case study will further analyse and draw out the implications of these findings for the development of sustainable innovation policy processes.

6. Conclusion: Emerging Hypotheses for Sustainable Innovation Policy

Drawing on the above theoretical and empirical research, and other current work in this area (Rennings *et al.*, 2004; Zundel and Satorius, 2004), we now conclude the chapter by outlining some emerging hypotheses relating to sustainable innovation policy-making.

(1) Policy-making in this area would be enhanced by taking into account the richness and complexity of innovation processes.

Policy design and implementation needs to reflect the systemic, dynamic nature of the innovation process. Consequently, greater understanding of how innovation systems actually work is needed, relating to: the actors involved and the flows of knowledge and influence between them; the drivers and barriers for innovation; and the ways in which current systems fail to promote movement of more sustainable technologies along the innovation chain. Policies may then be designed to address these 'systems failures', which will include but are not limited to conventional market failures.

(2) Effective policy-making requires a long-term strategic framework.

The transition to more sustainable socio-natural systems is likely to require significant re-orientation of investment away from resource- and pollution- intensive industries and technologies and towards the innovation and diffusion of more sustainable technologies. In order to achieve this re-orientation, technology developers and investors need clear expectations that markets for technologies with appropriate attributes are likely to exist and that policy measures to support the transition will be stable over the long term. This implies the need for a long-term strategic policy framework, in order to improve coherence of policy measures, ensure continuity and perseverance of policies over a longer time frame, and improve expectations of stability. Such a framework would also need to make clear when support would be withdrawn from technologies, either because they have failed to make sufficient progress towards commercialisation, or, preferably, because they can have successfully progressed to the stage of being competitive without further public support.

The Dutch 'Transition Management' model (Kemp and Loorbach, 2003) provides an example of such a long-term strategic framework, in which policy-makers and stakeholders from industry, NGOs and wider society work together to:

- define a vision for the long-term future of an industry or sector;
- agree strategic goals for the medium term;
- set out transition paths or 'route maps' for how these might be achieved;
- agree support for the initial steps or 'learning experiments' along these paths.

Such a model would need to be adapted to fit the circumstances of particular countries, institutions and industries.

(3) The details of the design and implementation of policy instruments can have a significant impact on the resulting pattern of incentives for innovation.

Many current unsustainable technological systems have benefited from long periods of increasing returns to adoption, for both the technologies, leading to reduced costs and improved performance, and in the institutional structures of standards, rules and laws supporting them. This may result in 'lock-in' of these systems, because of the difficulties of entry faced by potential new competitors. Hence, the standard policy prescriptions of support for R&D and internalising externalities, though important, are unlikely to be enough in themselves to promote transitions to more sustainable systems. Specific support for the innovation of more sustainable technologies in the early stages of their development is likely to be needed. One good, through controversial, example is the support of renewable energy technologies, in Germany and other countries, through a 'feed-in' law, which guarantees a premium market price for electricity generated from these sources. In addition, the implementation of measures to internalise environmental externalities associated with less sustainable technologies may exert critical influences on promoting or inhibiting more sustainable innovation. For example, in setting tradable permit schemes to internalise the environmental costs of emissions, the extent to which permits are 'grandfathered' to existing polluters, rather than auctioned, can make a significant difference to the pattern of incentives.

(4) There may exist 'windows of opportunity' for policy-makers to positively influence the innovation process.

Policy-making processes are systemic and dynamic, and exhibit 'path dependency', i.e. subsequent policy choices may depend on the historical path of development of policies and so on previous choices made. One consequence of this is that there may exist particular and limited 'windows of opportunity' for policy-making to influence innovation processes (David, 1987; Perez and Soete, 1988; Kingdon, 1998; Nill, 2003), e.g. in the early stages of technology and policy development, or under particularly favourable economic conditions. In the European Community context, the determination of the European Parliament's legislative programme, the determination of annual policy programme goals by the European Commission and the development of Green Papers may serve as early windows. At a later stage, Directive drafting consultations and the tabling of initiatives before the European Parliament's Environment Committee offer strategic opportunities to influence the promotion of sustainable innovation.

(5) Effective sustainable innovation policy is likely to feature a coherent and integrated mix of instruments, combining a variety of instrument types.

Given the market driven nature of sustainable innovation policy, the integration of a mix of instruments based in part on their sensitivity to market considerations (i.e. economic instruments, voluntary agreements, eco-labels, investment strategies, environmental management systems and innovation network concepts) with sustainable innovation policymaking activities seems likely to be appropriate. The variety in this mix might usefully complement more traditional forms of command and control regulation. This could be achieved through a series of policy initiatives or through the establishment of an umbrella (legislative) instrument that features a combined mix of policy instruments.

(6) At the institutional level, there is a need to achieve greater consistency in policy interventions towards sustainable innovation.

This consistency might be achieved if European Community policy filters and procedures such as integrated product policy, extended impact assessment, regulatory impact assessment, comitology, co-decision, co-operation were to feature a check on the development of policy instruments to ensure that they maintain and advance sustainable innovation as a policy goal. Until these policy filters and procedures are reformed, this may require actions such as the formation of a special Unit charged with monitoring and addressing policy disfunctions that detract from sustainable innovation. Such a Unit might also seek to promote the integration of sustainable innovation policy development among the European Commission Directorates General.

(7) There may be a role for stakeholders and 'enablers' to advance sustainable innovation throughout the policy-making and implementation process.

Stakeholder consultation processes and policy development procedures that feature significant multi-stakeholder dialogue and foster a sense of common ownership of policies are likely to be appropriate and effective. This kind of approach might assist in correcting the environmental policy problems of locked-in technologies (where substitution is desirable) and the observable lack of a represented "innovation" constituency with the political capital to advance sustainable innovation as a strategic policy goal. Furthermore, multi-stakeholder "enablers" could play a key role in fostering policy uptake within the sustainable innovation system through direct interaction with innovators.

(8) In a dynamic setting, a learning approach to policy-making may help to produce a better mix of policies that is not predicated on the achievement of an ideal, 'optimal' policy choice.

Given the limited ability of policy-makers to gather and process all the relevant information ('bounded rationality'), and the inherent uncertainties of innovation processes, there seems little likelihood of developing 'optimal' solutions. In addition, the path dependency of policy making and the interaction between policies further increases the complexity of the task. This suggests the potential value of moving to a 'learning approach' to policy-making, situated within a stable strategic framework, e.g. by designing periodic "policy self-correction" mechanisms to address circumstances where the unintended consequences of policy choices outweigh their benefits, or novel techniques and technologies enable new ways of achieving policy ends.

These hypotheses will be subjected to further investigation and analysis in the course of developing the project case studies and formulating and testing the final guidelines for improving sustainable innovation policy processes.

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Section B: Transition Strategies

Governing Sustainable Industrial Transformation Under Different Transition Contexts

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Introduction

In recent years, the analytical lens in innovation and environment studies has tended to pull back from firm-level processes of cleaner technology innovation. Studies have refocused on wider, linked processes that green the *systems* of social and technological practice by which we satisfy our needs for housing, mobility, food, communications, leisure, and so forth. These 'socio-technical regimes' have become the focal unit of analysis, and the challenge is to transform them into more sustainable configurations (Berkhout, 2002).

The new focus on regimes places earlier analytical concerns in a broader context, recognising that firms and technologies are embedded within wider social systems. Some of the reasons cleaner technology is not diffusing rapidly through firms, for example, relate to the overarching structure of markets, patterns of final consumer demand, institutional and regulatory systems and inadequate infrastructures for change. On issues such as these, firms have limited room for unilateral manoeuvre. However, the new focus is motivated by an additional assumption, that only radical changes at the regime level can deliver sustainable development (Rotmans and Kemp, 2001). The new focus seeks to understand and guide 'systems innovation' in order to facilitate not only greener firms, but more sustainable practices from all participants in any given socio-technical regime.

In transforming the industrial sustainability agenda in this way, the governance challenge becomes more ambitious and more demanding. We have argued elsewhere that approaches to sustainable systems innovation have hitherto been somewhat restricted. Despite the breadth of the concept, there is a tendency to treat regime transformation as a monolithic process, independent of important differences in *context* (Berkhout, Smith and Stirling, 2003). We also argue that existing approaches tend to be too descriptive and structural, leaving room for greater analysis of *agency* as a means to more informed, deliberate and effective processes of regime transformation. In short, if we are to engage both analytically and normatively with the complexities of governing sustainable systems innovation, there is a need for more explicit and detailed conceptual tools. In this chapter we propose as a heuristic, a systematic framework for understanding different transition contexts and associated governance implications. Our specific objectives are threefold:

1. To encourage greater attention to agency in our understandings of transitions in socio-technical regimes.
2. To distinguish more clearly between different elements in the context for regime transition: the *articulation* of selection pressures, and the *adaptive capacity* available to facilitate regime transformation.
3. Recognition of these different contextual elements is likely to affect both descriptive understandings and normative recommendations. We aim to explore some of the resulting practical implications for the governance of sustainable technology strategies.

With this particular interest in governance, we address the crucial question of agency by introducing the notion of regime *membership*. This recognises that technological regimes are not unitary entities, but involve the active co-ordination of lower order agency on the part of institutions, networks and actors as regime 'members' in their own right (see also Jacobsson and Johnson, 2001). This given, our model of regime transformation is then a function of three factors. First, the degree to which the selection pressures bearing upon a regime are *articulated* towards a particular direction of transformation on the part of regime members. We argue that without this articulation of selection pressures the conditions for systems innovation do not exist. Second, the degree to which the resources required for effective regime transformation (factor endowments, capabilities, positioning) are available either within or beyond the members of the incumbent regime. Third, the degree to which the response to these pressures is *co-ordinated* in a coherent fashion across regime members. It is these latter two elements (the ability to co-ordinate responses and the availability of resources), that we identify as the '*adaptive capacity*' available for regime transition (Berkhout, Smith and Stirling, 2003). In the end, the particular form and direction of regime transformation – and the associated modes of governance– will depend on the 'transition context': a function of the availability of resources and how they are coordinated.

The analytical framework presented here is preliminary, speculative and heuristic. The chapter is organised around each of the objectives above. The next section discusses the regime concept at greater length and, in particular, the networks of actors, institutions and processes by which regimes are reproduced. After this we discuss the origins of change for socio-technical regimes. We suggest that transformation processes can be organised according to whether they contribute to the articulation of selection pressures (exerting a demand for change), or whether they contribute to the availability of adaptive capacity (resourcing a co-ordinated response to selection pressures). Governance of regime transitions involves modifying the balance of selection pressures and adaptive capacities. It follows from this that different patterns of transformation can take place, depending upon the prevailing transition context. We introduce a simple typology to help map such transition contexts and guide the analysis of governance for regime transition.

Mapping Socio-Technical Regimes – an Agency-Based Approach

Socio-technical regimes are relatively stable configurations of institutions, techniques and artefacts – as well as rules, practices and networks – that determine the 'normal' development and use of technology in order to fulfil socially-determined functions. Regimes thus embody strongly held convictions and interests concerning particular technological practices and the best ways in which these might be improved. Modern agriculture, for example, has evolved along a trajectory in which increased factor productivity has been the goal, measured in terms similar to industrial productivity. This regime has consequently focused on mechanisation, specialisation and increased inputs of energy and chemicals that have boosted massively the agricultural output per unit of labour. In the meantime, an alternative conceptualisation of agricultural goals has struggled to gain limited acceptance. Organic farming was originally pushed by a small group of dissenting voices around the same time that the principles of modern agriculture were being embedded in government policy in the industrialised world in the 1930s and 1940s (Conford, 2001). Organic farming focuses on output per unit land area, usually favouring mixed farms, and is concerned with nurturing soil fertility through the relatively closed cycling of materials. It is only now beginning to reach the status of a substantial niche socio-technical activity (in the sense that there is a robust network of actors and institutions supporting the organic approach to agriculture).

But this sketch points up some of the problems with employing a concept as broad as the technological regime. It begs a number of questions: Where do we draw the boundaries of the regime? What constitutes the membership of a regime? In what sense can regimes be seen as competing? Is the source of selection pressures on regimes other competing regimes, or do they stem from broader societal factors? In this section we take as a starting point the behaviour of agents that constitute regimes.

Socio-technical regimes and their empirical application

In the established literature, the term 'regime' is used as a short-hand for a series of complex, nested real world phenomena, embodying natural and artificial physical elements, as well as social, economic, cultural and cognitive attributes. Regimes exist across different empirical scales, and can be seen as constituting the social and economic functions which they serve.[1] At a relatively high level of aggregation, the electricity generating regime is widely dominated by social rules and practices relating to centralised, large scale (usually thermal) power technology and high voltage alternating current grid infrastructures. Consumption patterns and supportive institutional arrangements are built around and reinforce this pattern of energy utilisation. This has been the 'normal' way of producing electricity in industrialised countries for at least eight decades. However, at the lower level of aggregation of individual power technologies, the electricity generating regime as a whole spans a variety of nested subordinate regimes, such as that based on the coal-fired steam turbine, the nuclear fuel cycle, large scale hydroelectricity or gas-fired combined cycle turbine systems. At this level, even within the emerging niche for renewable generated electricity, we may identify an incipient regime dominated by 3-bladed, horizontal axis megawatt-scale wind turbine operating in grid connected clusters and supported through public policy. This has become the normal way of generating power from the wind, and a network of actor practices has developed around this dominant mode of wind energy utilisation.[2] However, recent developments to promote distributed solar energy utilisation through PV installations integrated into the structure of buildings is another example of a new and quite distinct pattern, nested within the wider incipient renewable regime, itself a relatively small part of the encompassing electricity regime as a whole. Conversely, the electricity regime itself may be seen as nested within a global energy regime organised primarily around the extraction, global transport and thermal combustion of fossil fuels.

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1 New technologies often precede the definition of the functions they will serve. To give a contemporary example, the function of mobile digital photography is currently being defined.

2 This is in contrast to the vertical axis designs favoured by some governments at the early stages of modern wind energy innovation, and also in contrast to off-grid, smaller wind energy concepts advocated by others (Gipe, 1995).

The relative status of these particular power technology regimes (e.g. in terms of market share or future expectations by investors) will have an influence on developments in the energy regime at higher levels of aggregation. Some of these 'regime' examples (i.e. wind and PV) actually represent only niche practices and concepts when looked at from the higher perspective of the electricity regime as a whole, since they enjoy neither the institutional nor the market dominance that is a defining feature of the regime concept. Clearly, there is a need carefully to distinguish in any given context between what constitutes the 'nested' and the 'spanning' regime, and to be quite precise in the empirical application of the concept of the socio-technical regime.

Membership of socio-technical regimes

The present focus on the governance of technological transitions requires an explicit focus on the role of agency both within and beyond the regime. In particular, there is a need to think systematically about the empirical boundaries and inter-relationships bearing on regimes at different levels. At root, socio-technical regimes are produced and reproduced by networks of state, civil society and market-based actors and institutions. Take, for example, the regime that supplies water to urban and suburban areas of Europe. In this case, the regime rules and practices relate to a centralised system of water supply through pipes, meeting statutory quality standards, and funded by the regulated charges made to households and other end users. This is reproduced by a network of water companies, capital equipment suppliers, manufacturers of biological and chemical treatments, economic and environmental regulators, households and other water users, consumer groups, government ministries, trade and professional associations, education and training establishments, and so on. All of these actors contribute in some form or other to the operation of the regime by which water reaches the taps of households and firms. As such, all may be considered, to some extent, to constitute 'members' of the water supply regime.

It is clear that the regime is not a homogenous, clearly-bounded entity. However, as this water example illustrates, the question of regime membership is itself complex and problematic. Many members are to some extent also actors in regimes other than water supply. In the specific context of water, some regime members are more tightly networked together than others. That is, the exercise of their agency in the functioning of the regime is more *intensive* than others, and their interests and objectives tend to be more influential on the direction taken by the regime. Clearly, water utility companies are key actors in the practical functioning and evolution of the water regime. They operate key technologies and they make key investment decisions. Households might also appear to be intensively involved, in the sense that practices at household level create the daily demand for water. Households are also the primary source of revenue for water supply companies. But household involvement is mainly *passive*. Households are 'price takers', rarely engaged directly in shaping the rules and operation of the water supply regime. Their influence is most evident in the guise of aggregate demand projections, constructed by the water companies and others in managing the regime and planning change.[3] Government agencies play a more formative role in the operation and development of the water regime by setting standards and procedures for planning, safety, quality and pricing. They can therefore be seen as more directly involved in constituting the regime than households. In this

[3] Some sociologists argue that we need to deconstruct this passive consumer demand in order to understand water regime transformation (Hand et al., 2003). Changing lifestyles and technologies in the home, for instance, must be problematised, according to this view, and brought into regime development in a much more active capacity. The benefits of efficient washing machines can be lost if offset by patterns of consumption (e.g. popular conceptions of cleanliness) that lead to households washing smaller loads more frequently.

way, it is clear how institutions and their inter-relationships reflect and reinforce the exercise of agency on the part of different actors in any particular regime, and so condition the degree of regime membership.

The discussion so far argues that one way of delineating network boundaries empirically is by analysing the degree to which different actors contribute to the functions that reproduce a regime. We see that regime membership is a relative notion and can be independent of the frequency of economic and other transactions. Those actors who contribute intensively will be core members of the regime. Those actors whose involvement is less intensive will be peripheral members of the regime. Typically no single core member embodies all the elements needed to constitute or reproduce a regime. Although several members may be necessary to the proper functioning of the regime, none alone are sufficient. The crucial determining factor in the effective operation and development of the regime lies not simply in the agency of the individual core members, but in the norms and procedures governing their structured relationships and interdependencies.[4]

The recognition of these structured relationships highlights the arena within which the *strategic* exercise of agency is played out. The role of strategic competition between core members of a regime is vividly illustrated in the field of public health. Here, governments are dependent on pharmaceutical and biomedical industries as key components in the incumbent socio-technical regime. These industries are in turn dependent on government for licenses to market products and services and, in some countries, also as a major purchaser. The operation and development of this regime, thus depends on the effective interplay of these interdependencies. Strategic games emerge around issues such as the prioritisation of different public health objectives, the allocation of resources to contending research and development options, and the regulation of associated safety issues, pricing structures and intellectual property rights. The development of the regime as a whole is played out through active interplay – and sometimes highly adversarial negotiation – between core regime members such as government departments and industry associations. The influence of others, such as regulators, patient groups, the medical profession in this highly charged arena depends on how intensively they contribute to 'normal' regime functioning.

This issue of strategic interaction within the regime – and the differential levels of agency enjoyed by core and peripheral regime members – is especially acute in the construction of the 'guiding visions' which characterise, rationalise and reproduce the developmental trajectory taken by a regime (van de Ven et al, 1989; Rosenberg, 1994; Kemp and Rotmans, 2001; Berkhout et al, 2003). Different core members will have different ideas and interests bearing on regime development, will exert varying degrees of influence on the construction of these guiding visions and deploy their resources strategically to those ends. By analogy with the idea of 'appreciative systems' in policy analysis (Marsh and Rhodes, 1992), strategic interactions reflecting the agency of individual actors (rather than the regime as a whole) can exercise a crucial conditioning influence on these visions.

At times when the normal functioning of the regime is problematic or under stress, peripheral members or outsider actors may be able to intervene with their ideas to greater effect. Under such circumstances, criticisms of regime effectiveness or function appear more reasonable, and debate can be fruitfully opened up. At other times, when regimes are not under such stress, then such opening up is more difficult. Indeed, the way regimes service socio-technical functions can serve to close down the scope for alternative configurations. Regime stress is brought about through the

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4 Note that this idea is borrowed from the power-dependency theory that lies at the heart of policy network analysis in political science (see Benson, 1980 and Marsh and Rhodes, 1992).

greater articulation of challenging selection pressures, but which are often weak and incoherent. Sometimes, however, the intensity, salience and articulation of certain pressures (e.g. the declining profitability in the current way of doing things, or growing public alarm at the social consequences) induces stress in the regime and opens up windows of opportunity for non-members of the regime to intervene. These occasions are rare.

Socio-technical regimes as social structures

Given the interactions and interdependencies of regime members, it is unsurprising that the literature tends to stress the stability of socio-technical regimes and the rarity of systems innovations (Sahal, 1985). Regime inertia means that regime members tend not to look at familiar problems in a new light or to innovate according to a new vision and rules. Indeed, core regime members often resist change that is considered to threaten the benefits they receive from the *status quo* (Christiansen, 1997). Regimes consequently tend to channel their own development along technological trajectories that are path dependent, and which tend to transform the regime very slowly through an accumulation of incremental changes. This is compounded by the way regimes become increasingly institutionalised, in the sense that social systems like the science system, finance, legislation, training, technology standards, market structures and so forth, tend to entrench regime development by becoming enrolled in its reproduction. The difficulty of realigning such institutions with promising new niches can be a major impediment to their breakthrough into the mainstream (Perez, 1983). Infrastructures supportive of the incumbent regime, and the co-evolution of interdependencies with other regimes (e.g. suburban housing and the private motor car), can act to lock regime development deeper into historical trajectories.

As with many 'structural' accounts, the problem with this regime picture is that it says little about the conditions under which change occurs, or about the switches that may occur between regimes. Any ambitions towards transition management, say, whilst rightly recognising the many structural features of regimes, will also need to analyse and seek out sites of agency within and outside these structures.

Regime shifts or successions clearly have occurred in the past. Who knows, perhaps one day an organic food regime may displace the trajectory of intensive agriculture that has dominated these last decades. Perhaps the energy regime will be transformed by wide-scale adoption of distributed renewable energy systems oriented towards the provision of efficient energy services, rather than maximising bulk sales of energy units. The point, however, is that we need to understand how regimes come to be replaced or radically transformed if we are to sense the likelihood of such scenarios. We need to analyse the processes that enable the exercise of agency in such regimes. In particular, we need to be clear about precisely how, and under what conditions, networks of actors both within and outside the regime can successfully affect a process of deliberate, purposive change.

Socio-Technical Transformations

Despite their relative stability, regimes change. Given the breadth of empirical scope, the variety of regime members, and the structural characteristics of regimes, radical changes are likely to proceed through a complex and unique history of interrelated events. In cutting into such complexity it is helpful to have a relatively straightforward heuristic to fall back upon, in order to help organise one's thinking.

With this aim in mind, we adopt a quasi-evolutionary perspective on the fundamental processes that shape regime transformations.

A quasi-evolutionary model of regime transformation

We understand regime change to be a function of two processes.

1. Shifting selection pressures bearing upon the regime.
2. The coordination of resources available inside and outside the regime to adapt to these pressures.

The governance of regime transformation can be organised through intervention in these two realms. It may seek to address the form, intensity, articulation or orientation of the selection pressures that act on target regimes. Alternatively (or complementarily) it may address the quality and distribution of adaptive capabilities, including the capacity to mount a co-ordinated response and the availability or resources (such as finance, legitimacy or competence) to support these responses. In this sense, policies such as environmental taxation, negotiated agreements, and regulations seek to promote more sustainable configurations through favourable modifications to the selection pressures felt by a regime. Broadly speaking, this is 'back-end' governance that operates through regulatory or fiscal systems. Policies such as R,D&D, environmental management systems, foresight exercises, and capital allowance grants, on the other hand, tend more towards the reshaping of regime adaptive capacity. This 'front end' governance intervenes in the innovation system, in a way advocated by Constructive Technology Assessment. We now elaborate each of these approaches in turn.

The articulation of selection pressures

Conventional economic analysis for the governance of transitions towards more sustainable technology, tends to focus on those forms of pressure which operate visibly at the level of the firm, such as pricing, competition, contracts, taxes and charges, regulations, standards, liability, profitability, skills and knowledge. Analysis at the level of the socio-technical regime, on the other hand, includes such factors, but goes beyond them to consider less economically visible pressures emanating from internal institutional structures, changes in broad political economic 'landscapes', or wider socio-cultural trends. These can be directed at specific regimes, such as the anti-nuclear movement. Or they can be more general, like the ebb and flow of environmentalism as a popular concern in society. Trade associations and industry lobbies are just as involved in the public realm as environmental NGOs in pushing for different patterns of future development. In the energy sector again, for instance, many different actors are promoting visions for a 'hydrogen economy' (Rifkin, 2002). Such activity is significant because it has some bearing upon public policy processes, discussions about long-term strategies in industry, areas of interest to venture capitalists, and so forth. In short, debates in the wider civil society serve to frame the functional reproduction of socio-technical regimes.

Other pressures can derive from social change, which is not targeted at any specific regime, but which can bring about selection pressures on regimes. Examples might include demographic shifts, such as the aging populations of some European countries, or economic migration. Another might be the rise of consumer culture based on the individualistic definition and satisfaction of needs, channelled through an expanding consumption of commodities (Leiss, 1978). A further example might lie in the rise of a neo-liberal model of globalisation with more mobile capital and the deregulation of markets. All these features of the wider political and economic 'landscape' can create important selection pressures for technological regimes. Often these pressures are weak and incoherent, but at other times they become stronger and more coherently articulated.

The examples of selection pressure introduced above operate at a relatively high empirical level: the changing ideology of political and economic elites; the cultural deepening of consumerism; a greening of public attitudes to consumption, and so on. Of course, incumbent regimes face competitive pressures from other regimes too. This is the more conventional sense in which firms are understood to be involved in systems innovation. The coal-fired power technology regime has been under increasing pressure from the combined cycle gas turbine regime, for instance. In other cases, pressures might 'bubble up' from below, from innovative niches that are not yet so established as to constitute a regime. The transition management approach to governing regime transformation recommends this strategy: the purposeful creation and temporary protection of desirable, niche alternatives which can then be used to seed regime changes (Rotmans and Kemp, 2001).

Without at least some form of internal or external pressure in the broad and diverse senses discussed above, it is unlikely that substantive change to the developmental trajectory will result. However, selection pressures of the kind used as illustrations above are pervasive in post-industrial societies. There is typically no shortage of such pressures – of one sort or another – acting on a regime, many pushing in opposing directions. In practice, it is therefore not the existence of such pressures that is decisive. Instead, it is what we term the *articulation* of pressures for any given regime transformation. This comprises two elements.

First, there is the extent to which selection pressures are oriented coherently in a particular direction. As suggested, different pressures may often act incoherently to promote different forms of response, and so may tend to 'cancel out'. An example might be the conflicting influences on the development of renewable electricity generation in UK energy during the 1990s exerted by falling consumer prices on the one hand, and Government financial support on the other. Another might be the conflicting pressures acting on the global prospects for genetically modified crops, as embodied in strongly positive government and industry commitments in the USA and certain other major exporting markets, contrasted with intense consumer resistance and wider institutional opposition in important import markets such as Europe and Japan.

The second element in effective articulation lies in the processes which render these pressures explicit and translate them into a form that prompts and enables a response by the regime. Here, climate change can be offered as an example. It has taken many years for a scientific consensus to emerge (IPCC, 2001a and 2001b). This scientific consensus stands at the base of international agreement to cut carbon emissions has been reached, and signatory nations are developing their own policies and taking action to move towards lower carbon regimes. This process of identifying, translating and highlighting an environmental pressure is essential to its effective articulation with socio-technical regimes such as those in the electricity supply and private and freight transport. Elsewhere we have discussed some other less well recognised modes of articulation, and their associated pressures (see Berkhout, Smith and Stirling, 2003). Table 1 reproduces a range of different types of selection pressure, and for each illustrates some governance processes through which they might be articulated for the regimes in question.

Table 1: Regime selection pressure and their articulation.

Cause of selection pressure	**Example**	**Articulation processes**
The creation within niches of novel socio-technical configurations for meeting a social function.	Putting the organic farming vision into practice, and the spur this gives to mainstream industrial agriculture to become more sustainable.	Measures that support the niche, such as: Grants to create organic food niches. Establishing organic growing training programmes. Niche market creation (e.g. public procurement, green consumerism).
An innovation that seeds a transformation in a 'spanning' regime.	The impact of high-levels of wind turbine capacity on the structure and operation of the electricity system.	Measures to support expansion in the nested regime, such as: Price supports for wind energy. Strategic investments in infrastructure changes suited to wind energy. Environmental NGO campaigns for wind expansion.
The spur to innovation felt through competition from another socio-technical regime serving the same or over-lapping markets or social functions.	Competition between the different electricity technological regimes: coal; gas; oil; nuclear; and renewables.	Measures which promote technological or resource diversity, such as: Incentives to support a balanced portfolio of energy technologies and systems. A regulatory framework for fair competition between regimes, within environmental constraints.
The competition between different 'visions' for the future held by a variety of social actors, some of whom are more directly embedded within the regime than others; and the different power resources they have to pursue these visions.	Current contention over the use of 'science-based' risk assessment versus more broad-based 'precautionary' approaches to chemicals regulation.	Measures for civic debate, such as: Broadening participation in the framing of chemical regulatory decisions. Introducing contentious visions into processes of policy negotiation. Local protests against chemical establishments.
The generation of changes in the social landscape that put the regime in tension.	The liberalisation of energy markets in the EU.	Measures to understand the implications for regimes, such as: Monitoring social trends. Foresight exercises. Dissatisfaction with the poor fit of the regime with modern life.
Politically-motivated debates targeted at changing a range of problematic socio-technical regimes.	The current public debates and campaigns over genetically-modified foods in the EU.	Measures that create informed debate, such as: Public participation in policy agenda setting (e.g. identifying which regimes are effected by debates). Dissenting voices. A well resourced, educated, vibrant civil society

Articulation processes happen through coalitions of resource interdependent actors acting within and beyond established institutions of governance. They may or may not include regime members. Proactive industry leaders may, for example, push the case for changes within regimes. As with the delineation of regimes, so the identification of articulation processes is an empirical task. Whichever ways selection pressures become articulated, they only form one half of the regime transformation equation. The other factor is the capacity available either within the incumbent regime or outside it, to respond adaptively to that pressure.

Adaptive Capacity in Regime Transformation

Some regimes have the capacity to respond more readily to selection pressures than others. We refer to this feature as the *adaptive capacity* of a regime. One way of characterising regime adaptive capacity is with reference to five 'functions' that contribute to the reproduction of technological systems (Jacobsson and Johnsson, 2001).[5] These functions are reproduced in Table 2. The better able regime members are to carry out these regime functions, the better the regime as a whole will be able to respond to selection pressures. Regimes can be seen as being reproduced along trajectories that are in part determined by selection pressures being applied to them. The more intensive or threatening these pressures, the greater will be the resources devoted to defending the regime. This might be one understanding, for instance, of current efforts within the electricity supply regime to respond to climate change concerns by establishing techniques for the sequestering and environmental disposal of carbon from fossil fuel power stations.

We draw a distinction between capability and capacity. Capability is qualitative, and relates to the precise way regime functions are fulfilled. Capacity is more of a quantitative term. Adaptive capacity is about how much of any given adaptive capability one can bring into play. The regime membership might, for example, guide search directions (a capability) but in only limited areas at any given time (a capacity constraint). All else being equal, the more adaptive regimes would be those whose membership is able most effectively to reproduce the regime in the context of

Table 2: How different governance activities contribute to adaptive capacity.

Adaptive capability functions	Example	Governance contribution to that function
Creation of new knowledge: the main source of variety in technological systems.	Research into fuel cell technology and its applications.	Public R&D. Education and training policy.
Influence over the direction of search processes among users and suppliers of technology: the articulation of supply and demand is seen as critical to the perceived costs and benefits of regime switching.	The way a growing coalition of actors are building expectations for a future hydrogen economy, and how this influences research and industrial agendas.	High-level foresight exercises. Organisation of conferences with prestigious business speakers. Environmental lobbying which weakens faith in incumbent regime and raises the profile of others.
Supply of resources: These include capital, competences and input materials as well as political resources that support the legitimacy of a regime.	Ability to bring together the finance, technology, and fuel supply infrastructure to roll out local biomass energy businesses at more and more rural locations.	Public underwriting of risks and soft loans. Grants (public and private). Secondment of expertise to new initiatives.
Creation of positive external economies: This is a pivotal characteristic. An example is the formation of socio-technical networks that provide 'spill-over' effects by reducing uncertainty, reducing the cost of information, accessing tacit knowledge and sharing costs.	The entry of a large industrial investor into a hitherto niche activity, such as biomass energy, boosting the status of the niche (e.g. credit rating with financiers, interest from other firms). Or, the way development of wider biomass supply infrastructures makes it easier for new biomass energy firms to enter the market.	Public pressures on companies to seek out more responsible corporate activities. Publicity about the success of a growing niche. Study tours and sponsoring visits to projects. Infrastructure support. Favourable regulatory environments.
Formation of markets: Innovations rarely find ready-made markets, which therefore need to be stimulated or created afresh. Market formation is related to the marketing efforts of firms, as well as the regulatory and other influences on the shape of markets.	PV technology has developed through a series of niche markets, such as satellites, remote power supply, calculators, parking meters, and, more recently, household systems.	Green consumerism. Public procurement. Fiscal policy (impacts for relative prices).

Adapted from Jacobsson and Johnson, 2001

5 The technological system concept is very similar to the socio-technical regime concept.

selection pressures. Over time, we would normally expect more adaptive regimes to succeed and those with less adaptive capacity to be subsumed or substituted.

However, it may be that in some cases it is not the membership of the incumbent regime itself which proves decisive in providing these functions. Sometimes, when the adaptive capability of the regime is weak, it can be outsider groups who build up the functions that can generate the alternatives needed for change. For instance, an important source of change may be innovative niches, which pioneer new ways of constituting and satisfying a social and economic demand. Effective adaptive capabilities can respond to pressures by opening up novel niche practices as alternatives to the incumbent regime in some form or other (e.g. new technologies, new appraisal criteria). Sometimes it is outsiders that are able to marshal the resources needed to put the alternative vision into effect.

In this way a successful niche can challenge the dominance of the incumbent regime, and members of the incumbent regime may struggle to seize the new opportunities. Under such circumstances, the niche is exerting selection pressure. This point warns us not to limit our search for adaptive capacity to the membership of the incumbent regime. Indeed, depending upon the types of change being articulated by the different selection pressures, the greatest capacity for adaptation and change may rest in nascent networks of capable actors beyond the membership of the incumbent regime.

From the perspective of the effective governance of transitions to more sustainable technologies, the focus of interest lies in the potentiality for change, wherever this may arise. In this way, the notion of adaptive capacity transcends the regime, extending to cover the potentiality provided by hitherto peripheral or external actors radically to augment or transform capabilities. Any empirical analysis of the networks that uphold or challenge regimes will therefore need to use a wide canvas to review how actors contribute to regime functions.

Negotiating pressure, coordinating adaptation

Although the articulation of selection pressure and the provision of adaptive capacity are conceptually distinct, the actors and institutional settings involved in each need not necessarily be separate empirically. An actor such as an environmental regulator may simultaneously be intervening to articulate a selection pressure and also make efforts to help co-ordinate the resources necessary for adaptation. This empirical overlapping of the functions fulfilled by different actors is particularly acute in the contribution to the search direction function of adaptive capacity, since the articulation of a selection pressure may serve to open up new search directions for innovation.

The ability to articulate a salient pressure for regime change and / or build up an influential adaptive capability will usually require interactions and resource flows between actors, through networks or coalitions that may or may not involve the incumbent regime membership. The facility with which this can be achieved will depend upon each actor's negotiating position, defined in terms of their own interests and ideas, the degree to which they have power over others, and the centrality of the functions they perform (relative to the collection of selection pressures and adaptive capacities overall). Coalitions of prime movers are needed, who are 'technically, financially and politically so powerful that they can strongly influence the development and diffusion process' (Jacobsson and Bergek, 2003: 5). The greater the extent to which pressures for a particular form of change diverge from the norms and rules of the incumbent regime, the more acute become issues of power. Even if the membership is not active in its opposition to change, the regime may nevertheless present a considerable degree of inertia that must be overcome.

There are some potentially significant parallels here at a fairly high level of abstraction between the way that socio-technical regimes are conceived and the more general conceptual ideas of what constitutes governance. As with the technological regime, governance itself is exercised through relatively stable sets of norms, rules and practices that prioritise public issues, take decisions on them, and implement those decisions. Governance means something wider than the state (just as regime is wider than industrial sector). It looks beyond the ideology, institutions, structures and instruments of the state (such as ruling parties, industry ministries, parliamentary procedures, environmental regulators, public spending, policy instruments, and so on). The state is embedded within wider networks in civil society and market systems. Like regimes, this involves interaction between actors in networks. Moreover, because regimes and governance are both social phenomena, they will also involve processes of consent, dissent, inclusion, exclusion, and power between the different actors involved.

It may not always be possible to negotiate and coordinate a powerful coalition for a clearly envisaged change. Attempts may meet with partial success. Indeed it may be that such deliberate attempts do not emerge at all, in the sense that change occurs through a process of uncoordinated interactions between shifting, poorly articulated selection pressures and struggling adaptive capabilities. Clearly, the context in which regime transformation arises, both in terms of the nature of the incumbent regimes and the governance situation, is important for the processes of change that actually unfold. In the final section of our chapter, we use our quasi-evolutionary model of change as the basis for a simple typology of transition contexts.

Transition Contexts

As the relative strength of different selection pressures shifts, and adaptive capabilities change, so the transformation process will change too. Analysis begins when we relate this context of regime transition to general patterns of transformation. The art for any transition management project then becomes one of recognising which context prevails at any point in time and space, and which drivers offer the best leverage for guiding change in a desirable direction at that point. As we have already discussed, the articulation of selection pressures is one source of leverage. Building adaptive capacity is a second lever.

Transition contexts can be mapped using the two dimensions of change introduced earlier in this chapter. The first dimension measures whether change is envisaged and actively coordinated – either at the level of the regime membership or on the part of some higher level governance process – in response to prevailing selection pressures, or whether it is the emergent outcome of the normal behaviour of regime members (involving no new mechanisms of coordination). [6] This dimension seeks to distinguish between regime transformations that are essentially intended and deliberate and those that are the unintended and contingent outcomes of historical processes. An intended regime transformation would be guided by influential actors within the regime or by overarching networks of governance arriving at a common diagnosis concerning shortcomings in an incumbent regime. It would require some level of agreement on the appropriate prescriptive measures and their objectives, given the prevailing selection pressures as they are currently articulated and

[6] In making this distinction between low and high levels of coordination we want to move beyond a simple planned/market-based dichotomy, to take account of more complex processes of the social regulation of technologies that involve not just the state, but also other social actors including civil society organisations and consumers.

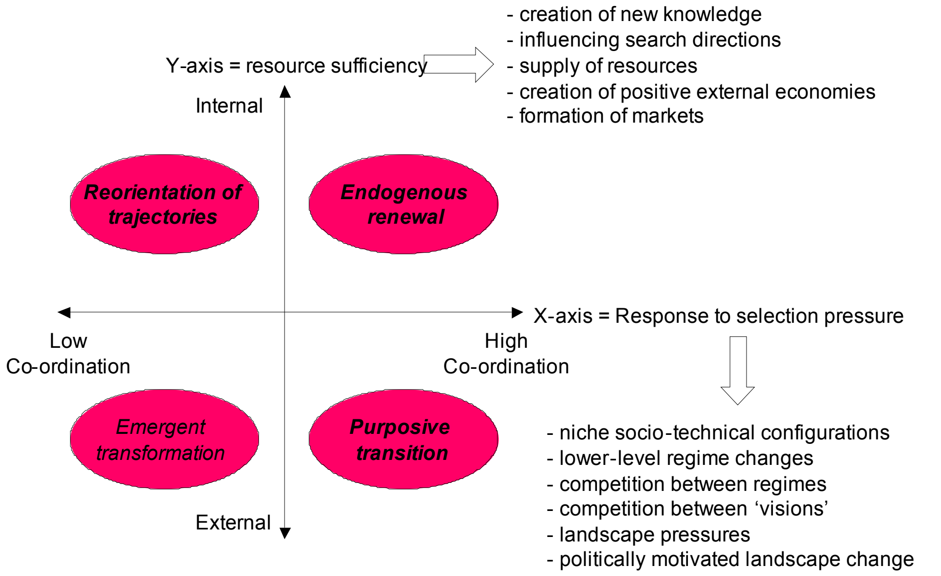
understood. Of course, this says nothing about the desirability – for instance the genuine sustainability – of the particular intended measures, objectives or outcomes. For present purposes, the point is simply that the regime membership itself, might choose to coordinate adaptive capacities to protect the interests of regime members. This dimension of co-ordination is blind to the merits of motives or outcomes, measuring simply the degree of intentionality and co-ordination involved in driving a given transition.

The second dimension concerns the degree to which the response to selection pressure is based on resources available within the regime (or which can be co-opted by the regime), or depends upon capabilities that are only available outside the regime. The *locus* of the capabilities to innovate and adapt is therefore important to the nature of the transformation process. If the resources required for transition are available internally, then change is likely to be more incremental and structural relationships within the regime are less likely to be overturned. If the capacity to adapt is highly constrained by the lack of resources internally, then the likelihood of major structural change increases. The *coordination of actors / locus of resources* framework gives rise to a fourfold mapping of transition contexts (see Figure 1).

As discussed in more detail in an earlier paper (Berkhout, Smith and Stirling, 2003) the four quadrants produced in this framework represent schematic 'ideal types'. Comparisons and contrasts between the elements of each transformation can be made against real-world regime transformation processes and our understanding of the variety of processes consequently improved. As has been suggested above, whatever the nature of the selection pressures and the responses to them, the four transition contexts may all play out operationally at different levels of aggregation. In attempting to make more explicit the distinctions between possible transition contexts, we hope to develop a richer and more robust basis for understanding the different processes of socio-technical transition and the associated opportunities for normative policy intervention.

This typology lends itself to two types of heuristic use of relevance to wider governance processes oriented towards the fostering of more sustainable technologies. One use is as an analytical device, and the other as a normative tool. First, in analytical mode, we can take as a starting point that prevailing circumstances and established governance practices are conditioning a particular 'default' transition context. The task of analysis by means of this heuristic then becomes one of identifying the *particular* type of transition that is underway. Assuming that the likely outcome of this transition is judged to be desirable – in this case in terms of environmental and social sustainability – then governance measures might be oriented towards assisting the committed process of change in a fashion that is as timely, efficient or socially acceptable as possible.

Figure 1: Summary of transition contexts as function of degree of coordination to selection pressures and locus of adaptive capacity.



The second approach starts the other way around. This rests on an appraisal process which concludes that a committed prevailing situation is unlikely to yield a desirable outcome. The appraisal process must then identify some more desirable outcome and the heuristic scheme used in normative mode to guide understanding as to how best to achieve this. In this case, the appropriate governance strategies are not those that best assist some prevailing process of stasis or change, but those which best foster the particular transition context identified in appraisal as being appropriate to achieving a desired outcome. So, for instance, if a prevailing situation of 'endogenous renewal' is identified to be oriented towards an unsustainable outcome, then the aim of governance might be to foster instead a 'purposive transition' to a more radical solution. This is obviously a more challenging mode of usage for any conceptual scheme, placing greater demands both on the taxonomy and on whatever governance measures may be deemed applicable.

The normative approach also begs the question, who is leading the governance strategy? As we concluded in the preceding section, governance is the result of interactions in policy networks, embedded in historically-shaped institutions, and lobbied by coalitions of actors with different views. In practice, the typology presented here could help each of these actors interpret the transition context in which a target regime operates. They could then use this intelligence to inform their strategy for influencing the governance of that regime.

Having discussed the governance possibilities of transition contexts, it is time to describe each of them. A series of stylised examples – emphasising the energy sector for the purposes of effective comparison – are used here to provide more concrete illustration.

Endogenous renewal (coordinated response, internal adaptation)

Endogenous renewal arises in the context of regime members (firms, supply chains, customers, regulators) making conscious efforts to finds ways of responding to a perceived competitive threat to the regime. In the terms of our typology, the pressure to change the regime is clearly articulated and there is a high coordination of response, based on resources originating within the regime. However, as has been discussed, given that innovative activity is shaped from within the regime itself, it will tend to be steered by the prevailing interests and values, cognitive structures, and problem-solving routines of the incumbent regime. Decisions over future technological choices will be guided by past experience. Thus the transformation process will tend to be incremental and path-dependant. Looking back over a long period of time the transformation can appear radical, but it will have come about through an alignment of smaller changes.

An example of this kind of process may be found in the progressive scaling up of the thermal capacity of steam-generating plant over the course of the twentieth century. Constituted by a multitude of individually minor organisational and engineering innovations, the result was a radical transformation in the character of the electricity regime (Hughes, 1987). Likewise, investment in flue gas desulphurisation plant as a response to concerns over acid emissions (Boehmer-Christiansen and Skea, 1991), or the development of carbon sequestration techniques might also be taken as examples of endogenous renewal. In either case, the long-term implications, were the processes of change to be deep-seated and sustained, would be one of incremental regime transition.

From a governance perspective, there are both analytic and normative approaches – as defined above – to consider. In the first, analytic approach, we understand governance (the collection of measures identified in Tables 1 and 2) to be content to enable and contribute to a process of endogenous renewal. The sustainable transformation of the regime is therefore likely to occur through incremental environmental performance improvements and an accumulation of marginal improvements in social equity.

In the second, normative approach to governance, the challenge for a regime that already fits this endogenous renewal type of context, is to identify how to steer transformation in a more sustainable direction. The regime membership demonstrates an ability to coordinate their response to selection pressures. They also have the capabilities to adapt successfully in terms of maintaining regime structures intact. If the regime is highly adaptable, governance strategies might best be focused on the coherent articulation of ecologically sustainable and socially equitable selection pressures.

Re-orientation of trajectories (uncoordinated response, internal adaptation)

Some socio-technical regimes exhibit an intrinsic property of 'systemness' (Rosenberg, 1994:216-17) in their processes of change while at the same time being highly unpredictable. In these regimes, trajectories of change may be radically altered by internal processes without being associated with discontinuities in the actors, networks and institutions involved in the regime. The stimulus for the radical re-orientation is a shock (from outside the regime or within) impacting upon the technological system. The response, however, is formed within the incumbent regime. In the electricity sector, an example of this kind of regime change might be seen with the advent of wide-scale adoption of combined cycle gas turbines, especially in the UK (Islas, 1997). This radical transformation in the technical and operational characteristics of generation systems was not widely anticipated or intended, but arose through the conjunction of a series of uncoordinated technological opportunities, changes in market regulation and obstacles facing alternatives such as coal and nuclear generation. However, the adoption of gas turbines was managed within the dominant electricity generation regime, rather than being a development imposed from without.

Analytically speaking, governance that contributes to good adaptability functions internal to the regime, under situations in which the sustainability challenge is poorly articulated and responses uncoordinated, will lead to regime transformations that reorient trajectories. Governance measures such as boosting appraisal capabilities, the innovation and adoption of cleaner technologies, favouring greener consumption within the incumbent regime, and so forth could radically transform the trajectory of development of the regime. However, if the selection pressures are poorly-coordinated, then the reoriented trajectory of development could take off in an unanticipated direction.

Using this transition context in more normative mode, then a governance strategy for intervention is facing a situation in which the incumbent regime is well furnished with the resources for the committed process of change, but where this is not necessarily the case for the particular orientation of change favoured in the governance strategy itself – for which the selection pressures may be incoherent. Thus the selection pressures will probably represent the best place to begin governance strategies: working with the 'back-end' of regulatory systems (regulations, taxes, and so on) to try and create a selection environment that induces the regime to apply its resources to more sustainable ends. In effect, this would push the regime from a reorientation of trajectories context over to an endogenous renewal context, and so regime transformation would ultimately move incrementally towards sustainability.

Emergent transformation (uncoordinated response, external adaptation)

Many classical regime transitions have an apparently autonomous (though socially-constructed) logic. This type of transformation in our typology arises from uncoordinated pressures for change and responses formed beyond the incumbent technological regime. The technological cycles described in Kondratiev's long waves have this character of emerging from highly complex social and economic processes that lead to the emergence of technologies with pervasive impacts. Many of the examples used in the technological transitions literature have this form (Christensen, 1997). Their origin is typically in scientific activity often carried out in universities and small firms operating outside existing industries (Dosi, 1988). These transitions can be observed, but there appears very little basis *ex ante* to distinguish between those alternatives that will 'catch on' (Mokyr, 1991:276) and those that will not. In the energy sector, a long term example is provided by the series of 'energy successions' governing the dominance of different 'primary fuels' running over a period of three centuries or so from wood, through coal, to oil and gas. Contemporary examples of these kinds of technologies with major disruptive potential include information technology and genetically-modification technology in the food and pharmaceuticals sectors. The impacts of these technologies have of course been across many different technological regimes – in this sense it is incorrect to speak of a single transition, but of many parallel transitions stimulated from a common technological basis and shaped by regime-specific configurations of interests and goals. It is also clear from the GM example that the environmental impacts (as perceived by key actors and institutions) of these emergent transitions may remain quite uncertain even some way down the process of path creation.

From our governance perspective, this case pertains in an analytical sense to situations where there is no coordinated response to poorly articulated selection pressures. Key adaptive functions are developed beyond the membership of the incumbent regime. Under such a governance situation the transformation will be emergent. Consequently, it will be difficult to anticipate clearly what form of sustainable development the transformation will take.

If taking a more normative perspective, and confronted with a regime exhibiting the properties that fit this emergent transition context, then the governance challenge is open. Governance strategies can be built up which inject greater coherence into the selection pressures and regime response. Alternatively, or at the same time, governance strategies can be pursued which build up the relevant adaptive capabilities. If key adaptive functions are built up internally, within the regime, then the situation (analytically speaking) will move into the endogenous renewal quadrant, and transformation towards sustainability will be incremental. Should adaptive functions be developed beyond the incumbent regime, as they were before intervention, then (analytically speaking) the governance situation will move towards the purposive transition quadrant, and transformation will fit that process, i.e. potentially following a process of more radical leap towards sustainability (see below).

Purposive transitions (coordinated response, external adaptation)

While emergent transitions have an autonomous quality, we seek to distinguish these from purposive transitions which have in some senses been intended and pursued to reflect the expectations of a broad and effective set of interests, largely located outside the regimes in question. A good example of this type of transition is the history of civil nuclear power in the industrialised world. Nuclear power was widely regarded in the 1950s and 1960s as a critical technology with the potential to generate broad economic and political (military) benefits. A common narrative was developed which involved a series of technological transitions from uranium fuel cycles (with the light water reactor as the main conversion technology) to plutonium fuel cycles (with the fast reactor being the conversion technology). Scientific, policy and industrial interests were co-opted to this vision to form a powerful interest grouping which was typically in strong contention with establish interests within the incumbent socio-technical regime of the electricity system itself. This latter example shows that this form of transition – imagined, planned and partially executed – does not necessarily generate social and environmental benefits.

Transition management is the transformation of a socio-technical regime guided primarily by negotiation between social actors from beyond the regime. Analytically, this governance strategy fits the present ideal type purposive transition. Key to the transition management project is that these social actors have a greater role in forming the socio-technical response to the co-ordinated pressure for change. Obviously, this demand for change has to be mediated by the regime actors. Transition management is also the outcome of a deliberate attempt to change the regime according to a consensus guiding vision (hence selection pressures are highly articulated). Thus, if our schema is accurate, the transformation process is most likely to be that of purposive transition.

Of course, as our discussion of governance strategies has indicated, the transition context for any given socio-technical regime need not be fixed. Contexts may change, and the proposition in this chapter is that any change in context will influence the pattern of regime transformation. It will also alter the governance opportunities available to different social actors. The heuristic typology presented here is intended to help us understand and frame apropriate questions for the regime transformation processes in a series of different governance situations (i.e. the kind of transition context the governance situation is creating) and / or aid policy-makers intervene in an informed way under given transition contexts. The governance of regimes can be understood as altering the given context of selection pressure and adaptive capacity, and thereby modifying transformation processes, in terms of pace and/or direction.

Summary and Conclusions

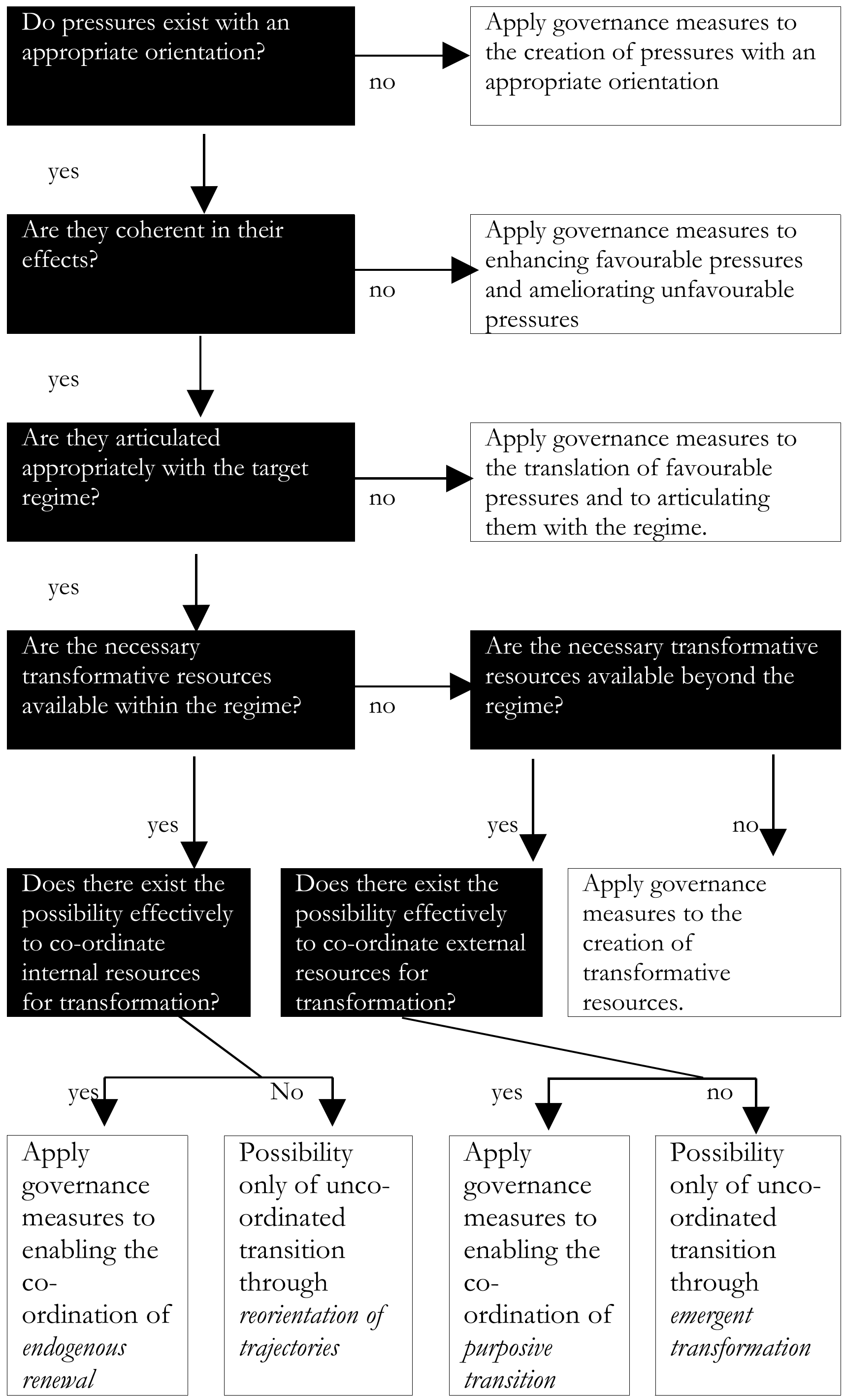
The currently burgeoning perspective focusing on technological regimes presents a fresh and potentially highly fruitful way of cutting into the challenge of industrial transformation – promising more profound and pervasive insights than the preceding approach focusing on the greening of individual industrial sectors. An industrial sector focus is concerned primarily with the firms involved in the production and supply of certain goods and services. A regime focus is concerned with the network of actors and institutions clustered around the fulfilment of social and economic functions. Sectors and regimes nest and overlap – and may be coterminous – but they are not the same.

As a consequence of this, transformation is understood to be change that is mediated by the practices of institutionally embedded *networks* of actors. Regime membership rests upon the intensity of involvement of actors in the reproduction of regime functions. Change might be sought by a specific coalition of actors, but it will need to be carried through within networks of actors possessing the wherewithal to adapt the incumbent regime or create alternatives. By 'carried through' we mean change will need some *coordination* and *resources* between actors. This will be built upon active processes of support and / or passive processes of acceptance in order to generate sufficient *consent* to put change into practice. However, not everyone will agree to change, there will be dissenting voices. At times, such dissent can make a useful contribution to the innovation of regimes by opening up search directions and redefining the multiple criteria by which regime performance is assessed (beyond ubiquitous economic criteria). Regimes, by definition, have a tendency to close down options and introduce stability.

The legitimate authority to push change through, or the resources available to build consent, or to raise informed dissent, or even to block change, will depend upon power relations across the networks of actors involved. Governance processes provide an arena for debates about how best to 'manage' or modulate regime transformation for sustainable development. We have suggested that governance can seek to influence or even guide regime transformation in a number of ways. These are summarised in general terms in the 'decision tree' scheme in Figure 2. We stress that this diagram is intended only as a summary of the argument, and we would caution against any inclination to use it in a mechanistic, unreflective fashion.

In particular, we argue that the task of governing successful sustainable technological transformations might be significantly assisted by distinguishing the role of the *articulation* of selection pressures acting on the regime and the twofold elements of *adaptive capacity* (the provision and coordination of resources for adaptation). These two dimensions to the governance of regime transformations form the key axes along which can be plotted different transition contexts. In this chapter we have put forward the hypothesis that the processes and outcomes of a regime transformation depend upon the transition context prevailing at that time. Contexts in which selection pressures are highly coordinated will go through a different process of change compared to those situations where selection pressures are uncoordinated. Moreover, if the functions that contribute to adaptive capacity are found predominantly within the incumbent regime, then transformation will differ from contexts in which such functions derive primarily from beyond the regime membership. Endogenous renewal, reorientation of trajectories, emergent transformation and purposive transition are four ideal types of transformation that unfold under these different transition contexts.

Figure 2: A Heuristic Decision Tree for Normative Governance of Regime Transformation



In any given instance, these particular forms of transition – like the substantive technological options themselves – may variously be seen in different quarters as desirable or undesirable objectives. Such judgements will be arrived at in any given case by active political deliberation. The role of a heuristic scheme such as this, is to reveal the variety of structural choices with which governance debates are faced and so help prompt fruitful questions and shape possible responses. The essence of sustainability lies in the recognition of agency in social choices about technological futures. It is by focusing directly on the challenges posed by different contexts for the transformation of technological regimes, that we may hope to do a better job of fulfilling the pressing social and environmental imperatives of sustainability.

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Time Strategies for an Innovation Oriented Environmental Policy[1]

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1. Introduction

Environmentally friendly innovations have attracted public interest, because they are subject to far reaching expectations. They should deliver double or triple dividends not only in terms of ecological progress but also in terms of economic success and jobs. A main driver of that debate is the hope that environmentally friendly innovation will lower the economic burden posed on society in cases of transition from an unsustainable path of technological development to a more sustainable one.

The following approach is inspired by the idea that the timing of political measures is an especially important condition for the success or failure of environmental policy in bringing forth environmentally-friendly innovations. The basic hypothesis is simple: political impulses at the wrong time either barely bring about a worthwhile effect , or else they cost much money and time to cause a real change in economic behaviour. At the right time, even weak political initiatives can stimulate external environmentally-friendly innovations. We label such unstable phases of technological development as windows of opportunities.

To provide a first impression of this hyprothesis' meaning in the second section of this chapter, an example of a transition based on the set of case studies from SUSTIME project is presented. The case of chlor-alkali-electrolysis was selected because this example allows a comparison of different kinds of policies (Germany and Japan) and thus illustrates successful and unsuccessful examples of time strategies.

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Obviously there is a close link between the hypothesis above and the description of innovation processes by evolutionary economics. According to evolutionary economics, there are two types of innovation - incremental and radical. There are stable periods and revolutionary periods consistently in technical change. In the latter periods, the field of technological inquiry changes quite dramatically when there is a change in a technological paradigm, e.g. the engineering consensus of the relevant problems and approaches for solving them. Such periods are windows of opportunity for changing the direction of technological progress in quite a considerable way. The evolutionary framework underlying our concept of time strategies is described in the third section of this chapter.

The selection environment of technologies includes not only economic factors but socio-cultural and political factors, too. In the fourth section, the selection environment is broadened using the notion of co-evolution of different social subsystems.

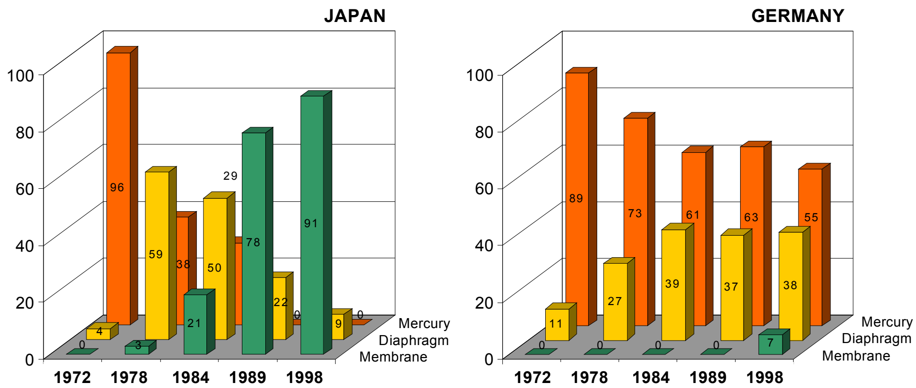
The concept of a window of opportunity in time is crucial for our concept of time strategies. One might get the impression that time strategies of environmental policy are restricted by using a time window. On the contrary, governments often can contribute in preparing these windows. Sometimes it is even possible for governments to open a window of opportunity; such an attempt is labelled as technology forcing in literature. In the fifth section, time strategies of this kind are investigated in more detail.

Due to knowledge restrictions governments usually must face, the steering philosophy behind the concept of time strategies can not be a "press the button, get a particular result" approach. Since there is a close link between the concept of time strategies and the concept of transition management a few remarks concerning this connection in the last section conclude the chapter.

2. An Example – the Chlor-Alkali Electrolysis

One case study in the SUSTIME project was chlor-alkali electrolysis (for more details see Sartorius 2004). Basically three technological possibilities for chlor-alkali-electrolysis are available: mercury technology, diaphragm technology and membrane technology. If we delve further into the technical details, we find that membrane technology is the best one in ecological terms and - importantly - also in economic terms. The diffusion of this technology is considerably different in Germany and in Japan, however, as shown in Figure 1.

Figure 1: Diffusion process in Japan and Germany



The diffusion of membrane technology in Japan has been much faster than in Germany. To explain such a phenomenon, economists usually look for the economic incentives in terms of prices of products and costs of production processes. If we examine this case more closely, we find that the basic cause underlying this difference lies in the fact that the relationship between the membrane cell and the mercury cell process is characterised by the (temporary) lock-in of the established and the corresponding lock-out of the new technology. Due to the sunk costs associated with the established technology, the substitute technology can bring its economic superiority to bear only after those sunk costs are very low. This point was reached much earlier in Japan than in Germany. Beyond that, the lack of growth in chlorine production capacity in the 1980s and 1990s only allowed for a very limited number of new (membrane-based) plants to be installed.

Membrane cell technology in Japan took explicit advantage of the role of the government in first supporting the related R&D and then actively pursuing the phase-out of the mercury cell technology. In Germany, by contrast, in the search for a quick, yet incomplete reduction of the mercury emissions, the government preferred to retro-fit the existing facilities. As a result, this tended to *decrease* the chance of membrane cell technology in proving its superiority sometime in the future. The dominance of the old path was supported by a particular regulation scheme.

3. Technological Change in Evolutionary Economics

This above example can be used for a first generalisation. Obviously technological progress has its own momentum. Stable phases exist where we receive more from the same kind of technological progress. In unstable phases, a transition to really new technologies, system innovation or more radical innovations is more likely to occur.

The distinction between periods of rapid change and periods of slow motion is well known in evolutionary economics. Technological development is described as an interplay of radical innovations, sometimes called basis innovations, and incremental innovations. It is typically cumulative and patterned, with new branches growing from old ones. In order to describe this pattern Dosi has introduced the notions of "technological paradigm" and "technological trajectories". (Dosi 1982). The notion of paradigm is borrowed from Kuhn. Along the lines of Kuhnian thinking, Dosi suggests the following definition: "... a technological paradigm can be defined as a 'pattern' for solution of selected techno-economic problems based on highly selected principles derived from the natural sciences" (Dosi 1988, 224).

The change from one paradigm to another can be labelled as a transition in the sense of Kemp and Rotmans who defined transition as follows:

"A transition

- is the shift from an initial equilibrium to a new equilibrium
- is characterised by fast and slow developments as a result of interacting processes
- involves innovation in an important part of a societal system." (Kemp/Rothmans 2001, 6)

In addition to framing technological development with the belief system of engineers – as emphasized by the term paradigm used by Dosi - there is a broad range of factors which stabilise a given trajectory of a techno-economic system. Literature addresses these factors under the label of increasing returns of adoption. The most important factors are economies of scale, economies of scope, sunk costs, learning effects and network effects (for a more detailed discussion of these factors see Sartorius/Zundel 2004).

Basically, economies of scale are due to the fact that the benefit arising from employment of more sophisticated machinery can more than outweigh its higher overhead cost if only the quantity of output is high enough. While production facilities at various output scales can well be based on different technologies, it is important to note that economies of scale are based on the technologies that exist respectively at any given point in time; learning does not play a role in this concept. Accordingly, economies of scale are basically measured on the firm level in terms of average unit cost as a function of output quantity per unit of time. On the other hand, , economies of scale have the potential to stabilise monopolistic structures or, at least, to provide firms who realise them with a powerful competitive (cost) advantage. The latter point turns into a disadvantage for many kinds of potential market entrants, but it is particularly relevant for new technologies which, at the beginning of their life cycle, cannot draw upon their own or foreign experiences with (and thus cannot make use of) the advantages of large-scale production.

By taking into consideration a firm's variety of production outputs, economies of scope - beyond the mere number of a firm's distinguishable outputs – can account for the realisation of synergies between different production lines. This includes the common use of certain resources, intermediate products, or production facilities. In any case, it requires a high degree of coordination between the production lines within a firm. A prominent example is the coupling of production in the chemical industry. As in the case of economies of scale, the effect of economies of scope is two-fold. On one hand, it leads to and accordingly is measured in terms of a relative decrease in average production cost, as such representing a substantial increase in profits or, more generally, wealth. On the other hand, when compared with economies of scale, the complexity of interactions between existing production lines makes it even more difficult for a market entrant or a new technology to become competitive. For this requires that either comparable synergy effects must be realised in the first place or the degree of superiority of the new technology as such must be high enough to outweigh such synergy effects right from the beginning. The latter point represents a major obstacle for the competitiveness of a new technology. As such, a detailed analysis of the interactions giving rise to synergy effects - in addition to the mere cost aspects of economies of scope - is an indispensable part of all attempt to identify a possible techno-economic window of opportunity.

Although the first explicit mention of 'learning by doing' goes back to Arrow (1962), the cost decreasing effect of growing experience in designing, constructing, and using production facilities ('learning by using') has been a part of common wisdom in economics since Adam Smith. Unlike the cases of economies of scale and economies of scope, the cost-decreasing potential of learning by doing and learning by using is a function of the cumulative output of a given branch of production over the entire period of time since its introduction. The learning effects relevant in this context are equivalent to incremental technical progress and they are typically expressed as the percentage of cost reduction per doubling of the cumulative production output. While scale effects could, at least in principle, be realised at any point in time, experience effects are the result of an ongoing developmental process. As a consequence, learning effects provide any new technology with a large potential for further cost reductions. At the same time, however, they require every investor into such a technology to subsidise its output until the cost of the respective product will have become competitive. Depending on the initial cost difference, this may explain the occasional need for an extensive, long-term investment effort.

Investment in a new, process or product-related, technology can cause significant sunk costs if this investment renders useless an old technology prior to its complete depreciation in the absence of the new technology. Schumpeter refers to this innovation-induced early depreciation as 'creative destruction'. Technological spillovers from other firms employing the same (old) technology significantly contribute to these sunk costs. For every firm that intends or is forced to carry out a change in its technological regime, sunk costs represent opportunity costs of the new technology (and, equivalently, negative externalities of the old technology). It is evident that in such a situation, a firm will substitute a new technology for an old one only if the return to investment in the new technology outweighs both the expenditure into the new capital and the sunk costs associated with the old technology.

While the scale and learning effects described above give rise to positive externalities on the supply side, network externalities refer to the fact that the utility derived by the users from the use of a given technology is positively correlated with the total number of users. The telephone network is a typical example. Alternatively, a technology can be subject to network externalities if it does not itself constitute a network, but relies on and is compatible with another technology that forms the network in its turn. The dependence of the internal combustion engine on a network of filling stations can serve as an example here.

Increasing returns of adoption do not last forever. One important reason for this appears to be that the problem-solving capacity of a dominant technology (the body of knowledge) is exhausted. Marginal returns within any given technological paradigm tend to decrease. This has been worked out by Windrum following an argument by Frencken and Verbart (1998). Windrum writes that "the functional form of the relationship between learning and the number of adopters is sigmoid. As the number of contributors increases in the initial phase of its history, so the problem-solving capacity of the user network supporting that technology increases exponentially due to gains of the division labour and benefits from arising of new fields of application. However, there is an upper limit to the problem-solving capacity of a user network. As a technology paradigm matures, so co-ordination costs start to outweigh the gains derived through further division of labour (…). The ability to identify and develop new fields of application is similarly limited …" (Windrum 2003, 302). Therefore increasing returns of adoption are at some point bounded from above, a necessary but not sufficient condition for technological change.

Real markets (niches) represent a further important condition because they facilitate processes of learning (about technology, the market, social acceptance) and processes of societal embedding (capital formation, setup of distribution, dissemination of knowledge, user-side adaptations to facilitate the adoption, gaining of user acceptance, removal of regulatory benefits etc.) that are necessary for the further development of a new technology or technology system (Kemp/Rip/Schot 2001). They help to create virtuous cycles that allow a new technology to emerge, by helping the technology to overcome initial barriers of high costs, the non-availability (or high costs) of complementary technologies and misfits between the new technology and the external environment during the infancy period of a new technology when it has not yet benefited from dynamic scale and learning economies.

If a new technology competes with old paradigm technologies we label this competition "old/new". If there is a new function which must be fulfilled and more than one technology is involved, the technology competition is a "new/new" one. Environmental regulation of pollutants, for example, can force completely new technologies without any predecessors. In other words, a new function has to be established. Examples are filter technologies which cannot be replaced by integrated technological solutions for technical reasons or because of high opportunity cost.

Based on this difference, we also can distinguish between two kinds of windows in the techno-economic system. Following the investigations of Kemp (2001) concerning old/new competition we can refer to the first one as an old/new window. This window is open if the investment cycle of old technologies comes to an end and new promising technologies are available at that time. Following the investigations of Arthur (1989) and David (1987) referring to new/new competition, we can refer to the latter one as the "Arthur-David-window".

This window comes into being in the early stage of competition between similarly far developed technologies. In principle, the economic competition between two new technologies is governed by the same forces as the competition between an established and a new technology. The main difference consists in the points of departure of the respective races. Due to the positive feedback mechanisms involved, even small differential effects accruing soon after the start of the competition are more decisive for the outcome of the race than larger effects some time later. Evidently, time matters more here than in the competition between old and new technologies. If unstable phases of technological development arise, then even so called "small historical events" (Arthur) can frame the continued direction of technological development. This phenomenon is often observed in the software programme market in which many company strategies are based on the idea of being the first to occupy the market and to erect market entry barriers through network effects. The case of Microsoft is a well known example of such a strategy. In unstable phases, appropriate timing is clearly an important factor for success.

Stable phases of technological development caused by a combination of small historical events and feedback mechanisms described above are addressed in the literature by the notion of path-dependency (Arthur 1994). Path dependent technological developments can bring about a lock-in of a dominant technology and correspondingly a lock-out of other possible technological solutions. In cases of unsustainable development, lock-ins create a development trap that has to be overcome by environmental policy. Before examining the details of this problem, we should touch upon the selection environment outside the economic system.

4. Broadening the Selection Environment

Variation and selection mechanisms of technologies are not restricted to the economic sphere. The selection mechanisms include not only selection by product markets. Selection is a "multi-dimensional phenomenon" (Windrum 2003). It includes selection of visions of future developments by capital markets. Selection takes place when new technologies must be adjusted to the existing technologies with which they must be combined. The existing infrastructure at a given point in time has a selective effect; private standards and public regulation work like a filter. Additionally, social concern and political mechanisms have an impact in the sense of a selection process. Stability and instability in the corresponding coevolving systems can have a great impact on the evolution of given techno-economic system. They can both reinforce and destabilize each other.

In giving this interplay a more precise meaning, we can simplify and distinguish between three social subsystems only: the techno-economic system, the socio-cultural system and the political system. Each system is partly determined by its own dynamics and partly by the interaction of the systems. The distinction between stable/unstable has its specific meaning based on the system to which it refers.

Public concern in the socio-cultural system is a main driver of environmental policy. We say that the socio-cultural system is stable with respect to the technological path in question; this is if the public is indifferent about the sustainability of this path and no real interest by mass media can be observed. The socio-cultural system is considered unstable if a growing concern arises in scientific communities about the ecological performance of the dominant technologies and a public debate can be observed in mass media.

Assigning possible states to the political system is slightly more difficult. Two features of this system are important: First, the system cannot be completely separated from society. In democratic societies, policy reacts – as it should – to public interests. On the other hand, the political system is not completely free in adapting public interests; it has its own institutional and social momentums. These mechanisms operate like a filter and influence whether and to what extent external impulses are picked up by political actors and are transformed into political concepts and actions. Against this backdrop, a three-part distinction of possible states of the political system is useful:

- The political system is open if its endogenous mechanisms are stable and do not impede external impulses for change.
- The political system is inert if its endogenous mechanisms are stable and impede external impulses for change.
- The political system is unstable if its endogenous mechanisms operate in favour of an external impulse for change. We refer to this constellation as a political window of opportunity.

The classical idea of the ideal sequence found in economic textbooks is as follows: sustainability problem is detected, public awareness arises, pressure is put on the political system for action, an internalisation concept is implemented in the economic system, and in the end the sustainability problem is (hopefully) solved. The sequence starts with an impulse for change in the socio-cultural system and ends with a successful internalisation in the techno-economic system. One alternate situation is when the impulse for change begins in the socio-cultural system and brings about changes in the techno-economic system without any political influence. In this case, public discourse indicates a demand for change, which can be transferred by smart innovations into private willingness to pay for new and ecological better products. The demand for high-quality food or the demand for textiles not treated with chemicals are examples of this, despite policy support in spreading these products in the meantime. This illustrates that there are many starting points for change and the classical constellation described above is only one among them.

For the limited space of this chapter it is not possible to describe the factors which stabilise or destabilise the socio-cultural system and the political system according to the techno-economic system (for more details see Nill 2002 and Sartorius/Zundel 2004). However, it is hoped that new, environmentally friendly technologies can arise if time windows in the techno-economic subsystem, the political subsystem and the social system are ordered in an appropriate manner (see also Nill 2002). This idea is explored in a more systematic way in the following section.

5. Time Strategies

"There is no guarantee that evolution, whether in nature or in the economy, will be beneficial." (Witt 2002, 13) Since there is no balancing mechanism between problem generating and problem solving abilities of technology progress, keeping society on sustainable paths will always be a political business, even if one admits that policy often fails in running that business successfully. The example in section 2 shows that policy can make a difference.

If a given techno-economic system brings about serious impacts on the environment - that is, it is non-sustainable - we can say that this system is not very well adapted to the environment in the evolutionary sense. A successful adaptation depends mainly on four different abilities of markets:

- the ability to adopt new insights out of the scientific system (discovery function of markets)
- the ability to generate a diversity of new promising solutions which are feasible in a technical sense (research function of markets)
- the ability to improve feasible solutions to competitive ones (development function of markets), and
- the ability to select the best solutions among the competing ones (selection function of markets).

Policy is well advised to use these abilities especially if a particular path of development is not sustainable, but these abilities do not automatically work in the direction of sustainable development. In case of a development trap on an unsustainable path, particular functions of markets are underdeveloped in relation to what is needed for a sustainable development; the main target of policy is improving these abilities for generating new and ecological better solutions. We refer to this approach as second order sustainability, which is an improvement of particular abilities of markets depending on time (see Sartorius 2003).

In principle, second order sustainability aims at an intelligent use of market forces: in particular the ability to create new environmental solutions that are low-cost and the ability to select the best ones through market competition. The relative importance of these different abilities or functions for new and better paths of technological developments based over time depend on and vary with the kind of competition (old/new and new/new) and the status of the techno-economic system (stable/unstable). Thus a strategic framework is required to take these distinctions into account.

In order to link strategies to possible combinations of states of different social subsystems and to develop a taxonomy, we use the idea of a sequence, beginning with an old path and the discovery that this path is not sustainable and no promising solutions are available from the outset. The sequence ends when a transition is completed and one new technology has taken over. It should be emphasised that it is not suggested that the complete sequence or a sequence in exactly that order must be carried out. Very often there are repeated attempts of transition in reality. It is also possible that government should not interfere, since the autonomous development of the techno-economic system tends itself to be an unstable situation. The following table provides a survey of time-critical situations.

Table 1: Survey of time critical situations

No	Status of the techno-economic system	Kind of competition	Quality of alternatives	Strategies
1	stable	not applicable	only theoretical alternatives exist	demonstration of technical feasibility
2	(still) stable	not applicable	promising solutions	diversity and development
2a	stable	not applicable	promising solutions	handling of political pressure
3	unstable	old vs new and new vs new	at least one competitive solution	making transition easier and avoiding rush selection
3a	unstable	mainly old vs new	one alternative solution is competitive, there are other promising solutions	making transition easier and avoiding new sunk costs
3b	unstable	mainly new vs new	multiple alternative solutions are competitive	making transition easier and avoiding rush selection
4	stable	not applicable	transition is completed	reviving selection function

With respect to the notion of window of opportunity we can assign the following names to the strategies, described above:

- Window preparation: enhancing diversity and solving development problems in the pre-market stage (1, 2)
- Window opening: technology forcing (2.a)
- Window utilisation: making a transition easier (3, 3.a, 3.b)
- Window closing: reviving selection function of markets (4)

In the following paragraphs these strategies are explained in more detail.

(1) The first situation can be characterised by three features: a sustainability problem linked to the old path is detected, the old path is stable, no techno-economic window exists and no promising solutions are available. The main target needed to improve flexibility of the techno-economic system is stimulating the development of promising solutions mainly by supporting scientific research and providing incentives to firms to adopt new scientific ideas.

(2) If promising solutions are already available we can proceed to the next step. The second situation is characterised by a stable old path, but now there is at least one promising solution. The main targets needed to improve the flexibility of the techno-economic system are creating diversity and stimulating firms to develop at least one competitive solution, for example by organising learning curves. Government should make best use of market forces; here this involves mainly searching for new promising solutions and developing new solutions until they become competitive to some extent. Expectation management is important for policies that prepare the emergence of future techno-economic windows. Weak signals such as long-term targets also might play a role. Mechanisms may include e.g. the creation of niches for or the support of new alternatives (strategic niche management). Additionally, we must keep in mind that environmental policy requirements might also hinder window emergence, e.g. delay investment cycles (retrofitting), thereby increasing sunk costs especially if end-of-pipe treatment is involved. In this case transition might be obstructed by environmental policy itself.

(2a) A situation very similar to (2) arises if strong social or (international) political pressure forces the government to open a window using political means under the conditions that the old path is stable and only promising solutions are available. This situation is different to that described under (2), because the government has to deal with strongly opposing market forces. Although this may be necessary we must be aware that the danger of add-on-technologies or retrofitting of existing technologies increases considerably, especially if governments use instruments that stimulate quick fixes. Governments have an incentive to do so if the political window of opportunity is shorter than the time period required for developing more fundamental alternative solutions. In addition to the targets mentioned in (2) government must balance the social pressure for a quick solution needed for political support and the time period needed for more far-reaching solutions.

(3) If more than one solution becomes competitive to some extent, the next step can be taken. This situation may be generally characterised by the following features: the old path is unstable or at least a techno-economic window can be anticipated, and there is competition between different new solutions. At least one of the new solutions is competitive in principle. In short, we face a combination of new vs. new competition and old vs. new competition. Fundamentally a transition is now possible and the government's target might be to facilitate this transition, for example by abandoning discriminating mechanisms for the new solution.

(3a) In some cases the situation is more complicated than in (3): besides the competitive solution there are other solutions that are merely promising and have not yet attained competitiveness. The development of their potential can be strongly impeded by simply following the target of transition. If some new solutions can use network effects and early economies of scale, they can gain an advantage, and cannot be overtaken by other promising solutions with a possibly greater potential. In other words, there is a trade-off between diversity and facilitating transition. In this situation the government must keep the window open by suppressing the selection function of markets until the most promising solutions have developed their potential. If this is too costly or not feasible and the old vs. new window can only be used by the more advanced technologies, at least a lock-in of new solutions must be avoided, e.g. through reservation of niches etc. An example is provided by the photovoltaic case study. It is clear that photovoltaic will not be competitive in the foreseeable future compared with conventional power plants; it will not be implemented when the conventional power plants have to be replaced by new power plants. Photovoltaic technology is not a real alternative in the next window of opportunity. Despite this, it makes sense to keep this technological option alive over the next years.

(3b) Sometimes the necessity of a transition is possible due to internal limits of the old path. As a result, new vs. new dynamics come to the forefront. For policies which take advantage of, or utilise, these new vs. new techno-economic windows, "utilise" can also mean "keep the window open" for a sufficiently long time. Political responsibility is also high here: environmental policy may act as the "small historical event" within the selection environment important for the increasing returns models, e.g. biases competition. This may reinforce or even lock-in first mover advantages. The political exploitation of techno-economic new vs. new windows consists mainly in assuring that in an open phase of competition the best technologies in ecological and economic terms have a chance of being selected.

(4) The key question to be solved now is whether dynamic allocation efficiency gains can justify the losses of static allocation efficiency by suppressing the selection function of markets. If no further technological progress of new technologies can be expected, the main target in this situation is a proper selection of best avail-

able solutions. This sometimes means that government has to end all political interference in market processes. This step is important because subsidies, protected markets and other political support create their own momentum; they bring about sunk costs and create many vested interests when support ends.

The simplest order may be when windows in all three systems exist simultaneously. In contrast, a transition is more difficult if time windows in the social and the political system do not accompany a techno-economic window. The empirical findings of our case studies in the SUSTIME project support this idea. In all cases, we observed favourable conditions in the social and the political system; these are listed under the heading "window utilisation" and can be regarded as success cases (for more details see Sartorius/Zundel 2004).

In addition, the case studies demonstrate that success conditions must be complex depending on the time strategy used and how radical the transition should be. Technology forcing by political means in a stable phase of the techno-economic system is much more demanding than a transition in an unstable phase. What we learn from our case studies is that technology forcing can only be executed successfully if a sufficient and long term public pressure exists, conditions in the political system are favourable and promising solutions are available and adopted by influential firms. This coincidence of events seldom occurs, and this is likely the reason why politically induced radical transitions are seldom observed in reality. The conditions for incremental changes are far less demanding and this is perhaps the reason why these changes form the usual pattern of environmental policy aiming at technology changes.

The role of promising solutions is very prominent in many case studies. Promising solutions are often decisive for transition, because the public perception of promising solutions brings about considerable support for political attempts in transition through new regulation schemes. A promising solution shows that a transition is feasible, sometimes at low costs, and is therefore probably the most important factor of a politically induced window preparation. These findings completely correspond with our idea that a transition is more likely to occur when more alternative solutions are developed.

6. Conclusion

Time strategies are not an academic artefact; timing problems are ubiquitous in environmental policy. One might think of the phase-out of nuclear power plants in Germany or of the broad range of political measurements in supporting regenerative energy sources. Timing is important in almost every important case of environmental policy. . This is not an accident, since path dependent developments of technological change are also widespread. Thus environmental policy should be well advised if political measurements are embedded in a strategic framework as described above.

Information is a scarce resource for political actors when choosing an appropriate time strategy depending on the state of the techno-economic system. To time their measures well they must know the state of techno-economic system, they must distinguish between theoretical ideas, promising solutions and competitive solutions; they must also know whether the potential of a promising solution has been explored and when public support of these will end. The widespread opinion in literature is that political actors are not well informed about these features of technological development and we agree with this opinion. Obviously such a knowledge base for policy is far beyond reach. However, what is possible is pattern prediction in the sense of Hayek (1969); what is certainly impossible are prediction of the outcome of technological development. Mainly for that reason the approach of time strategies must be understood in the sense of guiding lines of a transition management, by which political action under the condition of uncertainty is addressed.

By emphasising the limits of knowledge of political actors, many scholars allege that political actors are free in choosing a generic or a selective approach of technology or environmental policy, and that they should chose a generic approach since such a policy is far less demanding based on knowledge limits. Due to path dependency, however, even generic measures such as taxes or tradable permits often end up being selective depending on time of implementation. In a stable phase generic measures mainly bring about further improvement along the boundaries of dominant technologies; in an unstable phase generic approaches can - but not always - bring about more fundamental changes of technological changes. In taking this for granted, political actors often have no real choice between a generic and a selective approach. Empirical finding bear out this claim to some extent: almost every regulation scheme has a technological content discriminating against some technologies and supporting others. In light of this background, the real question is how far should - and can - political actors improve their knowledge base, while admitting that they face severe restrictions in doing so.

A learning-based adaptive approach developed by the concept of transition management (Kemp/Romans 2001) might be an appropriate way for handling the severe knowledge restrictions with which environmental policy is confronted.

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Transformation Dynamics in Utility Systems

An Integrated Approach to the Analysis of Transformation Processes Drawing on Transition Theory

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1. Introduction

Network-bound infrastructure systems such as electricity, gas, water and telecommunications currently undergo transformations on multiple levels resulting from various sources of dynamics. These include changes of the regulatory framework - deregulation and liberalization -, changes of the institutional settings and corporate structures, e.g. as part of privatization and internationalization strategies, the introduction of new technologies and the emergence of new practices and cultures of use, for example in the context of mobile phones or the internet. These transformations are of considerable importance for sustainable development because utility systems are closely intertwined with society and nature. The present chapter proposes a conceptual approach for analyzing these ongoing transformations in order to assess the potential for developing sustainable utility services.[1]

Utility systems structure the relations between society and the natural environment. Therefore socio-technical transformations of these systems typically imply transformations of the relation patterns between society and nature, also referred to as social-ecological transformations (ISOE 2000). Utility systems are particularly important, because they enable and structure a large number of activities in firms and private households. Furthermore, utility systems themselves cause important environmental impacts by extracting and transforming natural resources, directing material flows, the production of toxic or radioactive waste, emissions, intervening in local ecosystems etc.

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[1] The chapter is developed in the context of the project "Integrated Microsystems of Supply", a participative foresight project that comprises the analysis of dynamics in the electricity, gas, water and telecommunications sectors, the construction of scenarios together with representatives from different stakeholder groups, an evaluation of the sustainability potential of the scenarios and the development of strategy options for and with different stakeholders (www.mikrosysteme.org). The project is funded within the Socio-ecological Research Programme at the German Federal Ministry for Education and Research (www.sozial-oekologische-forschung.org)

Given the high capital intensity and the coupling of technological, institutional and knowledge structures in these sectors, socio-technical transformations tend to be relatively slow and strongly path dependent. There are few windows of opportunity for a departure from the established development paths. Radical changes in market rules, as the ones that have followed liberalization and resulting structural adaptations, open up windows of opportunity for developing more sustainable utility sectors. On the other hand, this situation also exhibits the danger to lock-in new but not more sustainable structures for the decades to come.

In this chapter we propose an analytical framework for the analysis of transformations at the level of individual sectors that also takes interactions between different sectors into account. We will illustrate how this concept can be applied to analyze transformation processes in the utility sector.[2]

Transformation processes result from dynamics at different levels: a) dynamics located at the meso level of sectors, b) dynamics rising up from the micro level of corporate and individual actors as utility companies, political actors and consumers, and specific innovation projects, c) dynamics resulting from processes at the macro level of broader societal, technological or ecological developments. Moreover, how the utilities will look like in the future is dependent on interactions within and across different action fields such as provision of utility services, the consumption of these services and the political governance of both.

In order to analyze the transformations of the utility sectors we start from the approach of "technological transitions", as developed by Rip, Kemp, Schot and others (Kemp 1994; Schot et al. 1994; Rip/Kemp 1998; Schot 1998) on the basis of insights from evolutionary economics and technology studies, and which has recently been elaborated by Geels (2002a;b).[3] However, for our problem at hand, the transition theory approach has to be extended in three ways:

- A stronger emphasis on non-technical sources of dynamics is needed, particularly institutional and service innovations.
- Most of the recent work in transition theory has concentrated on changes of single regimes or on the emergence of new regimes. In order to analyze transformations in the utility sectors emphasis is needed on the interaction between regimes.[4]
- A stronger consideration of transformation processes that follow other patterns than ideal type transitions – a so-called regime shift symbolized by an s-curved dynamic from one stable configuration to another one – is necessary.

In the following we will first give a brief outline of the multi-level framework of transition theory. We will then present major transformation processes currently happening in the utility sectors in general and we will argue for the necessity to consider also other transformation processes. Chapter 4 proposes a concept of socio-technical niches which goes beyond the technological focus. Chapter 5 then sketches a framework for analyzing multi-regime dynamics and presents potential dynamics in the utility systems resulting from these interactions. We will sum up in chapter 6 how transition theory can be fruitfully applied for the analysis of sustainable utility sector transformation.

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2 However, a thorough empirical analysis is beyond the scope of this chapter. For a more encompassing analysis see Konrad et al. (2004).

3 For a critique see Berkhout et al. (2003).

4 An extension of transition theory to the analysis of multiple regimes is the aim of a project recently started at the University of Eindhoven (see http://www.tm.tue.nl/capaciteitsgroep/aw/tech_studies/researchplan_feb2003.pdf).

2. The Multi-Level Framework

In this chapter we will give a very short overview of central building blocks and assumptions of transition theory: the concept of socio-technical regimes, the embeddedness of regimes in a multi-level framework and implications for socio-technical change to occur or to be brought about.[5]

According to Geels (2002b: 14) a *socio-technical regime* is defined as a socio-technical configuration, which fulfills a societal function, consisting of artefacts, user practices, markets and distribution networks, infrastructures, policy, laws, regulation, capital and finance. Socio-technical regimes are organized around the specific societal function, which is fulfilled by the socio-technical regime. The concept of regime refers to the rule-set or grammar which guides, but does not fix, action and cognition, for example by providing search heuristics for problem solving and innovation or roles of behavior (Kemp et al. 1998: 182). This rule-set may also be called a "semi-coherent web of rules", since these rules are coordinated, yet not necessarily perfectly aligned, so that tensions and frictions within the regime may emerge (Geels 2002b: 106).[6] The interrelations of the elements of a technological regime provide on the one hand a stabilizing function for the whole complex. Stabilization does not exclude change, but it gives a direction to change which makes certain changes much more likely than others and incremental changes more likely than radical changes. On the other hand, if changes in parts of the regime occur, due to the interrelations further changes may be induced.

Technological *transitions* are conceptualized as a change from one more or less stable socio-technical configuration to another (Geels 2002b: 15). Against the background of this conception we define *transformations* as major structural changes not necessarily of, but also *in* a socio-technical configuration, that is not necessarily a change *of* the socio-technical configuration as a whole. If these changes will ultimately be part of a larger transition process, is often impossible to predict in advance. Furthermore, they may not follow a dynamic pattern of a smooth s-curve from one stable state to another, but may include other macro dynamics, including steady incremental changes, cyclical movements or catastrophic changes.

The multi-level framework refers to a set of interrelated processes at three levels (see figure 1). Socio-technical regimes at the meso level correspond largely to the level of sectors. In contrast to incremental innovations, which may emerge within established regimes, radical innovations are typically generated in *niches* at the micro level. Niches are defined as socio-technical environments, for instance application domains, which are characterized by specific selection conditions diverging from the dominant regime (Hoogma 2000: 80ff.).[7] Niches are important for socio-technical change, because they provide a space for learning about design specifications, possible

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5 For more detailed presentations of the approach see Kemp (1994), Schot (1998), Rip & Kemp (1998), Kemp et al. (1998), Rip (2000); Geels (2002a; b) and Hoogma et al. (2002).

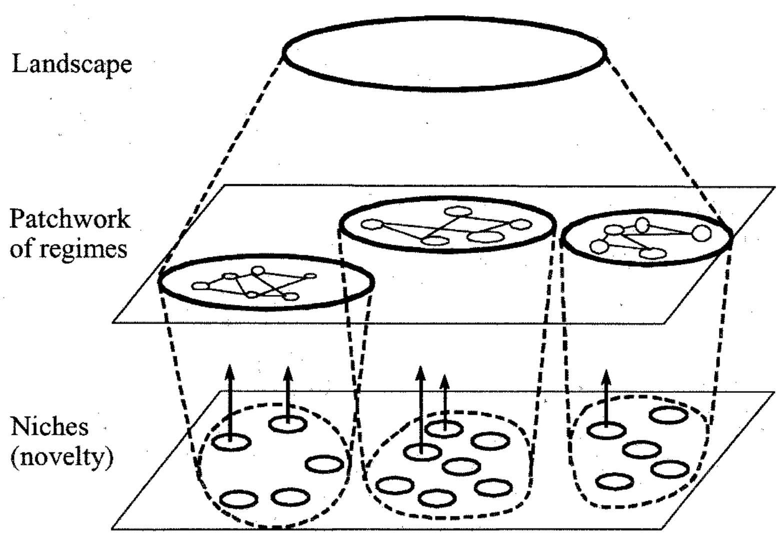
6 Therefore the concept of regimes refers to a less strictly coordinated entity as a narrow conception of a system would imply.

7 Two types of niches are distinguished. The first type refers to so-called *technological niches*, which are explicitly built up to provide a protected space for innovations to be tested and to gain experience. A typical example would be experiments and pilot projects with new technologies, which do not have to be economically viable, which might still show technical problems, or which do not have to fully comply with the usual regulatory requirements. In evolutionary terms this is to say that selection criteria are suspended or weakened or that the innovation is only partly exposed to the selection criteria (Hoogma 2000: 81f.). *Market niches* are also characterized by locally specific selection criteria. However, these are not the result of specific protection measures, but rather due to specific characteristics of an application domain and certain user groups, or they have been developed on the basis of a former technological niche (Kemp 1994; van den Ende/Kemp 1999; Geels 2002b: 100, 114).

ways of using and user requirements, new meanings, societal and environmental impacts, production and maintenance and the adequate regulatory framework (Hoogma et al. 2002: 28). Furthermore, niches allow for the build-up of supporting actor-networks. Major socio-technical changes as regime shifts typically start from niches and rely on a dynamic of niches: an expansion of niches, which eventually leads to the replacement of the old regime; a technology may also be implemented in a succession of different niches (niche branching or niche-cumulation) or the emergence of a new regime relies on the interaction of multiple niches (Schot 1998; Geels 2002a; 2002b: 121ff., 326f.). In the process of niche branching the technological design as well as the application domains may gradually depart from patterns that at the beginning had been rather similar to the respective regime (Hoogma 2000: 341ff.).

Rather inflexible or slowly changing structures external to a socio-technical regime are defined as part of the socio-technical *landscape* at the macro level. These external structures consist for example of macro economic developments, demographic trends, cultural changes, broad political changes or environmental problems (Geels 2002b: 109). They may have a considerable impact on the transformation dynamics of a regime, yet they cannot easily be influenced by the regime actors.

Figure 1: The Multi-level framework (Geels 2002a: 1261)



Whereas transition theory has situated dynamics largely as rising up from the bottom of niches, forcing itself on the predominantly stable regimes and landscape, Geels (2002b: 104) has rightly criticized this bias towards the novelty following a kind of heroic "David and Goliath storyline". A concept of technological transitions must also consider dynamics at the level of regimes, internal dynamics of certain elements of regimes as user practices, technology, policy, industry structure, or dynamics at the landscape level. Nevertheless, the interplay of these internal dynamics may lead to tensions in the regime, which will open up windows of opportunities for novelties and thereby may also lead to broader changes.

Before we elaborate on how we think the transition theory approach could be fruitfully expanded, the next chapter gives a short overview of relevant transformation processes going on in the utility sectors. As will be shown, changes starting from the landscape level have been just as important as changes at the level of niches – niches based on technological as well as non-technical innovations (see also chapter 4).

3. Transformation Processes in the Utility Sectors

One of the major changes happening at the landscape level which is common to all utility sectors is the recent break with regulatory paradigms associated with the provision of these basic services in industrialized societies. Meanwhile these changes have had an impact on most sectors at the regime level, as regulatory structures or organizational forms have been altered in many countries as a consequence of the new market orders.

In the course of industrialization, the provision of water and gas, sanitation, public transport and electricity were key factors for generating widespread welfare and setting the basis for other industrial activities to prosper. Originally in the late 19th century, these basic services were often provided by private firms.[8] However, due to lack of investment, ruinous price wars, and the fundamental importance for health and welfare these sectors got more and more transferred into state owned property or at least into regulated monopolies with tightly prescribed service levels and the obligation to deliver their service in a non-discriminatory way to all citizens in a given region. This understanding of utilities as a basic and taken for granted element of modern life was unchallenged and expanded over almost a century in most industrialized societies.

During the 1980ies, however, this fundamental consensus began to break up. This transformation at the level of the landscape had strong ideological origins (Gray 1998) or served to reorganize power relationships between utility operators and regulating bodies (Hirsch 1999; Young 2001). Once liberalization, deregulation and privatization got introduced into the political debate many of the taken for granted elements of the former utility regimes seemed to be at disposition. The changes at the level of the landscape were therefore weakening a series of relationships stabilizing the dominant regimes. The specific transformations in the different utility sectors may, however, differ quite strongly. Also within sectors in different national markets, as the example of the EU shows, a wide range of developments is possible. All the sectors are affected by the new ideas and the emerging paradigms about the good way to produce and supply utility services.

Transition theory may here be fruitfully applied. We shall therefore shortly sketch in how far the notions of landscapes, regimes and niches may help to grasp the different transformation processes. We will start from a notion of regimes which is strongly related to the sector definition of conventional utility services, i.e. electricity, gas, drinking water, waste water, telecommunications etc regimes and their transformation. A high degree of similarity exists between these different regimes. They in general deal with a commodity which is produced or generated in specific geographical locations and is distributed across a wide spanning physical transportation infrastructure towards the fixed points of consumption spread more or less evenly in space. Demand is taken as a given external factor to which the provision of services has to adapt. The distribution infrastructure is thus an important asset and normally has considerably long life times (20 to 100 years). As a consequence, turnover times are high and the introduction of new products and production processes is bound to follow strongly entrenched paths. Innovation is therefore rather slow and of a more incremental type.

This technological infrastructure is complemented by rule sets and institutions which are (or rather used to be) of comparable durability. Producer associations and

[8] For Great Britain see Guy et al. (1999).

governmental regulators determined the long term development plans of the construction and expansion of infrastructure (Hirsch 1999). Expansion plans were based on long term projections of past growth characteristics. The evaluation and selection of innovations was managed at the level of working groups in the national sector associations as a problem of negotiated search for a common way to proceed. Economic efficiency was of minor importance as investments were financed on the cost-plus principle. Consumer preferences played a minor role because of the high degree of homogeneity by which these services were characterized. Consumers on the other hand were rarely interested in these services because they often did not directly consume electricity or gas but rather the end-use services like light, heat or entertainment. All these characteristics led to a strong orientation of the actors on technical characteristics, low visibility and strong path dependencies over almost a century.

The recent landscape changes in the regulatory paradigms of these sectors are complemented by not less dramatic changes in fields like basic technologies. The former strong reliance on big plants, based on increasing economies of scale is more and more challenged by new more flexible I&T based alternatives, which increase the attractiveness of customer specific appliances. Therefore, long distance transport becomes less of a necessity and new decentralized topologies of service production and consumption come into reach. Concomitantly with these new technological conditions, new use patterns emerge. This is most obvious in the case of telecommunication, e.g. newly emerged use patterns of the internet or mobile phones. Furthermore, new service concepts are developed in niche markets, e.g. energy services such as the operation of customer appliances or the rental of efficient appliances. Increasingly mobile appliances also create new markets for highly decentralized electricity generation and storage etc. Former generalized concepts such as the separation between producers and consumers (e.g. in the case of electricity) or the separation between heat and electricity provision (e.g. in the case of natural gas) are therefore likely to give way to new constellations, which will increasingly threaten key stabilizing forces of the established sector regimes.

However, an analysis of ongoing transformation processes – as in our case – cannot know from the beginning, if these transformation processes will ultimately lead to a shift of regimes. Transformations may also be restricted to incremental changes or follow a different dynamic pattern. Hence, for a prospective study a broadened perspective is necessary, which considers the dynamics on all three levels independent of the final outcome. Secondly, it is often impossible to decide beforehand whether or not a specific alternative scenario will be more sustainable or not. Therefore, we cannot presuppose that a regime shift is the only way to go for. This calls for an expansion of the analytical focus of transition theory, which so far focused on radical transformations following largely an s-curve-shaped transition, and possible paths and dynamics leading to them. Studies have either analyzed historical regimes shifts (Schot 1998; Geels 2002b), or – as far as current or future transformations are concerned – have chosen a normative perspective, starting from the assumption that a sustainable way of fulfilling certain societal functions, for example transportation, can only be realized by a radical break with existing regimes (Kemp 1994; Kemp et al. 1998).

Transformations do not only happen within the individual utility regimes. One may expect a high degree of similarity between the processes across different sectors. Furthermore, the relationship between these sectors is likely to change too. Recently the concept of internationally operating multi utilities has gained increasing attention. By offering bundles of services, utilities hope to reap considerable synergy in the distribution and create substantial added value on the side of consumers. On the other side, jointly used, constructed and maintained physical infrastructure could be a source of considerable cost savings. The conventional understanding of utility services and its organizational form is therefore potentially subject to change, as well. Whether or not these synergies may be reaped is an empirical question. On the local level, municipal utility companies have practiced the multi-utility approach for decades, yet under different conditions. Given these transformation potentials, similarities and synergies, however, we have to enlarge the conventional focus of regime analysis to the interaction between regimes and add to the potential regime dynamics such processes like regime merging, regime split up or regime cross over.

Summarizing, we may describe transformation processes in utility sectors happening at all three levels of transition theory: landscapes, regimes and niches. These transformations have a potential for radical change. As elaborated above, we see three major aspects in which processes should be analyzed in more detail in order to grasp the future dynamics of utility services: (i) the potential to develop more decentralized structures for provision and distribution of infrastructure services, (ii) a strong transformation in the producer-user interface leading to more service oriented utility products and (iii) the structure of relationships between the utility services. Future transformations of the utility sectors are likely to include one or several of these aspects. The more these transformation dimensions will change, the more radically different will be a future utility system compared to the former one. In order to be able to discuss these transformations however, some additions to the existing body of literature on transition processes, regimes, niches and landscapes are needed.

4. From Technological to Socio-Technical Regimes *and Niches*

In chapter 2 we presented the concept of socio-technical regimes. This concept of socio-technical regimes implies a modification to the concept of technological regimes as it was introduced by Rip, Kemp, Schot and others. Kemp et al. (1998: 182, our italics) defined it as „… the whole complex of scientific knowledges, engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology. A technological regime is thus the *technology-specific context* of a technology ...". In contrast to the notion of socio-technical regimes it puts a certain technology or technological system at the center, social elements are grouped around this technological core. We prefer the concept of a socio-technical regime since – by putting the societal function to the fore – it implicitly avoids the a priori decision that the societal function fulfilled by a regime is primarily fulfilled by a technical core, which itself is depending on *secondary* non-technical context elements. If a regime is primarily defined by the societal function it fulfills and not by a core technological system, non-technical elements might just as well be as central as or even more central than technological elements. In the case of energy, water and telecommunications as they are provided for in industrialized countries today, large technical systems are indeed central elements of the regimes. Nevertheless, at other times and in other places, regimes of the provision of water, energy or communications had been and still are organized less technology-intensive, yet could still be described as a socio-technical regime.

Starting from this definition of a socio-technical regime we think it necessary to take one step more and extend the broader socio-technical conception also to the micro level.

Just as with *technological* regimes, technological niches comprise a set of heterogeneous elements centered around a technological core of *technological* innovations. However, innovations showing a potential to change a regime in a significant way are not necessarily technological innovations. We therefore propose the concept of socio-technical niches.

Transition theory and literature on strategic niche management has so far concentrated on the role of niches for *technological* innovations and eventually regime shifts (Kemp 1994; Schot 1998; Hoogma 2000: 81; Geels 2002b). An exception to this are Hoogma et al. (2002) and Truffer (2003), who – in the field of private and public transport – analyzed niche dynamics also for organizational innovations and innovations related to patterns of use. These innovations included new use patterns of established technologies or new organizational forms, more precisely institutionalized forms of ownership and use differing from the dominant regime (car sharing, various rental concepts), or the organizational coupling of separate regimes.

We propose to continue in this direction. The core of a niche innovation is not necessarily a new technology, but might just as well be organizational, product, service or institutional innovations, which are not applied on the regime level, but only locally. Considering transformation processes in the utility regimes these are, for example, innovations such as performance-contracting of energy services for hospitals and wellness facilities, new regulatory concepts such as least-cost-planning or green tariffs which have first been introduced by some pioneering municipalities or emission trading schemes first introduced within some big companies. Non-technical innovations are particularly relevant for the above mentioned transformations in the dimension of services.[9]

5. Interaction of Regimes

Transformation processes in the utilities are not restricted to transformations concerning one regime; rather several regimes are involved, interactions between these regimes may contribute to the transformation dynamics and transformations may also lead to a shift of regime boundaries. To analyse these dynamics we first have to consider, where regime boundaries may be identified (5.1). We will then identify different types of relationships between regimes (5.2) and finally present potential coupled dynamics of a multi-regime system (5.3).

5.1 Delimitation of regimes

When using the concept of regime in the field of utilities the question arises at which level this concept should be fruitfully applied. Does it refer to sector-specific regimes as a gas or water regime? Or rather to an overarching utility regime spreading multiple sectors? Or is it more reasonably applied below the level of sectors, e.g. to specific socio-technical configurations which have evolved around certain generation technologies like nuclear or wind power? To answer this question we have to consider, how regime boundaries may be identified. We propose to identify regime boundaries according to the density and strength of couplings between the elements of socio-technical configurations.

We differentiate between different kinds of couplings namely functional and structural ones. As functional couplings we identify input-output relationships between different elements, e.g. parts of the value chain. A further example would be enabling products or services of one sector for another, e.g. the coupling between the gas and electricity sector via a gas turbine driven power plant or the provision of telecommunication services for the regulation of power generation technologies.

9 In parallel to the concept of technological niches, it is useful to distinguish between socio-technical niches, where selection criteria are explicitly and strategically suspended or modified, and niches, where diverging selection criteria are due to given local characteristics (see Note 7). We will call these *protected niches* and *market niches*. The term *socio-technical niches* refers to both.

Structural couplings refer to elements which are at the same time part of two overarching complexes. These may be jointly used material structures, as water reservoirs used for the production of drinking water and power, or jointly used transport infrastructures, e.g. powerline cables used for telecommunication services. Structural couplings may also exist at the institutional level. These may be joint organisations as modern multi-utilities or traditional municipal utilities, joint professional associations of gas and water as they exist in Germany and Switzerland or laws and regulations applied to multiple sectors. On a normative level a further example may be the common conception of a basic service which is provided in an undifferentiated way to all citizens of a certain region, a public service.

If structures merely show a high degree of similarity between different sectors but do not actually constitute a common institution, organisation or material artefact we will not speak of structural couplings but of structural similarities.

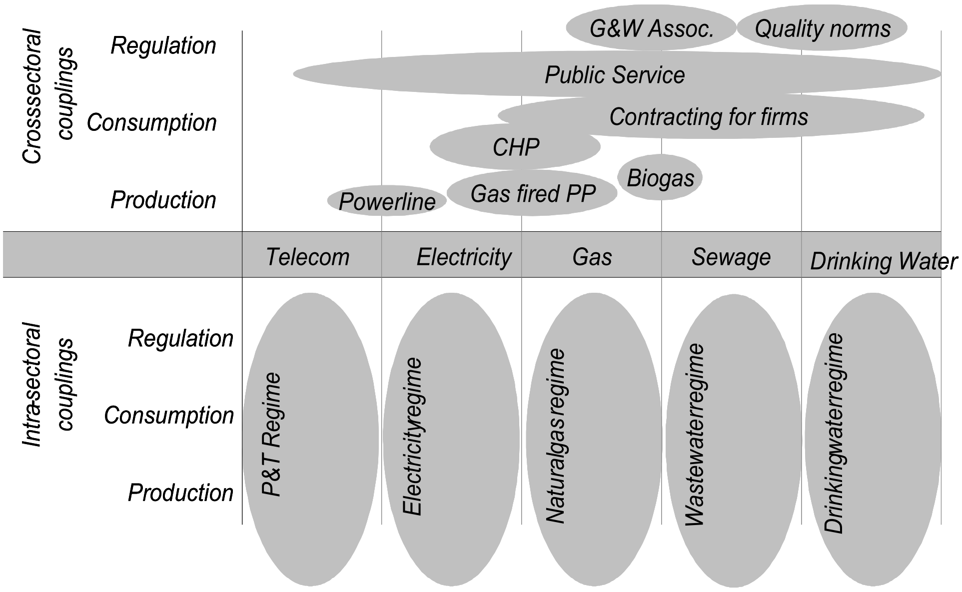
A boundary between two regimes may now be identified if we find relatively dense and hardly substitutable couplings within a complex of elements, whereas couplings between these complexes are less dense and more easily substituted. Furthermore, couplings within a regime will typically spread different structural dimensions as technologies, institutions or knowledge structures. In addition, as outlined in chapter 2, a regime as a whole has to fulfil a certain societal function.

Under monopoly market conditions the sectors considered here can be described as five regimes: an electricity, gas, drinking water, sanitation and telecommunication regime. They are characterised by a high degree of similarity as we expounded already in chapter 3 and a number of couplings exist between them; however these are less dense as the ones within. Within these regimes specific and largely independent institutional and technical structures have emerged. These are specific networks and generation technologies and largely specific organisational structures – either as independent companies or highly separated organisational structures within a utility company. The regimes were largely based on different resources, regulatory bodies and laws; the provision of the services was based on specific knowledge and differentiated professional structures. We split up the water sector in a drinking water and sanitation regime, since these are also largely based on specific networks and appliances, specific organisational units and professional associations, knowledge and professional structures; also the societal perception of these two services differs substantially.

The concept of a regime may to some extent also fruitfully be applied to the socio-technical configurations which have developed around specific generation technologies, e.g. in the electricity sector, if these consist of a densely coupled and mutually stabilising set of technological, institutional, knowledge and value structures. However, these are functionally highly – and *so far* in a hardly substitutable way – coupled to the overarching electricity regime.

Still the delineation of a specific regime may never be made as clear-cut as we may wish. There may be strong structural couplings at certain points of the value chain between regimes and other relationships within a specific regime may be in principle substitutable by alternatives. In the following figure 2 the structure of the different utility regimes is depicted as we may identify them for the times of monopoly market regulation.

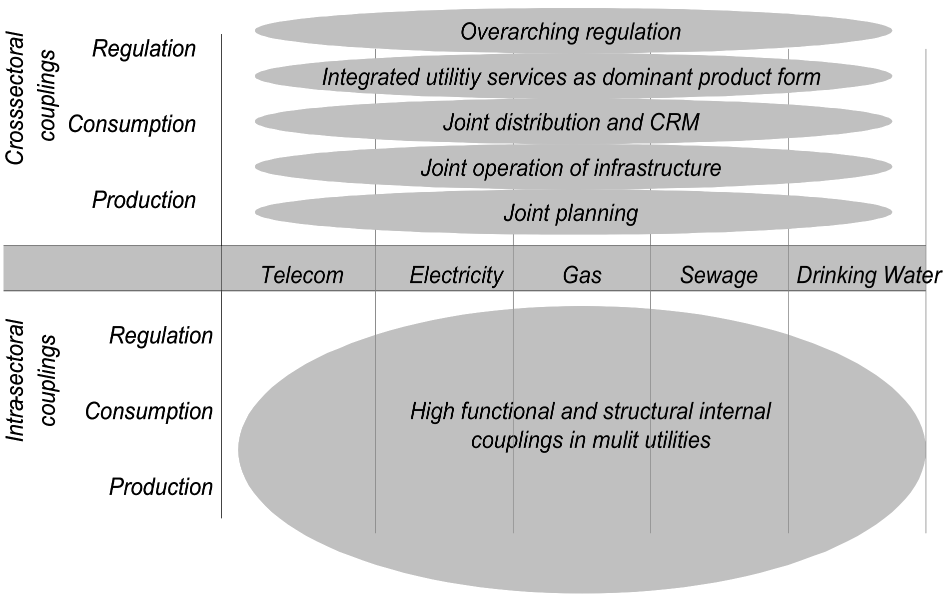
Figure 2: Representation of the inner-regime and cross-regime couplings for the case of monopoly market regulation.



However with ongoing deregulation, utility firms have begun to restructure their business fields and this may have impacts on the interaction of the formerly separated regimes. Some international utilities for instance began to position themselves as multi-utilities combining several services into combined offerings. Transformations may lead to the merging of formerly separated regimes, the splitting into sub-regimes or the integration of regimes at different levels of the value chain as in the case of vertical integration.

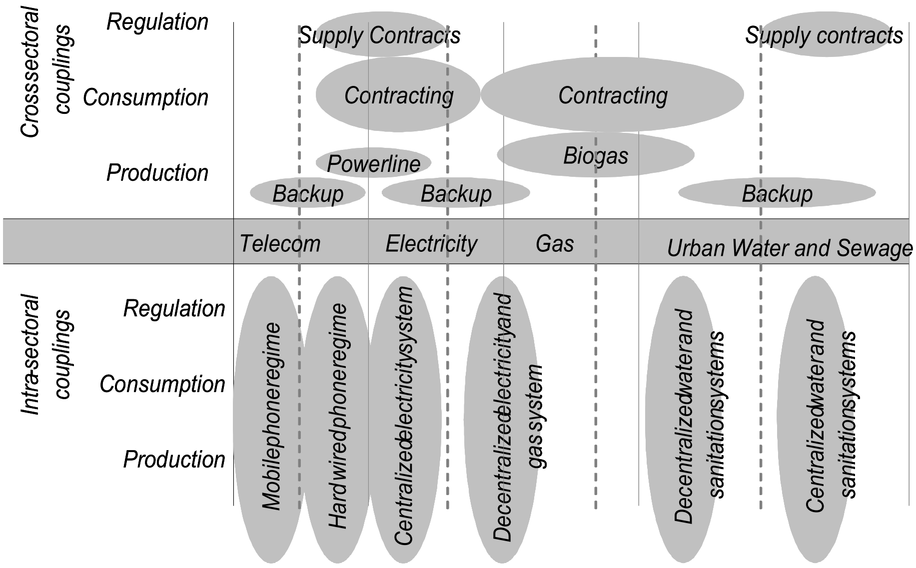
For illustration, we may identify two extreme scenarios which still seem realistic. On the one hand a strong integration of utility services may happen by the way of emerging new multi-utilities, the creation of overarching market regulators spanning all utility services, the joint planning, construction, maintenance and use of transmission infrastructures and the diffusion of new generators such as gas power plants. For the water part a strong integration between water provision and the waste water part seems feasible (figure 3).

Figure 3: Possible future regime of integrated utility services



However, also much more diversified developments may be imagined. The following figure 4 shows a newly reorganized set of utility regimes, which are not based on conventional media differences but which rather follow technological imperatives. There might be a new decentralized electricity generation regime, which is combined with a centralized gas regime. This regime would still have to rely on some services of a centralized electricity regime. However, technologies, use patterns, institutions, knowledge and values might be largely different when the centralized and the decentralized regime are compared. A similar situation might be imagined for the water sector, if used water is recycled within the household or a firm and the dependence on a centralized water provision system amounts only to a fraction of the quantities compared to the current situation.

Figure 4: Possible future regime of reshuffled utility regimes based on a dual centralized/decentralized structure.



Summarizing, we see that in order to discuss the future development alternatives of utility services, the focus of a single regime system is not sufficient. The changing relationship between regimes, the mutual influence between regimes becomes a major driving force and may be decisive also for the sustainability dimension of these sectors. In the following, we will discuss these interactions on a more systematic level.

5.2 Interactions between regimes

For the analysis of interactions between regimes, which exert an influence on transformation processes in the utilities, three types of relations between regimes have to be taken into account. Each type of relation implies different forms of interactions. We will first describe the three types of relations and then exemplify, which transformation dynamics between multiple regimes may result on the basis of these interactions in the case of utility systems.

Interactions between regimes fulfilling a similar societal function: Most studies of the historical development of regimes and regime shifts focused the competitive relationship between regimes, which fulfil a similar societal function. A prominent example is the interaction between private and public transport competing for passenger travel (Kemp 1998; Hoogma et al. 2002). Competition in end user markets can be seen as a specific form of a structural coupling between two regimes.

Interactions between regimes on the basis of complementary relations: Regimes are functionally coupled with other regimes. For example utility systems are coupled with a large number of regimes, which structure the different uses of the utility systems. These receiving systems may themselves be structured as specific socio-technical regimes fulfilling a specific societal function such as laundry, body hygiene, food preparation and preservation, room heating and cooling or telephony in the case of private households or pulp-and-paper-production, aluminium production etc. in the case of industrial activities.[10] The latter types of regimes – in our perspective from the utility sector, we may call them "use regimes" – often develop in co-evolution with the utility regimes.[11]

Interactions between regimes showing structural similarities: interactions between different regimes may also take effect if structural similarities between two regimes exist. Interactions may in these cases take the form of transfer of experiences from one regime to the other or because structural similarities open up synergies, which may be reaped by forming new structural couplings.

The three types of relations are not mutually exclusive. Regimes competing for certain markets may have important structural similarities as in the case of gas and electricity. However, this must not be, as can be seen with the more structurally diverse regimes of public and private transport. Furthermore, regimes fulfilling in some instances a societal function competitively may fulfil this societal function complementarily at others (see below).

5.3 Potential transformation dynamics between utility regimes on the basis of competitive and complementary relations and structural similarities

Interactions between regimes may contribute in two ways to transformations of regimes: as transformation processes *by* interactions between regimes and as transformations *of* the structure of interactions. In the following examples in the field of utilities for both forms of transformations are given.

Transformation by interaction: firstly dynamics in one regime may trigger off or contribute to dynamics in other regimes mediated by direct and indirect linkages between regimes.

Transformation of interaction: secondly the structure of couplings and interactions itself may be modified in the course of transformation processes. The result may be an intensification of the couplings between regimes, which may eventually lead to a shift of regime boundaries and an integration of regimes. On the other hand, a decoupling of regimes or a shift of couplings, which does not imply changes of regime boundaries, is possible. The new structure of couplings will then affect further transformation processes.

5.2.1 Transformations on the basis of structural similarities

Regimes showing structural similarities are not necessarily coupled in any direct way. Nevertheless, transformation by interaction is still possible if transfer of experiences or imitation takes place. This applies to forms of regulation, most obvious in current tendencies towards liberalisation in all utility sectors, but may also apply to changes in organisational structures, for example concepts of privatisation or internal corporate structures, customer management or new service offerings.

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10 For the laundry regime or laundry as a "system of systems" see Shove (2003). The concept of use regimes for the laundry and other domains has also been applied by Hirschl. et al. (2002).

11 For the laundry regime see (Orland 1991; Shove 2003), for the co-evolution of electricity and a number of energy-intensive industries Myllyntaus (1995), for air conditioning Shove et al. (1998).

Structural similarities may furthermore form the basis for actualising potential synergies. In the case of utilities, we currently see such efforts in the form of integration or co-ordination in fields as customer management and network operation. Synergies exist here for instance in the parallel or coupled laying of cables and mains, such as telecommunication cables parallel to gas mains or in sewage canals, or the co-ordination and integration of maintenance activities for different networks. In the field of customer management billing, metering and customer services could be integrated. Synergies are particularly important for structurally similar regimes, since synergies are more likely here than in other constellations. On the other hand, we may also find decoupling of processes, if former structural couplings are found to lack sufficient synergy at a later point of development. Generally these interactions are situated between specific elements of the regimes, e.g. specific parts of the value chain. They do not apply to the regime as a whole. Therefore increasing integration at one point of the linkages between two regimes may well go along with a decreasing integration at another.

The realisation of synergies between two or more regimes will easily bring about structural changes in the respective regimes. These are for example changes in processes, competencies and the organisational structures of companies, which may further go along with changes of corporate culture. Technological innovations may be implemented and patterns of qualification have to be adapted. In Germany new training courses are offered now that prepare for an integrated maintenance of networks (Rothenberger 2003). These structural changes do not *necessarily* imply profound changes in the overall regime structure. However, a dynamic is possible, where a stronger integration of regimes could induce further changes on the basis of the new structure of intensified interactions. A successful cooperation in the operation of networks could pave the way for the introduction of new integrated generation technologies and thereby a much stronger coupling of regimes. In quite the same way successful integration of customer management may be a first step in the direction of new offers of integrated services. An introduction of new integrated generation technologies and integrated services would most probably result in major changes in the utility regimes. Dynamics of this kind illustrate why in a prospective perspective it is difficult to differentiate between dynamics which do 'only' lead to limited transformations of a regime like the cooperation in the operation of networks or the integration of customer management and those, which ultimately result in more profound regime changes.

5.3.2 Transformations on the basis of competitive relations

Transformations by interactions on the basis of competitive relations could follow a shift from the use of electricity-driven to gas-driven technologies on the side of the users – be it via household technology or production machinery – or the other way round. As long as the shift is only marginal this will probably not affect the regime structure and the interactions between both. However, in the case of a far reaching shift from one dominant regime to another, changes in the internal structure as well as the structure of interactions between regimes are to be expected. Furthermore, markets will change and thereby also linkages with regimes fulfilling complementary functions.

A second type of transformation would be a shift from mainly competitive to more complementary relations between two regimes. Whereas regimes fulfilling a similar societal function compete on the one hand for common markets, at the same time this opens up a potential to fulfill jointly a common societal function. Quite often regimes competing at one point are functionally coupled at others fulfilling a certain function complementarily. In the course of a shift from competitive to more complementary relations new functional couplings are to be expected. In the utility sector an increasing use of gas as primary energy carrier in electricity generation could be an example. A much more radical dynamic in this direction would be a rather tight coupling of electricity, gas and the sewage system in the course of a potential transformation path leading to highly decentralized systems. Here the endpoint could be the merging of until now fairly separate utility regimes into a common larger utility regime.

5.3.3 Transformations on the basis of complementary relations

Transformation processes on the basis of complementary relations rely on functional couplings. Partly these are indirect interactions between regimes via common complementary regimes, e.g. certain use regimes. This could be an increase in the gas or electricity consumed because of an increase in the use of hot water, or, just the other way round, if less water is consumed, because energy is to be saved. A similar case is an increase in the use of electricity following the spread of new telecommunication applications (Huser/Aebischer 2002; Büllingen/Stamm 2003).[12] These use regimes are themselves coupled with other regimes, for example the regime of room heating and cooling is coupled with the regime of housing. Therefore major changes in the housing regime may indirectly affect utility regimes.

As mentioned above, complementary relationships often lead to co-evolutionary dynamics. Utility regimes and a number of its use regimes, in the private as well as in the industrial sector, could only develop conjointly as has been illustrated in historical studies. This type of dynamics typically goes along with a transformation or gradual emergence of interactions.

An important example may be illustrated by demand side management, an orientation of demand following supply, because this implies a stronger interaction between utility and use regimes, either based on technical, institutional, knowledge or value elements or some combination of these. These changes would imply considerable changes of the provider-consumer-relationship in the respective utility regimes (Chappels et al. 2000; Van Vliet 2002). A rather extreme version are concepts based on the possibility for supply side actors to actively turn on and off consumers of electricity (Kets et al. 2002). A development in this direction could be a correlative to an overall development in the direction to a decentralisation of utility systems.

6. Conclusion

In the present chapter, we have shown how transition theory might be fruitfully applied in order to discuss ongoing transformations in the utility sectors. The analysis of landscapes, regimes and niches helps to focus on stabilizing forces and to develop an integrated view of processes spanning consumption, production and regulation in order to identify future development paths, barriers and windows of opportunity. This step is an important precondition for identifying and assessing more sustainable futures of these utility sectors.

However, the concepts as expounded in the literature had to be broadened and modified in some important respects: First, we have enlarged the focus on technologies in order to include broader socio-technical transformations. As a consequence niches are not only identified for new technologies but also for other

[12] In the case of utility regimes the number of complementary use regimes is fairly large, so that an analysis of the role of complementary regimes for transformation processes in the utility regimes has to start by a selection of those complementary regimes that are likely to have a considerable impact on transformation dynamics of the utility regimes. This could be because of foreseeable internal dynamics and a strong coupling to the utilities, e.g. because they consume an important amount of the produced electricity, gas, water or telecommunication services.

innovation processes with a stronger focus on institutions, preferences and regulations.

The analysis of current transformation patterns in the utility sectors showed that non-marginal changes are possible in three domains: (i) a fundamental change in the technological logic of utility production and distribution. In former times orientation was focusing on economies of scale coupled with capital intensive material infrastructures connecting locations of production with locations of consumption. Recent developments show potential for more decentralized and flexible systems of generation and provision. (ii) Conjointly with market liberalization a fundamental break with user conceptions on the side of the utilities may be expected. Thus customer and service orientation may increase and gradually replace the former company logic which is more strongly based on technological necessities than on user needs. (iii) As a combination of the first two transformations, interactions and relationships between the utility sectors have the potential to change fundamentally. Therefore the delineation of regimes may undergo quite radical transformation and this may have substantial consequences for the environmental impacts of these economic sectors.

The analysis of the three major realms of change may be undertaken by discussing processes at the three levels of landscapes, regimes and niches. However, the theoretical apparatus has to be further specified in order to fit the specific needs. First, interactions between regimes have to be taken into account and their joint dynamics have to be analyzed. We proposed a concept for analyzing these interactions. Secondly, depending on the degree by which these transformations take shape it will be necessary to have a closer look at various patterns of regime transformation rather than to exclusively focus on ideal type transitions, leading to the substitution of a dominant regime by a new one.

The present conceptual analysis will be empirically applied in the context of a currently running research project in Germany. The goal of this project is to develop shaping strategies for long-term structural changes in utility sectors. Therefore it is necessary to identify possible futures for the utility sectors electricity, gas, water and telecom in Germany over the next 20 to 25 years. Emphasis is put on transformation potentials leading to more sustainable utility regimes. In this context, we have developed overarching scenarios for the four sectors conjointly with experts from utilities, governments, consumer and environmental NGOs and will analyze transformation paths which could ultimately lead to more sustainable futures. The present theoretically oriented analysis will therefore be brought to fruition for the interpretation of these processes.

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Evaluation of Early Processes in System Innovation

A Pilot Study on the Transformation of Dutch Agriculture and Food Chain to Sustainability

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1. The evaluation of system innovations for sustainable development

Despite many success stories in environmental policy, several quite persistent environmental problems remain, such as increasing CO_2 emissions, loss of biodiversity, the disturbance of the nitrogen cycle and excess noise in our daily surroundings. These persistent problems have appeared to be much harder to tackle with traditional environmental policies. The Dutch government has introduced a new long-term strategy to deal with these problems in its Fourth National Environmental Action Plan: *transition management* or the management of system innovations as a policy tool (VROM, 2001). This policy requires an integrated control of large scale institutional and technical changes within a context of uncertainty and complexity.

Such a policy implies a focus on the process of (the preparation of) system innovations, rather than strictly on the goals to be reached. A policy of system innovations distinguishes what should be done on the short-term in order to reach goals on the long-term. Management of system innovations does not necessarily mean that the national government plays the classic hierarchical role of controller. In order to be able to involve other actors in a society it may well be a fruitful strategy for a government to act as a facilitator or sometimes a director rather than as an enforcer of new rules. Transition management aims to provide the new policy instruments to deal with the persistent environmental problems.

A new policy instrument requires new methods for the monitoring and the evaluation of the effectiveness and the efficiency of this instrument. The shift in policy from a target approach to a system management perspective renders simple measurements obsolete. Gathering physical data and measuring straightforward developments does not suffice anymore. The monitoring of system innovations in society needs to involve social processes, to which many actors, institutions and innovations may play a role. Therefore, it is necessary to involve new parameters such as intentions, actions taken, networking, research and development, first movers and resistance against changes.

In this chapter we present some methodological elements of this new type of monitoring. The transition to a sustainable Dutch agriculture (and food chain) is one of the main targets in national environmental policy. This case is usded here to illustrate our approach.

2. General notions on the management of system innovations

Transitions or system innovations are often related to large-scale technological regime changes. In a fairly new context this concept is extended to large-scale changes in society as well. This extension allows for a more integrated analysis, as well as for policies that go beyond the traditional straight causal lines. System innovations as we will use it (i.e. as a socio-technical concept) can be defined as "a gradual, continuous process of structural change within a society of culture" (Rotmans et al, 2001). This same study states that "transitions involve a range of possible development paths, whose direction, scale and speed government policy can influence, but never entirely control."

An important notion on system innovations is the idea that they usually take the shape of an S-curve, that starts off from a take off-phase, through an acceleration phase and to a new stabilisation of the system. Many different smaller dynamics shape this main path to stabilisation, but they do not all by themselves take the required direction. Transition management is to a large extent the modulation of all the smaller dynamics in society in the same and preferred direction. In order to do so, it entails at least the following important features:

- *Goal setting:* It is important to have a certain focus, to be able to give direction to the smaller scale dynamics and innovations. Goal setting is necessary, but goals are not necessarily fixed.
- *Type of management* is transformed from hierarchical towards network management, which takes all relevant actors into account. This feature originates from the notion that direct steering of the large changes implied is not possible, and that the transition manager should focus on providing the framework and guidance to the other actors involved. Noteworthy is that some of the classic policy instruments are still available here, e.g. subsidies, taxation or regulations.
- Some changes involve necessary (technological) pathways afterwards, hence creating a 'lock in'. *Uncertainties* and the management of *lock-in* have to be incorporated in transition management.[1]
- Short-term policies should be placed in a *long-term context*. This has already been applied in several policy fields – such as e.g. present-day climate change policy – but it is not always clear to policy makers what the short term policy consequences are of setting long term goals. Transition management should take this more into account.
- System innovations not only go through different time phases, but also take place at different *scale levels*. The micro level involves individuals, the meso level networks, organisations and institutes, the macro level conglomerates, nations and the wider institutional context. These levels can be taken collectively to form the socio-technical landscape (Geels and Kemp, 2000; Geels, 2002). Policies should take the appropriate scale into account.

The management of system innovations covers a wide range of areas for focus of attention, from problem perception to the actual realisation of large scale changes.

1 See (among many others) e.g. Dosi (1982), Nelson (1988), Nelson and Winter (1977) on the Schumpeterian concept of lock-in.

Many publications have come forth dealing with the relevant aspects of system innovations and their management (see, for example, Boulding, 1970; Rotmans et al, 2000; Geels and Kemp, 2000; Rotmans et al, 2002; Butter, 2002; Molendijk et al, 2002; Geels, 2002; Spakman et al, 2002). Many of the recent conceptual contributions have originated in The Netherlands, no doubt promoted by the policy makers that have put the concept in practice.

In our own contributions to the system innovation concept, we have concentrated on the development of an evaluation methodology for transition management (see Spakman et al, 2002; Rood et al, 2002; Van Wijk and Rood, 2002; Ros et al, 2003). This methodology will be elaborated further in the following chapters.

3. Methodology for the evaluation of system innovations

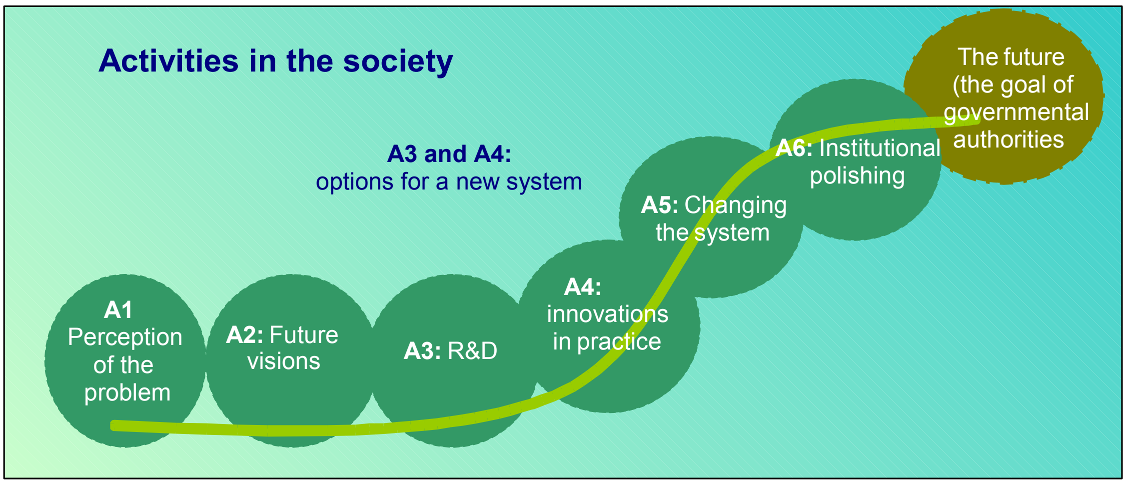
3.1. The methodology of evaluation

We have developed a framework called 'arenas in the transition process' for the evaluation of controlled system innovations. An 'arena' in the framework is defined as a 'set of activities with the relevant actors involved'. These arenas cohere with the process of system innovations along the theoretical S-curve, so as to basically provide an analytical framework to assess the activities carried out by the many actors at the various stages of the system innovation. We distinguish the following six arenas (see figure 1):

Arena 1 Problem perception;
Arena 2 Development of future visions;
Arena 3 Research and development;
Arena 4 Pilot projects and first movers;
Arena 5 System changes;
Arena 6 Final institutional polishing of the innovated system.

Noteworthy here is that the arenas are interrelated, not only in a serial, but also in a parallel process. To carry out a proper evaluation of the activities in each arena, we need to introduce a certain measure or indicator for these activities for each of the arenas. This quantification enables us to monitor progress in the system innovation at a later stage, but first and foremost it allows us to make a baseline evaluation.

Figure 1: Framework showing the 'Arenas in the transition process'



3.2. Elaboration of the six Arenas

A1 perception

This Arena shows the level of agreement on (the seriousness of) the problems. Here already some initial priorities are set with respect to solutions and options for action. The perception is based on a broad array of sources, such as scientific knowledge, calamities and the sacrifices anyone will have to make in order to accomplish potential solutions. The perception is often fed by the physical monitoring, but uncertainties are an important source of controversy at this stage.

A2 Development of future visions

Future visions are important to stimulate actors to overcome barriers on the way to reach a solution of the perceived problem. It is important to reach some agreement on explicit goals, as this will give direction to later developments of technologies and institutions. On the other hand, too much detail could hamper the actors in reaching agreement to the point that it could discourage relevant players by frustrating their creativity. This suggests finding an optimum between explicitness and level of guidance. Such an optimum depends on the state of the developments in the other arenas; making strides to the optimum spurs on the players involved, giving them a certain 'push' in the attempt to move into subsequent arenas.

A3 Research and development

A system innovation needs new technical options. Surveying the breakthrough chances for technologies will involve at least some insight in technological development, market structure and market chances, along with political backing. Such an assessment is therefore not only based on the characteristics of the technology itself, but also on the institutional environment. Innovation involves indicators such as R&D budgets, governmental support, competitiveness, synergy between researchers and potential users (see eg. Shapiro, 2002). It is key to develop a network of innovations, in order to improve interactions and hence gain momentum.

A4 Pilot projects and first movers

'First movers' are players able to combine conscience with the nerve to experiment (Rogers, 1962). They are usually the actors that are willing to take some risks and consequently will be found at the start of the diffusion process of any new innovation. Even before these initial processes of diffusion take place, pilot projects will be started to test and improve the new technologies. These experimental projects can be monitored. To evaluate whether first movers have taken their position, setting the stage for follow-up by the early majority, we can distinguish upcoming niche markets in agriculture and assess their potential and contribution to the sustainability trajectory.

A5 Changing the system

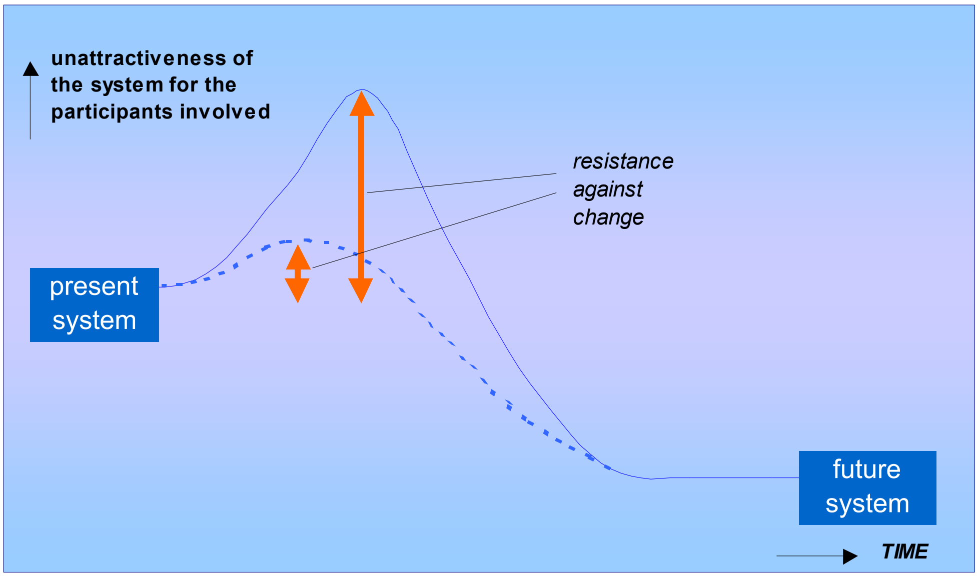
A key challenge in the process of system innovation is to overcome high barrier of resistance, that occur between the present and the future systems (see figure 2). This argument bears much resemblance to that used in the principles of thermodynamics, i.e. a 'hill of resistance' will have to be taken or a high energy input is needed in order to reach a system of high attractiveness and efficiency.

To quantify the resistance we use the so-called *MEI-model* methodology, which was developed to determine the efficiency of policy instruments (Van Wijk et al, 2001a and 2001b). The method is based on the driving forces or pressures on an actor in relation to the required targets. Such pressures could be, for example, financial impact, pressure of policy goals and social pressure. The forces and pressures are determined using a data mix of facts from various references in literature and from monitoring programmes, or from expert judgements when facts and measurements are not readily available. The separate pressures can each show either positive or negative directions.

A6 Final institutional polishing of the innovated system

The final phase of system innovation involves the institutional polishing of the new system. It is natural to include the phase of maintenance here. This arena may also include several new system participants when compared to the initial situation.

Figure 2: Resistance on the trajectory between the present system and the future system.



3.3. The framework

The arena framework as introduced allows for a closer evaluation of the underlying processes of system innovation. It does not necessarily relate to the policy goals of sustainability, but focuses on the activity of the processes in each stage of the transition. The methodology allows for the evaluation of other arenas even without first assessing these future visions. This does not mean that a transition can be organised without setting goals or elaborating future visions; this is exactly what is evaluated in the first arena. The overall assessment of a managed system innovation takes all the arenas into account.

One of the advantages of this approach is that relatively small signs of progress and activity can be identified. This framework can hence be applied at any stage of the system innovation. In the next chapter we will illustrate the application of this framework for the third and fourth arenas on the transition to sustainable agriculture. This should allow the assessment of the R&D and pilot projects phases by showing the activities of the main participants in these arenas.

4. Application of the evaluation framework

4.1. The R&D Arena on organic agriculture developments

4.1.1. Determinants of the environment for R&D investments

The third Arena of our analytical framework concerns the development and level of R&D. Research and development amalgamates a complexity of activities around the development of new technologies, often in co-evolution with institutional and organisational changes. A lot of research is done on the economic drivers behind R&D investments and technological innovation processes (e.g.: Fagerberg, 1988; Porter, 1990; Kemp, 1995; Stern et al, 2000; Shapiro, 2002; Montalvo Corral, 2002). We will not go too far into the discussion on the driving forces behind technological innovation and R&D, but limit ourselves to three main framework determinants: government policy, market structure and technological stage of development. These three framework determinants each incorporate many characteristics. Here we will briefly examine some of these characteristics.

Market structure is a rather fluid concept, but here we limit ourselves to either a competitive structure or a more co-operative structure. A competitive structure is often regarded as the best environment for a high level of R&D investments (Shapiro, 2002), even though this leads to a certain level of R&D over-expenditure (Verspagen, to be published). The competitive market structure uses firm profits as the main incentive for investing in innovations. The evolution of a co-operative market structure requires a director to organise the co-operation; the most obvious director is the government. An important indicator for the relation between innovative power and market structure is given by Porter's Index, which aggregates several indicators according to the quality of the innovative infrastructure and the quality of public research, as well as some cluster (or sector) specific indicators (Porter, 1990; Stern et al, 2000). Porter's Index is essentially aggregated in three main clusters: private research, public research, and the (institutional) links between these.

Technological development is represented by a point on the learning curve of a certain technology. This curve can be thought of as proceeding from invention to wide spread application, and usually takes the form of an S, similar to the system innovation curve we sketched earlier in this chapter. The R&D phase of a technology usually comes at a point where applications for a technology take form, hence distinguishing the phases of fundamental research and applied research. If a technology or invention is still far from application, R&D investments may still be very low.

Government policy stems from a reflection upon the role government wants to play, be it either very liberal or very market oriented. The policy determines the level of governmental interference. Basically, this interference can focus on market innovations (enhancing private R&D) or at universities and public institutes (enhancing public R&D). These options are not mutually excluding and they can be used in addition to each other.

For the purpose of evaluating Arena 3 in the transition to a sustainable agriculture, these three framework determinants can be represented collectively by a set of characteristics (see table).

Features for the R&D-lay out	**Determinants**
Technological barriers	Determine level of applicability of technology and level of private investment; they are determined by market structure (for finance) and technological development
Attention and competence	Determine level and direction of R&D investments; they are determined by policy agenda and market structure
Market position	Determines the policy agenda and level of R&D investments; is determined by market structure, government policy, technological development and position of alternative technologies

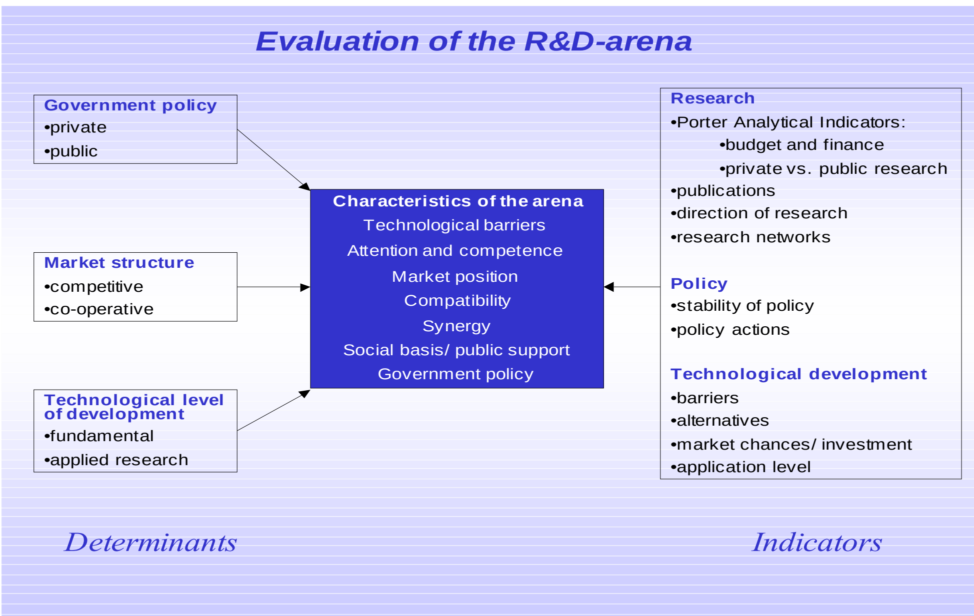
Compatibility on current technological regime	Determines whether new technology can be attached to prevailing technological regime; determined by technological development and by the position of alternative technologies
Synergy between developers and applicators	Determines whether developers and users work together proceeding from innovation to diffusion of technology; relates with level of technological development, market structure and government policy
Social basis / public support	Determines whether technology will be accepted; indicates market position
Government policy	Determines level and direction of R&D investments; is determined by market structure and public support

In earlier work we have designated these features as driving forces behind technological innovation (Van Schijndel and Ros, 2000), but here it is more appropriate to represent them as features or characteristics of the R&D lay-out, although they also influence the following innovations and implementations. These characteristics determine to a great extent the boundaries of the R&D investments, for example, when a new technology has a low compatibility with reference to the dominant technological regime, the R&D investments will most likely be inhibited.

The characteristics and determinants only sketch some of the features of the driving forces related to R&D investments. In order to be able to make a proper evaluation of the level and direction of R&D, it is necessary to have insight into policy instruments, market structure indicators and technological development indicators (see figure 3).

This inventory of indicators and instruments can indicate the *chances for breakthrough* of a certain technology or technology set. For our further evaluation we will first use an adaptation of the Porter Index variables. While Porter uses his indicators to characterise the innovative score of a country, we will try to focus them specifically on research for organic agriculture in The Netherlands. These indicators focus on the market structure of R&D for organic agriculture. We extent this set with some indicators on government policy and on the technological barriers as well.

Figure 3 Evaluation of R&D-arena



4.1.2. Choosing the R&D indicators for organic agriculture

In order to evaluate the characteristics of Arena 3 of the transition to an organic agriculture, we will have to score the R&D indicators in this arena.

Porter Index

Porter gives several indicators for the innovative structure of a country (Porter, 1990):

- number of employees in R&D jobs;
- R&D spending;
- openness for international competition;
- expenditure on higher education (% of BBP per capita);
- protection of intellectual property;
- BBP per capita;
- percentage of private R&D finance;
- percentage of R&D performed at universities.

Aggregated, these indicators represent the self-named Porter Index, which can be used to compare the innovative quality of a country. In order to evaluate the R&D on organic agriculture, we will have to adapt Porter's indicators. After focussing some of the indicators on the topic of organic agriculture, and by deleting the indicators that are too broad to allow for focusing, a proper set for organic agriculture could now be the following:

1. budgets and financing of R&D for organic agriculture;
2. private R&D versus public (academic) R&D.

In addition to these indicators, we need an insight in the government policy and technological development. These are domains are elaborated in the following indicators:

3. direction of research;
4. number of publications;
5. research networks;
6. policy support for knowledge development and innovations;
7. policy stability.

4.1.3. Evaluation of R&D indicators for organic agriculture

Budgets and funding of R&D for organic agriculture

The overwhelming majority of the research budget on organic agriculture is distributed by the Dutch ministry of agriculture (LNV). The ministerial budget for organic agricultural research (in the broad sense of the definition of 'organic'), for 2003 is about € 13M, which is roughly 90% of the total organic agricultural research budget. This covers essentially all research of relevance for organic agriculture. The national research budgets from the Ministry are planned to decrease slightly to € 12M annually for the coming years. This is quite remarkable, since other budgets on the stimulation of organic agriculture have been cut back much more dramatically, such as subsidies for farmers that alter their production methodology to the organic farming system (RIVM-MNP and Wageningen UR, 2003).

Other major funding bodies in the Netherlands for organic agriculture R&D are the combined Commodity Boards for dairy products, arable land farming and horticulture, which generate around € 1M for R&D on organic agriculture. The EU for its share has allocated funding for a major project within the Sixth Framework Programme on food safety and quality of organic products. Minor budgets are generated by the provinces and aggregate to several hundreds of thousands euros maximum.

The fact that most research is financially supported by LNV shows a high policy support for knowledge development and innovations on organic agriculture.

Well over 90% of the research is performed at the Wageningen Agricultural Research Centre (WUR), the main academic centre in the Netherlands on agricultural research. WUR has indicated its goal for the very near future to direct 10% of the research funds to organic agriculture. Also, there is a relatively small specialised research centre on organic agriculture and farming, the "Louis Bolk institute" (LBI), with around fifty employees. Finally, other institutes and universities perform several minor projects.

Private and public research

Although most of the research on organic agriculture is done at public institutions, rather than in a market construction, it should be noted that a fair lot of the innovative structure of organic agriculture may be developed on farms or in a learning-by-doing setting. Such innovations can often be generated with (very) low budgets, for which the largest Dutch bank in the agricultural sector, the Rabobank, has introduced special funding programmes for innovations and for sustainability programmes.

The private part of the R&D phase mainly concentrates on acquiring know-how for producers of organic products and for farmers in transition to organic production. LNV supports the dissemination of knowledge, which in practice is done by organisations such as Biologica Foundation. A specialised research programme in organic agriculture is supported by the WUR (*Innovatiecentrum Biologische Landbouw*), which concentrates on publicly financed research, the stimulation of innovations at farm level and dissemination of knowledge. Farmer's organisations (including the national farmers and horticulturists organisation, LTO) as well as organisations like the Innovation Support Office in Wageningen also mediate in farm-scale initiatives, although they focus for the most part on innovations in regular agricultural practice, and much less on organic agriculture.

Direction of research

Since most of the R&D on organic agriculture is financially supported by LNV, the Ministry is to a large extent able to determine the direction of the research. LNV has selected six bottleneck issues for research on organic farming (LNV, 2003): plagues and diseases, mechanic weed control, energy use and nutrient control in horticulture, soil and nutrient control, mineralisation of organic fertilisers and labour productivity.

The focus of the research is on primary production, e.g. research for alternative methods of pest control and fundamental research on multi-cropping or soil processes. Research on processes further up the food chain, such as epidemiological effects, is still in its infancy.

Much emphasis is laid on dissemination of research result, making them available for use in practice as early in the process as possible. Research is therefore to a large extent very practical and applied.

Publications

We have compiled a list of all scientific articles on agriculture in 2002 from the Science Edition of the Journal Citation Report (JCR, 2002), which added up to 15471 articles from 156 journals. This includes articles within the selected fields of agricultural economics and policy, agricultural engineering, agriculture, dairy and animal science, multidisciplinary agriculture and agronomy.[2] Dutch institutes contributed to 411 articles, which is 2.66 % of the total of articles.

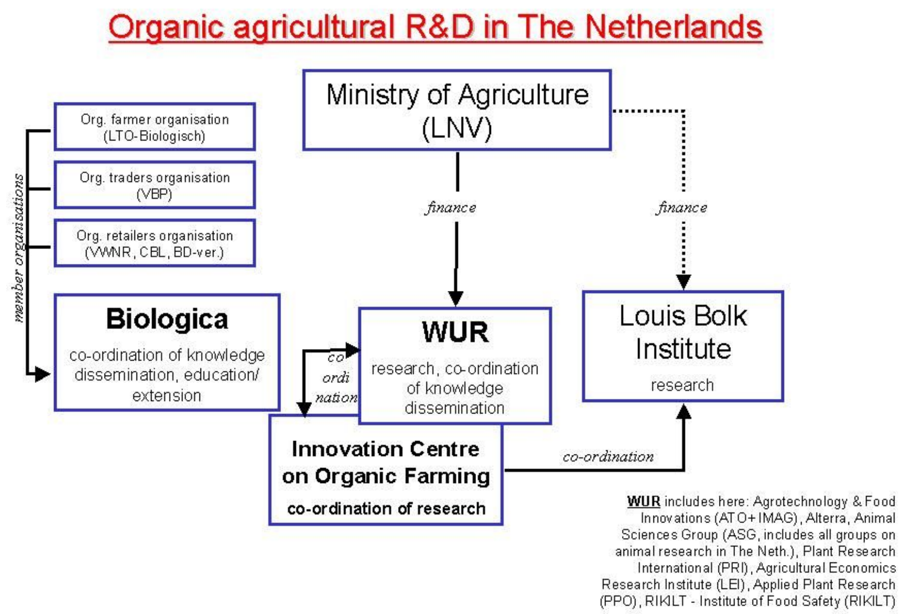
2 the JCR selection specifically *exludes* journals from the social sciences, which are collected in another database. However, some multidisciplinary journals are included here.

Of this selection 25 articles were selected on the keywords 'organic', however, most of these articles deal with subjects related with organic chemistry. Limiting the search to 'organic agriculture' or 'organic farming' yields 5 articles on the topic, which is 1,2% of all Dutch articles in the agricultural sciences. Two articles were written in international co-operation.

Research networks

The research network on organic agriculture in the Netherlands is highly determined by the financial currents and therefore mostly concentrates around the WUR. The Innovation Centre on Organic Farming, which is supported by WUR, co-ordinates much of the research in the country. This centre is allied to the Biologica Foundation. This foundation includes several co-ordinating organisations as members and therefore is able to mobilise much support and backing in the organic food chain. The Louis Bolk Institute (LBI) is an independent research institute. Figure 4 gives an overview on R&D for organic agriculture in the country.

Figure 4: network for organic agricultural research in The Netherlands



Technological development

Technological developments are dependent not only on market developments and policy structure, but also on the characteristics of technological barriers and compatibility with the present technological regime. It is not always easy to assess these characteristics with proper indicators, but it is possible to make a driving forces analysis, as can be seen in our short case study on the weeding robot. Since organic agriculture is very labour intensive (as it refuses to use pesticides), alternative weeding techniques are a hot topic for research. The weeding robot could be an interesting option here. This robot is an independent piece of equipment based on GPS techniques, which are used to distinguish structured patterns on the field (the crops) from unstructured patterns (the weeds). Expectations are that the first prototypes can be tested in about four years (LEI, 2003), but a full marketing is still considered to be at least ten years away (Ros et al, 2003).

The advantages for this technique are that the present weeding *alternatives* are either not acceptable in organic agriculture (i.e. chemical weeding), or are too expensive (labour intensive manual weeding). This obviously creates a market for this technique, although its development is clearly dependent to what extent it can overcome the disadvantages of the alternatives. A robot could replace 95% of the manual work and therefore could be a very attractive technology.

The disadvantage of this robot technique is presently that a fair bit of research is still necessary before a working model can be presented: the technique is still in its early development phase. This implies the necessity and a justification for continuous (public) *financing*, to ensure further development. At some point this will be taken over by private parties, once applications can be made and profits of marketing the technique are within sight.

Market chances can increase rapidly once stricter environmental standards originating from organic agriculture are applied more widely to common agricultural techniques. If chemical weeding is widely restricted, alternatives like the weeding robot may become attractive, stretching beyond a much wider market than organic agriculture (see Smits and Koole, 2002). This could greatly increase the *synergy* of development, possibly becoming a very important incentive for the development of the weeding robot, since the growth in the national market for organic products has been insecure for some years now. If the market remains as small as it is, potential new techniques may not be developed further for such a small market only. However, a dilemma can be recognised here, since the hampering growth of the organic production is at least partially attributed to the shortages in (seasonal) labour.

Policy stability

An important feature of the strength of the R&D arena lies in policy stability. A stable policy and market determines to a large extent the expectations of the research investor. Insight in the evolution of policy stability for research on organic agriculture could be quantified in terms of funding fluctuations and in the conditions for fund receiving parties. For this case study no insight is available yet on this issue.

4.1.4. Conclusion on Arena 3

From the above indicators we conclude the R&D-arena on organic agriculture in the Netherlands to be fairly active. Funding is relatively high and the research covers most areas of interest on this field, apart from epidemiological and toxicological studies on human health issues related to organic food stuffs.

Although funding and support is high, the research network is relatively small. One university performs about 90% of all (fundamental) research and most of the funding comes from the Ministry of Agriculture. This bears some risks for policy stability: if a new political course were to decrease (or increase) funding for R&D in organic agriculture, this would have immediate effects. Policy stability is hence very important here.

On the other hand, there is an increasing interest from private parties in the concept of organic agriculture, which may lead to the creation of new markets and hence stimulate further innovations in this field. We can tentatively conclude that the chances for a transition to organic agriculture (which is not necessarily the same as sustainable agriculture!) is supported by the present R&D level and direction.

4.2. Arena 4: Development of new forms of agriculture

4.2.1. Niche-markets for new developments

New forms of agricultural practice could prove to be the embryonal shapes of an innovated and sustainable agricultural system. The so-called first movers (or trendsetters), who introduce the new innovations in practice will often apply new concepts. Some typical new activities in the agricultural sector are agro-tourism, management of nature and landscape, and organic agriculture. These new activities can be characterised as expressions of *broadening* and *deepening* the fundamentals of traditional agricultural practice (Van der Ploeg et al., 2002). These activities create new sources of income for the farmer, as they extent the farmer's markets, either by offering a wider variety of products (broadening, e.g. agro-tourism), or by competing on the basis of added product quality (deepening, e.g. organic agriculture). Other new activities relate to a reconstruction of organisation of the agricultural practice, such as the new co-operative arrangements that seek to re-organise relations with the state and its policy makers (Van der Ploeg et al., 2002). An appropriate policy in this stage of the system innovation could relate to *strategic niche management*, which involves some level of protection for innovations on sustainability, to 'mature' them for later market introduction (Kemp et al, 1998; Kemp, 2000).

4.2.2. New initiatives in Dutch agriculture

Several new activities in Dutch agriculture are shown in figure 5, some of which show turbulent growth rates. One of these is the agricultural protection of landscape and nature (as a broadening of the agricultural practice), which is growing steadily at annual rates of up to 20% in terms of area. From the national statistics, we observe the area under agricultural nature management to be almost twice as large as the number of farms in this business, suggesting that the first movers are found among the large farms.

Figure 5: Some niche markets, 1980-2002 (RIVM, 2003)

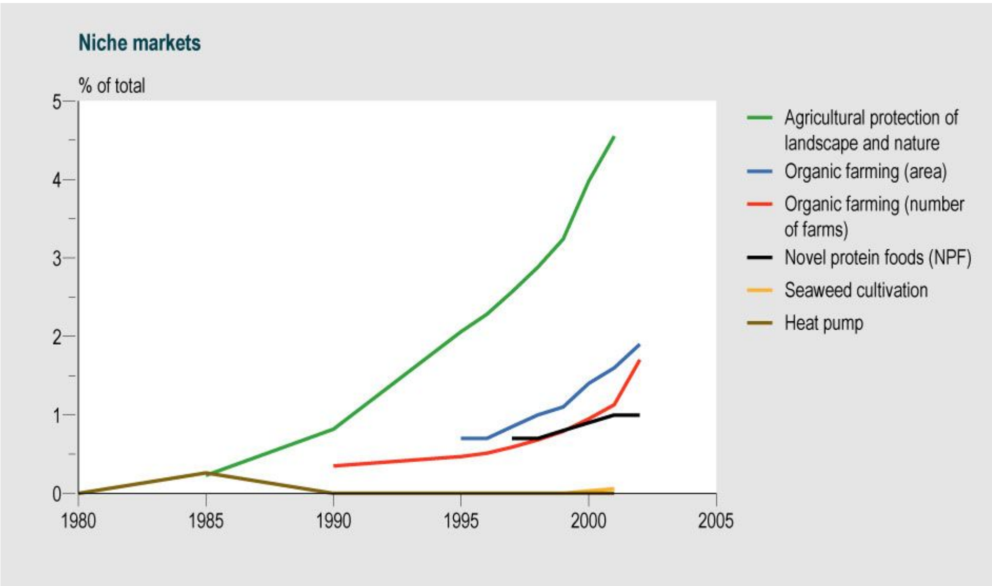


Table: Management of nature and landscape, 1980-2001

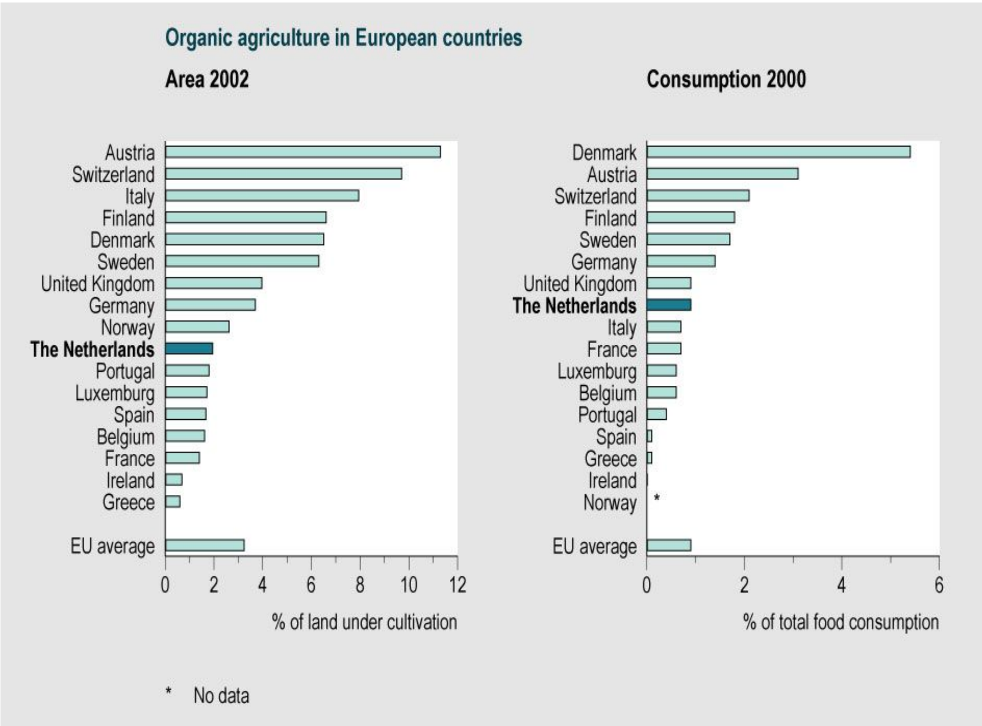
	1985	1990	1995	1996	1997	1998	1999	2000	2001
Agricul. nature management (% of total agricul. area)	0.23	0.82	2.06	2.28	2.57	2.88	3.24	3.98	4.55
Annual growth rate (%)				10.7	12.7	12.1	12.5	22.8	14.3
Agricul. nature management (% of total number of farms)						1.44	1.88		

Source: CBS (Statistics Netherlands)

The sales of novel protein foods (NPFs) showed several large increases of over 10% for some years, but this market has now stabilised to just under 1% of the meat market. An innovation that failed to take the market is the gas fuelled pump or heat pump, which uses methane gas produced by the livestock for heat production. Recovery time for the investment proved too long for most investors.

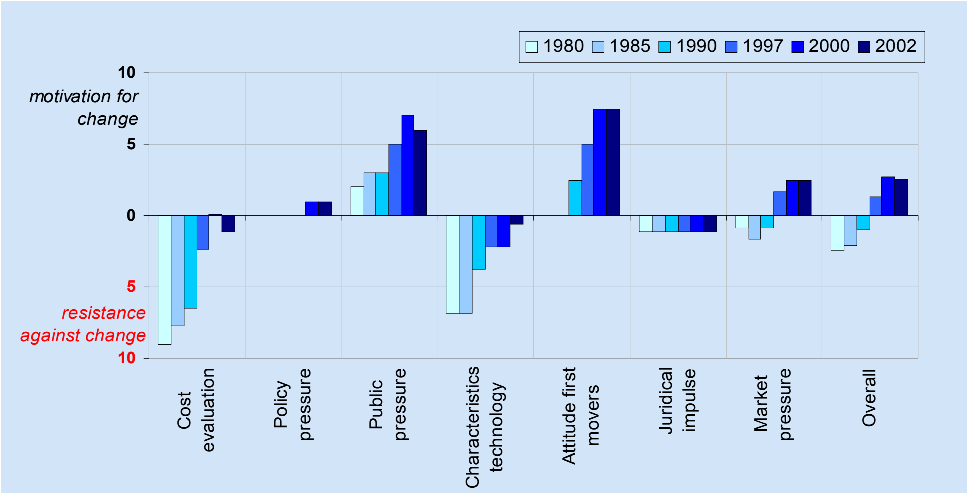
Organic agriculture shows an increasing number of farms, although their share is still small: 1.9% of the agriculture area in the Netherlands and 1.7% of the total farms. Compared with other European countries the Netherlands is average in terms of market share, a list that is topped by countries like Denmark, Austria and Switzerland (figure 6). In these countries the sale of organic products may be well over 60% in some common supermarkets. This can also be related to the much lower price added for organic products in these countries, about 20% lower than the European average. In addition, these countries usually employ a common national labelling system for organic products, which greatly increases consumer awareness.

Figure 6: Organic agriculture in Europe, by area and consumption level *(Hamm et al., 2002; Yussefi and Willer, 2003).*



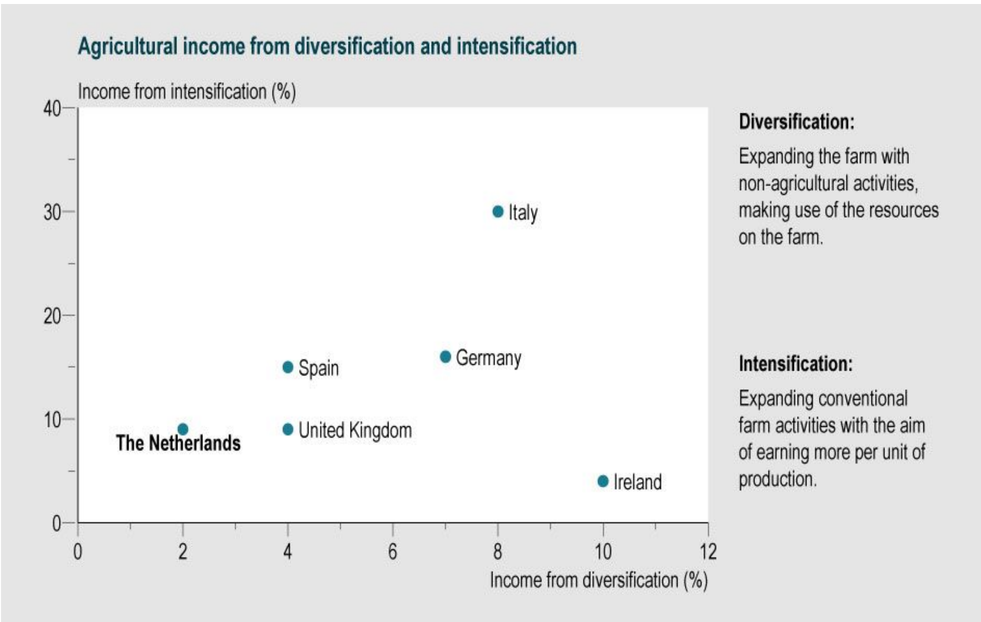
The food chain crises in Western Europe from the mid-nineties and thereafter have greatly enhanced the policy discussions and social pressure on changes in the set-up of regular agricultural practice (OECD, 2002). These crises have provided new market chances for alternative agricultural systems and opened markets for organic products, for example. On the production side of the food chain, dairy farms can be transformed to organic farms relatively easy. An analysis of driving forces on the first movers show that arguments for transformation change over time (figure 7). Main driving forces that play a role for the decisions that first movers make are: social, political and market pressure, farm economic evaluation, familiarity with the techniques, attitude of the first movers and judicial impulses. The overall (aggregate) positive force for changing to organic dairy practice arose at the time of crisis in common agricultural practice in the late nineties.

Figure 7: Driving forces on the first movers among the dairy farmers in the transformation to organic agriculture, 1980-2002.



First movers carry out many experiments on broadening and deepening their agricultural management, with some niches successfully arranged. However, compared with other European countries, the Dutch agricultural sector still realises only a relatively small income from the broadening and deepening of agricultural practice (figure 8).

Figure 8: Income from broadening and deepening of agricultural practice in EU-countries (*Source: Van der Ploeg, 2002, Edited by authors)*



5. Assessment of evaluation methodology

The evaluation of progress in system innovations is different from traditional environmental policy evaluation. The latter usually assesses from the perspective of the policy goals and analyses the efficiency of the policy for reaching those goals. The evaluation of a system evaluation takes the perspective of the process itself. Such processes usually involve some broadly described targets or future visions, much like ‘sustainability’ or ‘open markets’. In order to be able to evaluate the progress towards such broad visions, we have developed a methodology that takes the assessment of the social activity in each phase of the system innovation as a starting point.

In this chapter we have described some elements of this evaluation method, splitting the process of system innovations in six characteristic phases, or *arenas*. These all have their own specific institutional setting, as well as social and political activity. Each can be assessed with quantitative or descriptive indicators, as we have shown for two of the six arenas. The social activities should be included with the choice of indicators. By showing (progress in) the most important indicators for each arena, policy makers can come to grips with the most important processes *and* participants in each phase of the transition process.

It should be noted that the indicators as such are not indivually indicative for system innovations. What makes them specific for system innovations is the clustering in arenas, each of which describes a phase in the process of system innovation. The arena-framework itself is specific for the evaluation of system innovations, as it takes the the perspective of the different phases of such a system change as a starting point. This method involves especially the early phases of a transition, which are often excluded or left for speculation. Finally, it incorporates a multi-phase approach with multiple levels of participants, institutions and technologies in one methodology. This method could therefore be better equipped than classic methods of evaluation, especially in distinguishing the first movers, fresh initiatives and new innovations. An extension of the conceptual framework of our methodology, especially on the relationship between the developments in the different arenas and the relationship between policies and the observed developments, could provide an even more solid evaluation method.

The case study described in this chapter on two stages in the system innovation for sustainable agriculture leaves some room for the assessment of our evaluation *methodology*. However, we cannot yet claim to provide a full insight in the actual assessment of the intended transition to a sustainable agriculture in the Netherlands. This is largely still due to a lack of data, which we intend to supply in future work. We believe that this methodology can provide a framework for the analysis of these data, as shown in the assessment done here in two of the arenas.

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Middle-Range Transitions in Production-Consumption Systems: The Role of Research Programmes for Shaping Transition Processes Towards Sustainability

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Introduction

It is common knowledge today that moving towards sustainable development is a long-term process that requires major changes and adaptations in many different realms of society. The approach of transition management has been suggested as a framework to guide such long-term processes of smooth system transformation towards sustainability. In contrast to other, more technology-oriented attempts to drive socio-technical change towards sustainability, it is based on the notion of a co-evolutionary and multi-level process of change, involving technological as well as socio-economic, organisational and institutional changes.

RTD[1] programmes for sustainable development

RTD represent one of the building blocks of any long-term strategy to move towards sustainable development. As a consequence, many research programmes have been conceptualised and implemented over the past years that explicitly aim at contributing to a move towards sustainable development, both at the level of European Member States and of the EU. Several programmes even carry the explicit label of sustainability or sustainable development in their title, while others are rooted in sectoral or thematic domains where a re-orientation towards sustainable development is sought (Whitelegg/Weber, 2002; CEC, 2001).[2] However, it is still an unresolved issue how to design research programmes to enhance their impact with respect to the objective of a transition path towards sustainable development. What can they realistically achieve in the context of the national-sectoral innovation system and a national sustainability strategy? How should programmes be defined, set up, structured and implemented to ensure their orientation towards sustainability?

1 RTD = Research and Technology Development Programmes
2 Examples of thematic programmes can be found in areas such as mobility, energy and water supply, but also in production technology.

Many sectoral or thematic programmes share certain characteristics which compromise their potential to contribute to transitions to sustainable development:

- Programme definition and the role of research for sustainable development: The role of sustainable development as a policy objective to be taken into account in research and technology programmes is not always very well defined, for instance in terms of an explicit sustainability policy and strategy, from which programme objectives are derived. The potential role also depends on the wider context of the national sustainability strategy and the national innovation system.
- Intermediate layer between guiding visions and concrete projects: While there may still be widely shared agreement about the overarching objectives of sustainable development, it is very difficult to operationalise these at the level of individual thematic programmes. There may be catchy guiding concepts in place (e.g. sustainable mobility), as well as specific technologies or socio-technical projects (e.g. to reduce particle emissions from diesel engines), but an intermediate level that bridges generic visions and concrete technologies is often missing. This, however, would be a good level to define and specify tasks for research programmes.
- Operationalisation of criteria for the assessment of projects: In most cases, sustainable development represents just one of the programme objectives, next to their main objective, such as the improvement of competitiveness of industry, the stimulation of research and development in a certain technology area, etc. Moreover, in order to stimulate bottom-up initiatives the work programmes of RTD-programmes are often defined by broad categories (such as 'efficient process technologies' or 'renewable resources' in the case of the 'Factory of Tomorrow' programme in Austria). Too generic thematic categories of the programme structure tend to lead to heterogeneous, unconnected, individual projects with little integration in a transition path. In more operational terms, there is a need to assess individual projects with respect to sustainability and a transition path. At programme level this requires corresponding assessment criteria and mechanisms to be in place in order to ensure that a transition towards sustainability is seriously taken into account.
- Broadening the scope of programmes beyond technology: Many RTD-programmes aiming at sustainable development still follow a rather technology-centred path, implicitly assuming that the development of environmental technologies alone is sufficient to trigger transitions towards sustainability. Accompanying transformations at the institutional and social level (as foreseen in most sustainability strategies) are not taken into account in such programmes, although the development of new technologies cannot be separated from these changes. Without a broader perspective on socio-technical transitions it is not possible to assess the strategic relevance of technical innovations and create conditions where such innovations make a significant contribution to policy aims such as sustainability.
- Specific difficulties arise in small countries with small RTD-programmes: What difference can comparatively small programmes make with regard to objectives as broad as sustainability? Is it better to focus on a few priorities, or to promote the growth of a broad range of small-scale initiatives?

Strategic support for 'Factory of Tomorrow'

These and similar issues have also been raised in the context of the ongoing Austrian research programme "Factory of Tomorrow", where several research projects have been funded over the last years. The programme is faced with a number of specific difficulties that need to be taken into account in the design of the project. The overall funding volume is comparatively small, while production represents a very broad research domain, even when projects are clustered around a small number of sustainability principles as in the case of the programme in question. As we will argue later in this chapter, the specific conditions of RTD-programmes in general and of the Austrian 'Factory of Tomorrow' programme in particular represents a challenge for the concept of transition management in several ways and require a number of adaptations and modifications.

The project aims to explore exemplary transition paths at an intermediate level of *transition fields*, a level that is geared to the requirements to sustainability-oriented research programmes that need to bridge between highly abstract guiding visions and very concrete (technology) projects. As such, the results of the project are expected provide a *methodological* orientation and – by way of example – explore transition paths for selected *thematic* fields that are of potential relevance for the future development of the programme.In this chapter, we will first introduce the programme "Factory of Tomorrow" and some of the conceptual building blocks underlying the project approach and methodology. Apart from transition management itself, we will concentrate on the question of operationalising the approach of transition management at a level that is geared to the specificities of a research programme in the field of manufacturing. Subsequently, we will present the methodology of the project and then introduce the three candidate transition fields to which the methodology shall be applied in the course of the project. We will end with some preliminary conclusions and an outlook on what we expect the project to deliver at the end of its two-year duration.

The programme "Factory of Tomorrow"

"Factory of Tomorrow" is one of the subprogrammes of the Austrian research and technology programme "Technologies for Sustainable Development" which has been initiated and financed by the Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT).[3] The programme is intended to have an impact on the Austrian economy and innovation system and to support the structural shift towards eco-efficient management and a sustainable production system through research, technological development, demonstration and dissemination measures. Beside "Factory of Tomorrow" two more subprogrammes have been established so far: "Building of Tomorrow" and "Energy Systems of Tomorrow".

Towards a sustainable production system

With respect to sustainable development, the programme is based on a number of "guiding principles of sustainable technology design":

- Orientation towards benefit and need
- Efficient use of resources
- Use of renewable resources
- Multiple use and recycling
- Flexibility and adaptability
- Fault tolerance and risk precaution
- Securing employment, income and quality of life

For the subprogramme "Factory of Tomorrow", these guidelines have additionally been specified by defining the "Factory of Tomorrow" as a factory aiming at zero-waste and zero-emission production, producing and providing products and services of tomorrow by using materials of tomorrow to meet tomorrow's needs. Thus the

[3] www.nachhaltigwirtschaften.at

thematic priorities of the calls for projects focus on innovative development in the following fields:

- Sustainable technologies and innovations in production processes
- Use of renewable raw materials
- Products and services with consequent focus on the performance and service of the product

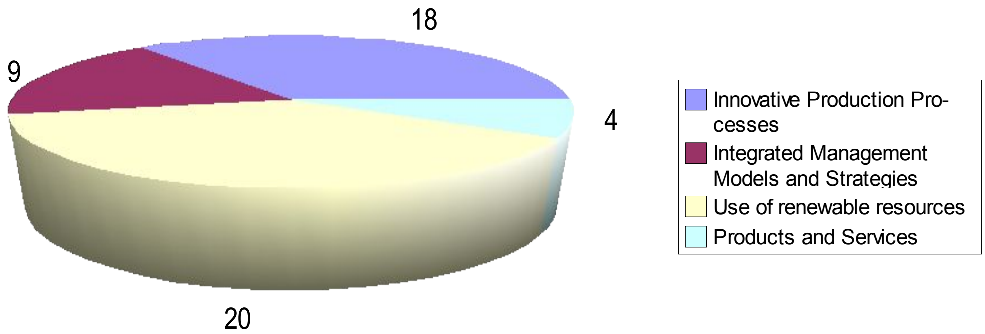
It is interesting to see, how the broader definition of sustainability as laid out in the seven guiding principles above (including social aspects, albeit in a very general way) is translated into more specific descriptions at the level of the work programme. Here one can observe a much stronger focus on technical aspects of materials and the technical organisation of production processes.

The programme "Technologies for Sustainable Development" is seen as one of several activities providing first steps to contribute to the aims of the Austrian Strategy for Sustainable Development (Federal Ministry of Agriculture, Forestry, Environment and Water Management, 2002). The subprogramme "Factory of Tomorrow" is closely related to two out of 20 key objectives of the strategy, namely *Successful Management through Eco-efficiency* and *Strengthening Sustainable Products and Services*. The Austrian Strategy for Sustainable Development aims at increasing resource efficiency by a factor of 4, while the "Factory of Tomorrow" wants to enforce "Factor 10 Technologies". Although these objectives are already challenging, other programmes or research projects on sustainability and sustainable technologies which focus on longer time horizons (e.g. Weaver et al., 2000; Partidario/Vergragt, 2002) emphasize that in the long run (20-50 years) a reduction of the environmental burden by a factor of 10 to 50 will be necessary for industrial countries.

Projects funded by the programme

Within the first two calls of "Factory of Tomorrow" (2000 and 2002) 54 projects have been funded with a total volume of about Euro 6,5 million. Apart from three accompanying measures the projects are subsumed by the programme management under the following topics:

Figure 1: Funded Projects of "Factory of Tomorrow" within the first two calls



The concept of the programme clearly states that in addition to technology development, structural and social innovations will be of great importance. In line with our earlier observation that the detailed work programme focuses on technology-oriented categories, also the funded projects tend to deal with rather specific technical issues, but also structural and management questions are addressed, especially within the project areas *Management Models and Strategies* and *Products and Services*.

A procedural aim of the programme: building networks

The Austrian programme intends to promote the development of "new partnerships", cooperations and networks within the different fields of activity. As in the first call of "Factory of Tomorrow" 71 and in the second 118 project partners (companies, institutions and organisations) have been involved in the projects, a contribution to increased cooperation can be observed at the level of the individual projects. It is however more difficult to establish links and exchange between the projects. Here again, the great heterogeneity of the domain of manufacturing compared to issues like energy systems or sustainable households comes into play. The "Factory of Tomorrow" programme is confronted with a higher diversity of groups of actors, research and policy fields. Moreover, common topics, problems or visions which provide the potential of interaction or integration are more difficult to identify. Therefore, it is much more difficult (but at the same time also very useful!) to establish a common platform and vision of the field than, for instance, in the sister programme "Buildings of Tomorrow" where a number of accompanying measures promote the interaction of the funded projects.[4]

In a way "Factory of Tomorrow" is designed with intentions which have also guided the Dutch programme *Sustainable Technology Development,* where Weaver et al., 2000, point out that policy programmes should try to shift the balance of R&D efforts of firms and technology developers toward long-term issues, focus their attention on the long-term challenge of sustainability and increase the success rate of their innovation efforts, especially by facilitating the networking process and helping network members to reach some agreement on problem definitions, visions of possible futures and expectations. However, as our short analysis of the programme structure of "Factory of Tomorrow" demonstrates, the operationalisation of long-term strategies for structural and social change (as implicated in the underlying sustainability principles) and their integration into detailed work programmes still represents a major challenge.

Managing transitions to sustainable development

The basic question of our accompanying project to the "Factory of Tomorrow" programme is, whether the concept of transition management could be of help in the process of updating and upgrading the programme and embed the projects in long-term oriented transition strategies to sustainable production-consumption systems. Before outlining our ideas to modify the transition management approach in a way that makes it more useful for the specific circumstances of the programme, let us first present some of the basic principles of transition management.

Transitions: What they are and why they are important

Over the last years the expectations with respect to the role of innovation in society have gone beyond the traditional growth objectives and now include several long-term issues which are often subsumed under the notion of sustainable development. This implies that innovation policy is increasingly required to develop capabilities that enable society to address long-term issues and challenges such as climate change, agriculture, mobility, water management, the health systems reform, etc., and to induce corresponding shifts in the technological regime that determines innovation processes.[5] Mainly originating from Dutch debates, the concept of transition manage-

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[4] For example, see the OEKOinFORM project - a platform for the exchange of information, which integrates about 60 projects concerning ecological buildings.

[5] In Kemp/Schot/Hoogma (1998) a technological regime is defined as "the whole complex of scientific knowledge, engineering practices, production process technologies, product

ment has been developed as a framework for long-term strategies in innovation policy-making with a view to long-term transitions towards sustainable development.[6] The ability to manage transitions is regarded as an additional key capability that raises specific requirements with respect to innovation policy and its governance.

Several examples of transitions are known from past history. For instance, the move from a coal-based energy supply system to a gas-based system, or from an industrial to a service economy can be interpreted as transition phenomena. Usually, transitions are long-term processes that can stretch over several decades,[7] and they are characterised by a co-evolution of institutional settings, markets, technologies, cultures, behavioural patterns and policy-making and policy. Often, individual niches are at the origin of regime shifts and further on of changes in the socio-technical landscape in the wider sense.[8] The interactions and interdependencies between these different realms give rise to irreversibilities that stabilise and reinforce the transition path.

The policy perspective: From transitions to transition management

From a policy perspective, the understanding of past transitions raises two questions, namely a) in how far can comprehensive and goal-oriented transformation processes be influenced and guided in a desirable direction at all (i.e. in the direction of sustainable development), and b) what role can and should government actually play in this process.

It is well known that the uncertainty, ambiguity and complexity of future developments prevent any attempt to plan the future in a linear fashion. Consequently, transition management is not about the central planning and realisation of future development paths but implies the conscious implementation of structures and collective processes for governing long-term transitions in a goal-oriented and adaptive manner. It is a multi-level and multi-actor learning process in society that aims to integrate the distributed intelligence[9] of the actors involved in order to improve the co-ordination and coherence of their behaviour. In particular, experimentation and bottom-up learning processes are regarded as key elements of transition management in order to maintain the adaptive capacity of an innovation system. Shared problem perceptions, common guiding visions and overarching strategies contribute to orienting the decisions of the different actors towards common goals.

Policy, and innovation policy in particular, is supposed to provide the necessary framework conditions to enable such collective learning and co-ordination to happen. This requires first of all to stimulate processes of anticipating and formulating long-term perspectives that can serve as an orientation and focusing device for the range of actors involved. Secondly, there is a need to monitor continuously the policy actions taken and to adjust them to the evolving visions of the future (see Figure 2). Moreover, conflicts of interest may emerge where government action is needed to mediate between the parties involved. Finally, given the pivotal role played by experimentation, innovation policy can support a transition process by supporting socio-technical experiments that are geared towards the societal goals striven for.

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characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures".

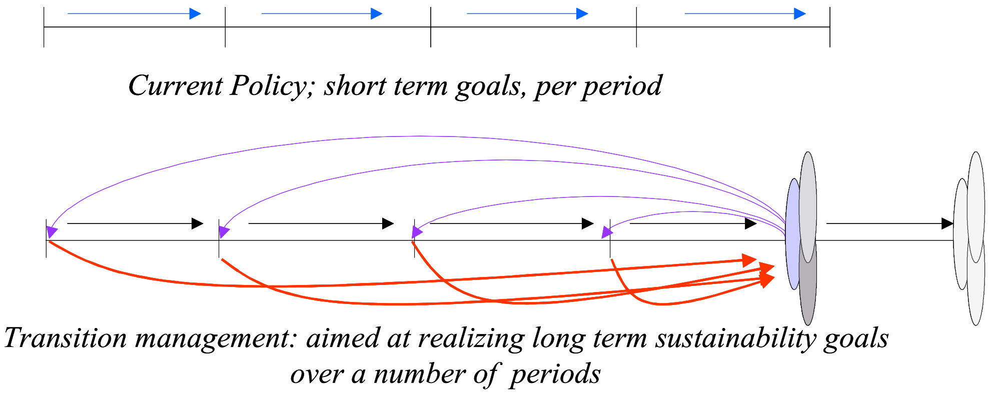
6 See Rotmans/Kemp/van Asselt (2001) and Kemp/Rotmans (2003)

7 Transition processes can thus be interpreted as comparatively smooth transformations, whereas terms like rupture, revolutions or breaks imply a rather fast and abrupt type of transformation process.

8 See for further details Geels/Kemp (2000) and for an extensive case-study Geels (2002)

9 See Kuhlmann (2001) for a detailed introduction to the concept of distributed intelligence.

Figure 2: Transition management offers a long term perspective for formulating short term policies



Three levels of transition management

The key difficulty of transition management is to ensure the link between open and collective learning and innovation processes on the one hand and the societal goals implicit in the transition concept on the other. In order to operationalise abstract goals such as sustainable development in the context of a transition management process, it is useful to differentiate three levels of action. First of all, *transition arenas* are defined on the basis of comparatively broad problem areas that reflect basic functional needs of society (e.g. energy supply, water supply, mobility, etc.). In a transition arena, government actors, knowledge institutes, businesses and NGOs/consumers interact in order to develop the visions and frameworks/paradigms necessary to guide a transition process. Below this strategic level, *innovation networks* composed of representatives from the same constituencies formulate specific transition agendas, define key projects, and mobilize and expand the network. At the level of the *testing grounds*, concrete experiments are developed, implemented and monitored in order to put the transition agendas into practice and feed the findings back to the other levels of transition management.

These three levels of transition management reflect also its main phases or elements: 1) development of long-term sustainability visions and overarching joint strategies, 2) organisation of a multi-actor network, mobilisation of actors and execution of projects and experiments, and finally 3) monitoring and evaluation as inputs to the collective learning process.

Transferring transition management to other contexts

It is still an open question in how far transition management, which has been mainly developed in the Dutch context, can actually be transferred and adapted to other countries. It is at least a matter of debate whether so-called "best practices" of policy learning in innovation and technology policy can be sensibly transferred and adapted from one country to another. Political cultures and institutional settings are recognised today as important factors determining how policy learning actually takes place and how coherent an innovation policy can actually be developed and implemented.

The challenge to adapt transition management to RTD-programmes

As outlined above, transition management is a very comprehensive approach to shaping societal transformations. It provides a number of generic building blocks for policy strategy. However, RTD programmes, such as "Factory of Tomorrow" tend to address very specific projects and technologies. One of the crucial challenges of applying transition management approaches to such RTD programmes appears to be the identification of appropriate intermediate levels of analysis (and policy!), which link broadly defined functional transition fields with specific technologies and technological research issues. For such intermediate levels useful conceptual building blocks are still lacking in the transition management discussion.

More specifically, the adaptations suggested for the use of transition management approaches to support the "Factory of Tomorrow" programme are as follows:

- *Extending the application of the transition management concept to new thematic domains, here production-consumption systems.*
  So far transition perspectives have been applied mainly to infrastructure domains, such as energy supply, water management and transport. The domain of production is more heterogeneous than these other domains and thus poses specific difficulties. We would thus like to test the usefulness of the approach to more diverse contexts such as production.
- *Building a conceptual bridge between highly general macroscopic concepts and very concrete projects in the field of the programme.*
  Some relevant research work on the domain of production-consumption systems has focused mainly on the end-user needs, but not traced the implications back to individual production processes, which may add further difficulties.
- *Assess technologies with respect to their potential contribution to a transition path/scenarios.*
  It is very difficult to assess individual projects and technologies with respect to their potential role in wider scenarios that comprise also the needs side of production-consumption systems. Is this a promising approach to guide policy and programme development?
- *Pinpoint additional transition elements for the assessed technologies*
  Within the framework of a technology research programme, projects at a rather technical level constitute the majority of the funded projects. Therefore, necessary changes of the socio-economic context, policy strategies, changes in social practices etc. to support the diffusion of sustainable technologies in case of the two examined examples of production-consumption systems will be explored.
- *Testing and assessing the transferability of the transition management concept to other socio-cultural contexts*
  Transition management as mentioned above has been developed and tested mainly in the Dutch context, but it promises to be of great use also in other countries. However, socio-cultural contexts differ, and transition management presupposes certain conditions for governance and decision-making. In this sense, the project aims to check whether transition management as a guiding framework can actually be transferred (and if necessary adapted) to the Austrian context.

Operationalising transition management for the meso-level of production-consumption systems

When trying to break down the approach of transition management to more specific domains than "the production consumption system" as such, it is necessary to specify the transition fields that shall be addressed in more detail by a research programme. As a starting point, we take the observation that production is meant to serve certain "needs". The fulfilment of these needs is ensured by systems of production and consumption, i.e. socio-technical systems that range from the provision of raw materials (including recycling) to service concepts and products for final consumption.[10] The closer you get to the needs side of this chain, the more prominent are

[10] See for instance the EU-funded project SusHouse where final needs in the realm of the household have been analysed and explored (Vergragt, 2000; Green/Vergragt, 2002).

the social practices and routines of the users for defining this stage. In earlier phases, technical design practices are an important social component, while technical considerations play an important role throughout the entire chain.

When looking at production-consumption systems in a more differentiated way, we can thus start with the delimitation of three levels of analysis:

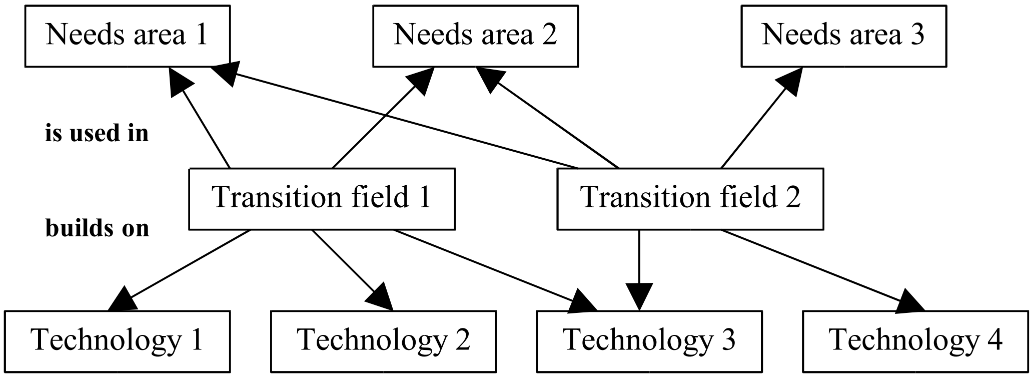
- Needs areas: Final needs of end-users or consumers can be met in different ways. By concentrating on satisfying these final needs, it is possible to overcome the conventional product orientation and think about alternative ways of meeting needs by providing the necessary services and/or products. For instance, the final need of "mobility" cannot only be met by individual car ownership, but also by means of new service approaches such as car-sharing, door-to-door mobility services, etc. Often these alternative concepts are embedded in wider "visions" or "Leitbilder" that capture both these new services and the changes in social, regulatory or organisational practices required. "Sustainable mobility", "sustainable household", "factory of the future" or "green chemistry" are examples in case, often expressed even in terms of concrete performance targets. However, these visions remain at a fairly abstract level. In general, the concept of needs areas can also be applied to other levels of a production-consumption system, i.e. also intermediate users (not only end users or consumers) can define a needs area to be addressed by a research programme.
- Transition fields: More specific than the broad-ranging needs areas, transition fields represent the areas where systemic solutions for meeting needs are developed. Transition fields are formed by technologies, actors and their objectives, and they can be interpreted as arenas, where systemic solutions for ensuring the provision of certain functionalities evolve. In other words, it is at the level of transition fields, where specific technologies are tied together with and embedded in social and organisational practices in order to offer an alternative solution for providing a functionality needed. Transition fields are thus an intermediate systemic level, at which the integration of individual technology projects into the provision of needs-oriented products and services takes place, guided by an orientation towards long-term sustainability.[11] For instance, in the case of sustainable mobility, the introduction of an intermodal and integrated mobility service is an example of a transition field. Real-time travel information could be another example, as well as on-line or mobile booking. As an example of an intermediate transition field, vehicle maintenance services could be mentioned.
- Individual technology projects: The practice of research programmes shows that the individual projects often focus on specific technologies, without particular attention to final needs or social context. In other words, they tend to be conducted in a rather isolated way and need to be integrated and adapted at the level of the transition fields. In other words, these specific technical solutions need to be contextualised at the level of transition fields in order to diffuse more widely. In principle, an individual technology can be applied in different transition fields to meet different functionalities, and correspondingly a functionality can be realised by using different individual technologies. For instance, travel information can be provided in real-time to your mobile phone using GSM, but it can also be transmitted by means of local information terminals or by phone services. Integrated

[11] In principle, transition fields can be categorised in several different ways. They can be described in terms of different functionalities they address, in terms of policy arenas or in terms of networks or industrial branches. Especially in the case of manufacturing a sectoral differentiation can be useful (at least in some cases) if this is in line with the production-consumption system under study. "Printing" is an example of a functionality that can be roughly represented by specific industry branches while "dyeing" is scattered over many industrial branches and policy arenas. Thus it should be noticed that usefully delimited transition fields can also be constructed around branches (the paper industry) or resource bases (biomass use).

intermodal services can be achieved by standardised integrated ticketing (like in urban transport "Verbünde") or by means of an electronic bidding service where prices may vary according to demand, etc. Obviously, we are particularly interested in new and innovative technologies that have the potential to contribute to a transition to sustainable development.

These three levels of analysis build on each other, thus reflecting the idea of a production-consumption chain. However, these chains should not be seen in isolation. Certain functionalities can be useful to serve different needs, just as some technologies have the potential to be applied for fulfilling different functionalities (Figure 3).

Figure 3: Three levels of analysis



An illustrative example of how transition fields can relate to visions of different needs areas on the one hand and different specific technologies on the other is given in the case of polymer coatings with special focus on the application in the automotive industry (Partidario/Vergragt, 2002). They develop long term scenarios (period up to 2050) that combine visions of new fulfilment of the function of surface protection and colouring of cars with visions of new ways of providing transport functions. Specific technological innovations in surface protection and colouring are currently under way with a scope ranging from incremental process improvements to pollution reduction at the source, improved coating fitness via a change in raw material (e.g. C to Si based resins, powder coatings, renewable materials), complete recycling opportunities and strategies to avoid surface treatment by 100% plastic or metallic cars. These technological solutions are combined with questions of integration along the supply chain and management of the product life cycle, e.g. car producers managing the whole product life cycle. As regards transport and mobility, needs visions range from business as usual with individually owned cars via multimodal transport systems, leasing and renting to public/shared transportation and the offering of transportation function instead of automotives with non-polluting alternatives. Here several technical alternatives are currently in the R&D phase that need to be combined in new organisational systems for mobility service provision.

The importance of "transition fields" as an intermediate analytical level

From the perspective of a research programme, the transition fields are clearly the most interesting level of analysis to study. It allows to bridge between needs areas and images of the future for certain fields of production and consumption on the one hand and concrete technology projects of the programme on the other hand. This bridging of need fulfilment and individual technologies makes transition fields a key concept to define and select intermediate transition fields as the core of research programmes strategies geared towards sustainability-oriented transitions.

Abstract images of the future are available for many domains as well as individual projects and technologies that are somehow related to these visions. What tends to be lacking, however, is a useful operationalisation at an intermediate level of analysis applicable to structuring a research programme, i.e. a description that is sufficiently concrete to relate easily to individual technologies, but at the same time sufficiently general to be compatible with more abstract visions of the future at the level of needs areas. Moreover, a transition field within a research programme should be defined as a sub-field of the production system that is sufficiently coherent and limited in scope to be able to operationalise a well-defined transition process. In order to reduce the complexity of the scenario development and policy process it appears to be helpful, if a transition field does not consist of too many actor constituencies and if it relates to a limited set of needs areas and technology fields. A certain homogeneity in these areas may be an important argument to select or delimit certain functionalities when demarcating a transition field addressed by a research programme.

Whereas a transition field is characterised in terms of the technologies, organisational structures and actors, the notion of "functionalities" is a particularly useful concept to explain the role played by a transition field for the other two levels of analysis. As a result of integrating specific technology projects in a social and organisational context, socio-technical innovations emerge at the level of transition fields that allow to provide functionalities in an alternative way that serve to satisfy final or intermediate needs.

Not only for analytical reasons, the level of the transition fields is of crucial importance: Their peculiarity is of special relevance for the sustainability of the whole production-consumption chain. Changes from one way to fulfil a functionality to another way sometimes can change the overall environmental effect of the need satisfaction much faster and more radical, than changes in the needs themselves (societal needs change relatively slow) or by isolated technological developments (mainly incremental changes).

Three examples of production-consumption systems

From the broad and heterogeneous domain of production-consumption systems, three specific transition fields have been selected in order to exemplify our methodological considerations. For this selection, a number of criteria were applied, partly derived from the requirements of the transition framework and partly inspired by the clusters of ongoing projects within the programme "Factory of Tomorrow":[12]

- Significant innovation potential with respect to a regime shift towards sustainability.
- Associated to the preceding point, existence of a relevant research capacity in Austria.
- Ecological relevance and connection to the guidelines of sustainable technology development of the programme.
- Existence of a significant industrial basis or potential for its emergence and clustering. This criterion serves to ensure that the area selected is of economic relevance.
- Existence of a common "technological regime" to ensure the homogeneity of the field of investigation.

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12 These criteria cannot only be used for selecting the case examples in our project but – at least in principle - also as selection criteria for project proposal in the programme.

- Existence of other, complementary forms of research funding and support in order to be able to assess the additionality of the programme "Factory of Tomorrow" with respect to other research and technology policy measures.
- Existence of a relevant number of projects in the programme "Factory of Tomorrow", if possible for different segments of the chain.
- Potential to link up with similar transition fields in Europe in order to go beyond the limited scope of the Austrian market.
- Existence of a lead actor who could at least potentially adopt and carry ahead a transition agenda.

Moreover, the two transition fields selected should concentrate on different segments of the production-consumption chain and differ in important characteristics. The areas chosen are "wood as a structural material", a transition field largely defined from a resource-based perspective and integrated within an important industrial branch in Austria, and "dyeing with renewable materials", a transition field constituted around a specific functionality but spread over several branches and needs areas. Striving to define and demarcate these transition fields which will be the basis for further scenario development processes shall also help to develop a clearer view on the characteristics a transition field should fulfil to

Transition field 1: Renewable structural materials

Within the rather broad functionality of "providing structure" one of the main sustainability principles that can be applied is the increased shift to renewable resources. Within the potential spectrum of renewable structural materials, we will especially focus on timber. This means on the level of technologies that we will focus on technologies which make use of wood to provide structural materials. At the level of need areas, timber is increasingly used as structural material for buildings (or as a function: providing shelter). We will firstly focus on applications serving these needs, while further need areas may gain relevance within the scenario process.

The choice of this specific transition field is supported by the following arguments:

- timber as structural/constructive material has been identified by the Technology Delphi Austria (ITA, 1998) to be one of 11 potential fields for technological leadership of Austria;
- wood is identified within the Austrian Strategy for Sustainable Development to be one of the renewable materials where considerable expansion possibilities exist, since only about two thirds of the annual increase of woody biomass is used and with 47% of the federal surface covered by forest, timber production has a special importance for Austria;
- there is a significant industrial and research basis in Austria for this topic and clusters have already been established (e.g. timber clusters in the provinces of Salzburg and Lower Austria);
- the Wood Composites & Chemistry Competence Centre is one of 18 Austrian Competence Centres financed within the technology structural programme K plus by the Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT);
- within the programme "Factory of Tomorrow" 6 projects relate to wood or timber (see table 1)
- Wood and wood products is also an important sector of European industry, with major application potential in a wide range of other industries (e.g. car manufacturing)

- Although the wood products industry tends to be dominated by medium-sized enterprise, cooperation with large users could be a promising model for establishing a lead actor.

Within the comparatively broad domain of wood production and use, the focus could also be put on new emerging types of technologies and functionalities, such as for instance bio-polymers where there is still a major, but unexplored potential of particular interest to a forest-rich country like Austria.

Transition field 2: Dyeing – renewable dyes

The functionality of "dyeing", meaning the colouring of fibrous materials such as textiles, paper or wood, is performed for the production of many different kinds of goods. These goods serve most different needs from the protective and social functions of clothing and home textiles to the comfort provided by textile coverings in cars.

Applying sustainability principles leads to attempts to re-establish the use of herbal dyeing substances. The aim is to substitute the common use of synthetic dyes, which contribute to the proliferation of toxic chemicals in the biosphere. Especially avoiding allergic reactions to synthetic colouring agents is a very important motivation for such efforts of substitution.

Similarly, for the surface treatment with paint and finish, bringing also colour to our lives besides protecting many product surfaces, organic substances have been used for hundreds of years, before the bulk production of synthetic coatings from mineral oil became prevalent. For the substitution of such synthetic coatings with all their ingredients (solvents, pigments and additives) changes in different production-consumption systems are needed that differ very much from the ones needed for renewable dyeing. For this reason, the two fields of transformation shall be looked at separately within this exemplary exercise.

At the level of technologies, the promoters of renewable dyes are aiming to reduce any need to change the way of application, when substituting conventional dyes with their products.

The choice of this specific transition field is supported by the following arguments:

- A study of Industriewissenschaftliches Institut on behalf of the Austrian Ministry of Agriculture, Forestry, Environment and Water Management (Industriewissenschaftliches Institut, 2001) stated the feasibility of a production of renewable dyes in Austria and promotes consolidated research activities. The report on the preparation phase of the programme "Technologies for Sustainable Development" (Katter et al., 1999) states a high potential for paint produced on a renewable basis to enter the market of printing paint. As a conclusion of an expert forum on vegetable dyes in Germany, Vetter and Biertümpfel stated in 2001, that contemporarily "in principle, nothing can get in the way of vegetable dyes being used for the colouring of textiles, leather, paper and wood. […] That the complete 'break through' has not occurred – although the production chain is complete from the producer of vegetable dyes through to the dipper, and despite of all the available applications – can be blamed only to the fact that so far no important trader of textiles has ordered naturally dyed products" (Vetter/Biertümpfel, 2001).
- Over the last seven years, a number of well established Austrian research institutions including the University of Innsbruck, the Austrian Ecology Institute and the Vienna based Universität für Bodenkultur have carried out research on wide range of issues from the selection of suitable species through to marketing aspects. They

were actively supported by the Bundesanstalt für Landtechnik Wieselburg, an agency of the Austrian department for agriculture and environment.

- The production of vegetable dyes is an attractive option for Austrian agriculture, since there exists wide experience with the production of herbs for medicinal and food applications. This is comparable in terms of high requirements of quality and comparatively small quantities.
- Research agencies and other promoters of vegetable dyes have established strong ties with some interested commercial partners. Many networks of actors concerned with the use of renewable resources in general have been established over the last years. The German Forum Färberpflanzen is regularly conveying meetings of up to 70 people concerned with the production and use of dyeing plants on a two-year basis. There exist rather mature niche markets in certain fields of application, such as hand woven carpets (Turkey) and eco-textiles (Germany).
- The EU is supporting research projects on natural dyes with up to 2,5 million Euro (Vetter/Biertümpfel 2001). Complementary activities are supported within the programme "Nachwachsende Rohstoffe" of the German government (allocating grants worth about 25 million Euro annually), including activities for market penetration.
- Within the programme "Factory of Tomorrow" two important projects relate directly to renewable dyes (see table 1). These are very interesting projects in terms of scope, aim and perspectives (strategic product development and substitution strategies with regard to different realms of society).
- Renewables dyes is a small market, also in most other European countries. However, the recent developments in Germany point to a potential for exploring a larger market. Globally, the potential is huge, at least in principle, given the size of the textile industry.
- For the moment, there is no clearly identifiable potential lead actor in Austria. There are nevertheless a number of firms that could take a lead role if adopting renewable dyes for their products.

Transition field 3: Biorefinery

A broad range functionalities can be provided by means of products from biorefineries, addressing an equally broad range of needs areas. Examples are proteine-rich components for animal feedstock, lactic acid, certain types of fibres, etc,. The underlying technologies use chemical and biochemical processes to produce a variety of products from different types of biomass (oil seeds, sugar beet, cane sugar, wood, grass, etc.).

In terms of sustainability, the main benefit of biorefineries consists of a reduction in the use of petrochemicals, entailing often the production of toxic by-products. In order to have a noteworthy effect, however, biorefinery should not be restricted to fine chemical products only, but be used also for bulk products.

The arguments for considering this transition field can be described as follows:

- Biorefineries offer the potential to produce flexibly mass products for large markets, even if production volumes are today still rather limited. Changing to biorefineries would have major impacts on the entire resource supply chain (e.g. agriculture) as well as competing non-renewable chemical production systems. The potential for system innovations and a regime shift is therefore very high.
- Biorefineries are still in an early phase of the their technological life-cycle; first pilot plants are currently being implemented and tested in order to learn more about the potential for upscaling and economic feasibility.
- In terms of ecological impacts, a positive net effect is usually expected, but as long as there are no concrete (pilot) plants in operation, it is hard to make any definitive judgements. As shown in recent study, green biorefineries can have a number of

positive impacts with respect to transport, the use of fossil resources, regional embedding and adaptation, and regional income and quality of life (Schidler 2003). However, large-scale biorefineries could also have adverse effects on local and regional agriculture.

- In economic terms, green biorefineries look quite promising already, even if the details depend on a number of framework conditions (e.g. benefits from heat and power exports) and on the market perspectives for the biorefineries' products.
- For the moment, the transition field is still quite homogeneous due to the fact that there are only a few research projects under way and a small number of plants in operation. The main actors in Austria are already cooperating at regional level, but there is still a need to establish a network at national level, involving in particular also additional actors from agricultural and structural policy..
- Apart from the projects conducted in the context of the programme „Factory of Tomorrow", research on biorefineries is also conducted at the University of Natural Resources and Applied Life Sciences in Vienna. However, overall, research capacity in Austria is very limited.
- Three main technological trajectories for biorefineries can be distinguished.
  - LCF-biorefineries (Lignocellulose Feedstock Biorefinery)
  - Cereal and corn biorefineries
  - Green Biorefineries, using humid biomass such as grass, lucerne, etc.
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- Green Biorefineries, using humid biomass such as grass, lucerne, etc.
- Biorefineries are an issue in several other countries of the EU, notably those with an important chemical industry and/or agricultural sector. Also the EU is considering biorefineries and bioenergy in particular as important future technologies.
- For the moment it is still hard to identify a potential lead actor given the early stage of development of the field. However, some of the industrial actors involved in the ongoing projects of the programme "Factory of Tomorrow" could in principle take on such a role,

Overall, biorefineries are a transition field in an early phase of development, but with good promises for the future.

The next steps within the project will be a more detailed analysis of the present situation with respect to the three transition domains in order to select two for which a transition scenario development process will be launched, as described in the following chapter.

Table 1: Overview of projects in "Factory of Tomorrow" related to the chosen transition fields

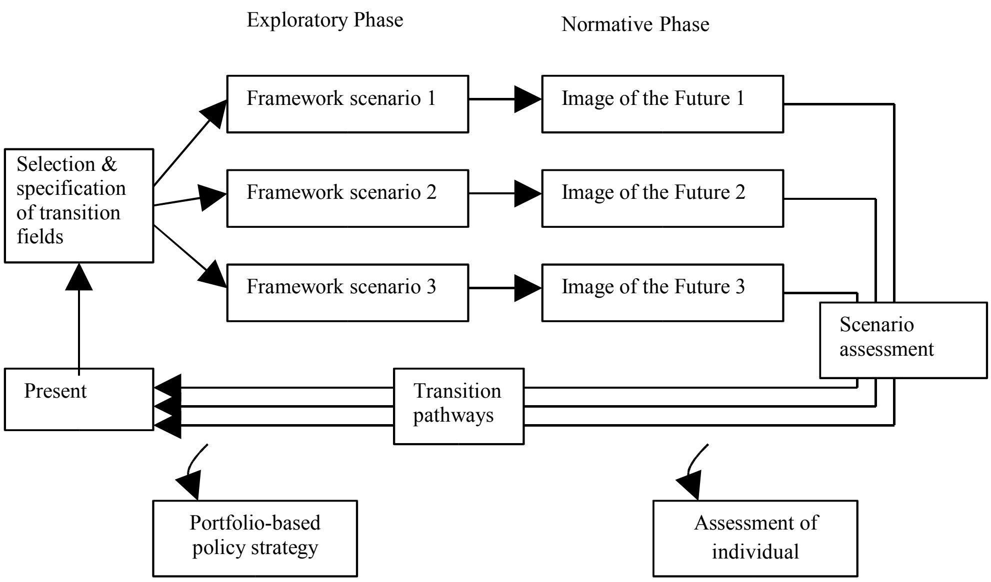
Functionality	Project Title	Synopsis
wood based structural material	Wood-processing employing a s uperimposition of ultrasonic vibrations	Development of wood-processing techniques employing high-frequency ultrasonic vibrations in terms of applications in the woodworking industry.
wood based structural material	Characterisation of material parameters as basis for innovative processing methods and products made of large dimensioned wood aiming at economically sustainable use of Austrian timber resources	Facing the problem of decreasing demand for large dimensioned timber, investigations are carried out concerning certain properties like strength and fibre characteristics. Due to the data it is possible to create a model about the variability of special properties of a stem.
wood based structural material	Sustainable outdoor use of larch wood through classification of durability by means of innovative measurement methods	In this project the utilisation of untreated larch wood is promoted by means of innovative measuring-technologies. Optic-spectroscopic measurements are linked to extractive contents and mass-decay, in order to predict the "natural durability".
wood based structural material	Wood Plastic Composites – adding value by splints	Systematic investigation of a new family of materials, which are produced of waste products of timber industry and combined with thermoplastic polymers (polyolefines, 5-40%). This materials provide characteristics similar to timber but can be manufactured by technologies of plastics industry.
wood based structural material	Wood Plastic Composite - Direct extrusion	In wood plastic composite extrusion, wood is typically palletised, compounded or agglomerated. In this project a new feeding dosing equipment is being developed to allow direct use of wood fibres, chips or powder, even combined with polymer pellets.
wood based structural material	Wood Plastic Composites - Development of an extrusion tool	Development of a new generation extrusion tool for a wood plastic composite. This material will be developed in a second project an should show a fibre content of 60 – 85%.
Dyeing	TRADEMARK $^{\text{Farb\&Stoff}}$ From an idea to a trade product ready for marketing: Plant dyes for the textile industry.	TradeMark Farb&Stoff is about making the next and, indeed, crucial step: developing marketable plant dyes for the textile industry. In the efforts to establish a resource-efficient and economically interesting product line, residual plant material from the lumber- and food processing industries is mainly used.
Dyeing	COLOURS & TIES	New cooperations between agriculture und industry are necessary to ensure the utilization of renewable materials. The project focus is upon natural dyes and their application in textile industry. The goal of the project is to create a contact institution which connects various suppliers of diverse plant materials, takes on the processing, and standardising of the natural dyes, and makes a product that can be used by the industry.
Biorefinery	Development of foamed products based on proteins	Goal of the project is the development of a new foamed product based on by-products and waste products rich in protein. Possible applications are mounting parts for thermal insulation for building materials, parts of furniture, motor vehicle interiors and bulk good.
Biorefinery	Green Biorefinery – separation of valuable substances from grass silage juice	Juice from pressed silage grass has a high content of lactate and free amino acids. The goal of this project is to develop a technology for the separation of these valuable products.
Biorefinery	Green Biorefinery - Primary Processing and Utilization of Fibres from Green Biomass	Tests on optimisation of the essential process unit mechanical fractionation of the primary raw material "green biomass" into a liquid and a solid – fibres containing – fraction. Furthermore, lab and pilot scale tests with respect to technologies and processes for primary processing of the solid fraction (e.g. technologies for obtaining specified well defined fibre fractions, reduction of odour etc.). Finally, lab and pilot scale tests regarding manufacturing of prototype fibre products (fibreboards and adhesives & fillers for the construction sector) based on specific well defined fibre fractions from green biomass as primary raw material.

The scenario methodology

One of the main objectives of the project is to explore future trajectories of transition fields and associated needs areas in order to assess the potential role to be played by the technologies funded by the "Factory of Tomorrow" programme and to suggest possible fields for future research. For that purpose, it is first of all necessary to develop scenarios of future transition paths that capture the levels of needs areas and functionalities.

In principle, the transition management perspective lends itself to a normative approach to scenario-building, where, based on a single desirable scenario, a backcasting methodology is applied to identify a promising future pathway at the levels of needs areas, transition fields and technologies. However, while such an approach may serve as a useful orientation and guidance with respect to the direction of change that ought to be taken, it neglects the fact that the future is inherently open. A future development path, even the most desirable one, is contingent on many other factors that are outside the influence of, for instance, a small country like Austria. A fully exploratory approach would not be appropriate, either, because it is not amenable to an assessment in terms of sustainability. These considerations show that a simple and straightforward application of a normative or an exploratory scenario-building methodology would not be appropriate in our case. What is needed is instead a combined approach, allowing to take into account bottom-up exploratory elements (for instance new technology options, external driving forces) with top-down normative features implied by the sustainability-orientation of the images of the future drawn.

Figure 4: Schematic overview of the project methodology



Moreover, the project itself has a limited scope and volume. It can therefore not address all the research fields covered by the programme "Factory of Tomorrow" but has to focus on a subset of interesting and relevant transition fields. The lessons learnt from these selected fields shall nevertheless be instructive for defining research themes at programme level in the future. It should thus shed some light on the overall perspectives for the programme.

Figure 4 gives an overview of the methodology developed for the project. We suggest to apply a combined exploratory and normative approach. The initial phase serves to identify, specify and select two transition fields to be subject to the scenario development process. At this stage, also the most relevant needs areas related to these transition fields will be analysed. Then the actual scenario development process will be started, aiming to develop first a set of different possible framework scenarios at the level of needs areas. This step will follow an exploratory method. It is not unlikely to assume that this will deliver a set of framework scenarios that will differ in terms of their overall sustainability orientation. This is regarded as a very useful outcome from a policy perspective, because it allows to discuss further on how to move towards sustainability even under detrimental conditions. In fact, in view of a generalised economic slowdown it is not unlikely that the wider framework conditions for manufacturing will be geared towards other objectives than sustainability. Each of these framework scenarios will serve as a starting point for specifying at the level of transition fields the most desirable outcome possible, i.e. "best-case" images of the future for the transition fields under the conditions of the different framework scenarios.[13] These best-case images can then be characterised in terms of sustainability.[14] These most desirable, but nevertheless contingent future images then serve as a normative starting point for studying possible pathways leading to these images. Here, particular emphasis will be put on barriers, systemic effects and critical events needed to realise such a pathway. Individual projects and technologies can then be assessed with respect to their likely contribution to the different transition pathways. As a result, we get a set of possible and desirable scenarios/images together with the corresponding pathways at the level of transition fields and functionalities. They provide the foundation for a portfolio-based approach to policy-making (i.e. for foundation for developing robust and adaptive policy options that allow to deal reasonably well with different possible futures).

In practice, the methodology can be described in six steps as specified below. It will be implemented in the course of a series of workshops with participants from relevant projects of the research programme and external experts and stakeholders. In addition to the initial selection and specification workshop, three workshops are foreseen for each of the two transition fields, complemented and prepared by desk research and synthesis work using secondary sources and the results of the workshops.

1. Definition, specification and selection of transition fields: It is essential to have a clear understanding of the transition fields and how they can be systematically represented in terms of the three levels of analysis suggested above. In particular, the needs areas that are related to a transition field need to be identified.
2. Development of framework scenarios at the level of needs areas: Based on first sketches of potential framework scenarios, a workshop will be organised to further explore, modify, elaborate and refine them. These framework scenarios will be strongly based on social, economic and political "driving forces", but will also take general technological orientations in society into account. Obviously, particular emphasis will be put on user- and needs-sided aspects.
3. Development of "best possible" images of the future at the level of transition fields: The framework scenarios are based on an exploratory scenario approach, and are subsequently used as a frame for specifying "best possible" images of the future at the level of transition fields. The main difficulty is to integrate the

[13] It is still open for discussion whether we should go for several or just for one normative scenario. However, even if we develop several, there will be a best one that could serve as a basis for the transition analogy.

[14] The assessment can be conducted along the lines of one of the different approaches for sustainability assessment, for instance the approach of the Helmholtz-Society project on Sustainability "Global zukunftsfähige Entwicklung – Perspektiven für Deutschland" (Coenen/Grunwald, 2003; Grunwald et al., 2001)

framework scenarios for different needs areas into the specification of the images of the future of a transition field.

4. Assessment of the images of the futures: In terms of a predefined set of criteria, the images of the future will be characterised with respect to sustainability. This will not be an in-depth evaluation (which would go beyond the scope of the project), but it should deliver a rough assessment of the desirability of each of the images, differentiated according to key sustainability dimensions. What is particularly interesting from a transition perspective is the question in how far a scenario/image implies a potential for a major shift towards sustainability (i.e. a "regime shift").
5. Analysing transition pathways: A key question of any scenario analysis is: How do we get there? What are the requirements and systemic implications the scenario (or here better images of the future) would raise? At this stage, barriers to diffusion of new technologies will be analysed as well as missing links or elements to ensure the realisation of the pathway. This stage will have to build very strongly on inputs from the workshops.
6. Policy analysis: As part of the final stage, the role of individual technology projects with respect to the transition pathways can be assessed. Probably even more interesting will be a look at the implications of the project results for the design of research programme and policy portfolios to support a transition process. This will be the topic of a final workshop.

Conclusions

The methodology suggested builds a conceptual bridge between highly general guiding visions and very concrete projects of a research programmes. It thus allows to contextualise the projects of the research programme "Factory of the Tomorrow" under the conditions of a set of a longer-term transition perspectives. Moreover, the transition fields can be studied with respect to the potential influence of different driving forces, framework conditions and systemic effects. Two transition fields are selected to test the applicability and usefulness of the approach..

The scenario process is expected to stimulate debates about long-term perspectives for the transition fields under study. They serve as an orientation and thus as a focusing device for the strategies of the actors involved. From a policy perspective, the project is expected to result in a number of benefits, also beyond the level of an individual research programme:

- Analysing and assessing transition fields offers the opportunity to identify promising future themes for research programmes. Moreover, research themes would not only be selected on the basis of technological considerations or very general sustainability strategies (renewable materials, efficiency, etc.), but also in terms of their possible impact on transitions to a more sustainable production system.
- Transition scenarios will help identify critical socio-technical barriers and effects not yet addressed and understood by current research and thus point to new inroads for future policy.
- In principle, transition scenarios provide an orientation for staged research strategies towards sustainability, ranging from a broad range of exploratory and more ground-laying research projects to applied research pilot actions.
- Other policy areas than RTD policy often play a crucial role for the success of a technology and the evolution of a transition field. The transition perspective allows to define overarching transition strategies for the fields analysed and identify complementary .policy measures needed to enable and strengthen a transition path.

- By developing different scenarios that combine exploratory and normative elements, it is possible to underpin the formulation of robust and adaptive policy strategies, i.e. of strategies that are geared towards the objective of sustainable development, but at the same time allow to get prepared for different uncertain futures.
- The scenario building process also serves as a forum to enable interaction between the different projects of the programme (at least those related to similar transition fields) and other actors external to the programme. The process should thus facilitate networking of the programme participants and second-order learning effects by giving them an opportunity to reflect on the contribution and conditions required for success of their projects. These networking and learning processes should also lead to a better alignment of related projects and actor strategies.

In general the broader perspective provided by the transition scenarios of our project is expected to open up new perspectives for the process and the content of a next generation of the "Factory of Tomorrow" programme, based on the objective of initiating transition processes towards sustainable development. Nevertheless, at the present stage only a limited number of transition fields is dealt with in our accompanying project. It would be desirable for the further proceeding of the programme that the results of the example scenario development processes are convincing enough to trigger similar processes for other fields. As a first step this would require to draw up a more comprehensive list of transition fields covering most of the production sector. These transition fields could then be assessed according to the criteria presented above (potential contribution of the area to sustainability; relevance for the Austrian innovation system, etc.) in order to have consolidated basis for including the ones with the biggest potential impact on sustainable production as priority fields into future work programmes. Due to their socio- technical character, these transition fields could help overcome a too technical orientation in many research programmes aiming at sustainable development. With such a programme design, the consideration of integrated transition strategies would become an elements of RTD programmes and create closer links between technical development, social and organisational changes, and policy making for sustainability.

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Industrial Transformation Between Ecological Modernisation and Structural Change

Martin Jänicke

Ecological Modernisation and its economic-technical and political potential

"Ecological modernisation" describes the wide spectrum of possible environmental improvements that can be achieved through technical innovations beyond end-of-pipe approaches (Jänicke 1985, 2000, Hajer 1995, Mol/Sonnenfeld 2000, Young 2000, Mol 2001). An environmental problem, for which we have a marketable technical solution, normally creates less political difficulty than one that requires "negative", restrictive intervention in the established production, consumption, or transport structures. The concept of ecological modernisation opens up both economic and political opportunities.

If the innovation is only incremental and its diffusion restricted to niche markets, the potential of a new technology to bring about environmental improvements is not fully exploited. Therefore, ecological modernisation as a political strategy essentially needs to aim at radical innovations with a maximum of market penetration. Given the global dimension of most environmental problems, a far-reaching penetration of the world market is required to realize the full environmental potential of the new technology.

Innovations in environment-friendly technologies increasingly tend to stand out by virtue of the following characteristics:

1. Environment-related innovation and diffusion processes are to a large degree politically determined (Porter/van der Linde, 1995; Wallace, 1995; Hemmelskamp et al. 2000, Jänicke/Jacob 2004). Due to market failure, they need political or at least societal support. Government therefore plays a role in environmental innovations that goes far beyond its role in R&D policy. Markets for environmental innovations are usually government-regulated or government-supported markets. In this context, NGOs such as Greenpeace can also play a market-creating role (e.g. the CFC-free refrigerator or the 3-liters-per-100-kilometers car).
2. Innovations in environment-friendly technology are a strong basis for environmental policy, by providing potential win-win solutionsn and hence open up new opportunities for action.

3. Environmental innovations are highly problem-related, which generally reduces the long-term uncertainty of predicting potential demand conditions (as normally encountered with "normal" consumer preferences). Given the increase in the world's population and industrial production and the decrease of the global environment's capacity to absorb the effects, the demand for environmental efficiency is likely to grow, thereby providing innovators with incentives to invest in environmental technologies.
4. Environmental problems have a world-wide dimension. Environment-friendly technologies, therefore, refer to "future global needs" (Beise, 1999: 3), which are very important for the creation of lead markets and represent a specific potential for international diffusion. That is why environment-friendly technologies have a good chance of meeting worldwide demand on global markets.
5. Contrary to fears of a competitive "race to the bottom" (Drezner 2001, Volgel 2001, Eliste / Fredricksson 1998), the environmental issue has to a certain degree become a dimension of the process of technological innovation in general. It has also become important in the competition for innovation between the highly developed countries (Jänicke/Jacob 2004). This is in conformity with the high correlation between an ambitious environmental policy and economic competitiveness (World Economic Forum, 2000). The causal relationship between the two is open to questions. But there seems to be a third explaining variable: GNP per capita. High national income means both, high *perceived* environmental pressure and high capacity to solve environmental problems. The combination of environmental pressure and capacity seems to be the crucial basis for environmental innovations and their early adoption in highly developed countries.

These findings explain why e. g. Porter/van der Linde have come to the conclusion, that "(h)ow an industry responds to environmental problems may, in fact, be a leading indicator of its overall competitiveness..." (Porter/van der Linde 1995). Many highly developed countries have formulated their strategy for sustainable developments in terms of a policy for innovation. The German red-green government, for example, which is in power since 1998, has explicitly adopted a program of "ecological modernisation".

Sectoral Environmental Strategies for "Dirty Industries"

The crucial task of environmentally sustainable development is to change policy sectors in *co-operation* with "their" economic clientele. Therefore, we should turn to sectoral strategies for polluting branches ("dirty industries"). There are basically two options for such strategies (beyond end-of-pipe treatment):

- Ecological modernisation of the sector in the sense of technological innovation (e. g. Japanese Steel industry or the Swedish paper industry)
- Inter-sectoral structural change, i. e. the reduction or even phasing-out of an environmental intensive industry (e. g. coal mining). Structural change may also may be understood as intra-sectoral change, if the discussion is about sectors that encompass a broad number of products and process technologies (e. g. change of modal split in the transport sector, change of energy mix in the energy sector, or increased organic farming in agriculture).

Ecological modernisation may not be no a sufficient solution where (a) the inherent logic of certain economic sectors or branches is responsible for the intensive use of environmental resources and (b) adequate technological solutions are not available.

In this case, structural solutions, i. e. the relative or absolute reduction of a product or process, may be indispensable.

To illustrate my argument, I come back to the case of Germany using two different examples: one for structural change (the planned phasing out of nuclear energy) and one for structural rigidity (the structural persistence of lignite coal mining).

Phasing out nuclear energy

Nuclear energy is an industry which – regarding production, transportation and the final deposition of waste – causes heavy risks for health and the environment. Except some incremental technological risk reductions, an adequate technical solution is so far not available. Therefore, "structural" solutions have been proposed, especially since the Chernobyl accident. In 2002, the German "Atom Energy Law" was amended to phase-out nuclear energy (1/3 of the power production) until 2020 (Mez / Piening 2002).The policy was based on "consensus" which – however - was not completely voluntary (stick behind the door, increased liability costs, forced intermediate storage installations). The first shut down has just taken place in Stade in 2003. The consensus with the power industry may not survive the present red-green government. The German case is however not completely exotic, since other European countries have also turned away from atomic energy. In the OECD countries, the nuclear capacity will be – at least up to 2010 – lower than today (OECD/NEA 2003). Up to 2010, there is only one nuclear power station proposed for construction in the EU (Finland). Even France – traditionally the main proponent of nuclear energy in the EU - has announced its plans to create 7 Gas power stations and support another 7 wind parks and other kinds of renewables, while refraining from the creation of new nuclear power stations (PLATTS 2004). In other words, the structural solution to the nuclear risk in Germany was party due to favourable framework conditions (costs, liberalisation, public opinion), but can also be understood as a purposeful strategy of eco-restructuring. The German phase-out policy has had a positive side-effect on innovations: The role of renewables as substitutes for nuclear power was radically improved. In this case, structural change was a good pre-condition for innovation and ecological modernisation.

The structural persistence of the German (lignite) coal industry

The German coal-based power industry (RWE, Vattenfal) provides the opposite example. As long as the elimination of CO_2 is no technological option (at least up to 2020), there is a fundamental contradiction between climate protection and power production based of the CO_2-intensive lignite coal. Due to the stability (in the West) and even the revival of the lignite coal sector (in the East of Germany), the CO_2 emissions of the power industry have increased by 6,4 % since 1999. This was in obvious contradiction with the ambitious climate protection policy of the German government. Without this increase, the CO_2 reduction would have reached a remarkable 18 % until 2002, while the actual reduction was only around 15,4%. Moreover, in 2004 the national implementation of EU-emission trading directive was opposed by a massive, well-organised campaign of the coal and power industry, which included demonstrations of workers and mobilisation of the media. The coal and power industry did not even hesitate to revoke a voluntary agreement on CO_2 reduction (45 Mio t. 1998 – 2010) signed only in 2003 by the leading industrial organisation and the government. Furthermore, the highly incompetitive German hard coal will be happy to receive some 16 billion € until to 2012. The powerful coal and power industry – a stronghold of the trade union - and their supporters in some federal states were also able to prevent the expansion of CHP and of modern gas power stations. In general, they were able to undermine the credibility of the established climate policy and the pioneer role of Germany. In this case, the structural rigidity of a powerful environment-intensive industry clearly caused restrictions for ecological modernisation in other parts of the economy. The German case is highly illustrative for the present restrictions to climate policy throughout the world (taken countries like the US or Australia). Here, we clearly face a "structural problem" that cannot be solved only by means of ecological modernisation. The solution can only be found in a sectoral strategy beyond mere technological improvements. The political difficulty of this undertaking has been demonstrated.

Limits of Ecological Modernisation

The German case illustrates that environmental innovations do not necessarily lead to structural change. Structural rigidities can even prevent innovation or at least their diffusion; this could already be learned from the work of Schumpeter. Without overcoming the structural resistance of traditional environment-intensive branches, environmental innovations often remain within niche markets.

Sectoral strategies of eco-restructuring are not least relevant where ecological modernization reaches its limits. Ecological modernisation, as mentioned, relates to technical, system-compliant solutions to environmental problems (Jänicke 2000). The potential of this technological approach is remarkable - the present energy consumption of the world could be supplied by renewable energies. But potentially marketable technological solutions to environmental problems are not always available. The so far unsolved "persistent environmental problems" - namely climate change, but also land consumption, bio-diversity, threatened species and soil erosion as well as final storage for nuclear waste – illustrate these limits.

On top of this comes the fact that incremental increases in ecological efficiency are still no causal, sustained solution. They are easily wiped out by subsequent growth processes (e.g. specific emission reductions subsequently neutralised by increasing road traffic). These facts were recognized as early as the late 1970s as the "dilemma of the N curve" (Jänicke, 1979: 111). This up-down-up curve can be observed, when a problem has to be addressed in the context of growth imperatives and is treated not as a cause but as a symptom. This dilemma does not only apply to "clean-up" environmental protection (end-of-pipe treatment) but even to efficiency improvements. For example between 1973 and 1985, Japanese industries succeeded in saving energy and raw materials in a remarkable way, but the high industrial growth simply cancelled the positive effects.

Ecological modernisation therefore is, despite its impressive potential, not sufficient to ensure long-term environmental stabilisation. This is not only due to its inability to cope with all environmental problems, but also to a double "hare-and-hedgehog dilemma" of ecological modernisation. Firstly, we have the afore-mentioned race between incremental environmental relief and economic growth, and secondly ecological modernisation is confronted with structural limits imposed by "modernisation losers": If industries and private households save energy, cut their consumption of valuable raw materials, or use environmentally less intensive substitutes, all this will cause losses in the affected (supplying) industrial sectors e. g. mining, raw materials industry, power generation. However, these old industries, with established structures of power and influence, nonetheless often succeed in opening up new sales possibilities. For example, the power sector finds new uses for electricity, which in turn neutralize the above-mentioned efforts to save energy. Similarly, the successful environmental protection campaigns against using chlorine have since been counterbalanced by the expansion of chlorine uses in other areas. As long as environmentally intensive sectors try to counteract ecologically desirable decreases in its production, we must go on reckoning with an environmental "N" curve. Ecological modernisation is thus severely hampered by the absence of genuine restructuring and by evasive behaviour on the part of the modernisation losers. Their reaction is of course all too understandable – as long as the adversely affected industries and regions have no alternative perspectives and change takes place in ways that are not economically and socially acceptable.

This is why the distinction between the system-compliant and very often successful path of ecological modernisation and the much more difficult, so far often unsuccessful, but indispensable path of ecological restructuring is necessary. Problem-solving in the form of ecological restructuring affects systems of behaviour which – irrespective of technical eco-efficiency improvements – stand out by their high environmental intensity. The distinguishing feature in most structural solutions is that they involve no marketable technologies and thus cannot use the inherent logic of the economic system as their driving force. Rather they rely on political-social mechanisms and capacities being set up over a long time, which require a different and disproportionately greater effort.

Green Industrial Policy as a Sectoral Strategy

Strategically, ecological industrial policy is above all to foster industrial restructuring by means that make it socially and economically acceptable (Binder/Petschow/Jänicke 2000). A strategy of eco-restructuring can promote diversification in other product types. The diversification even from heavy industry to tourism (as in the case of the Preussag AG) has proved to be possible. Industrial policy can also support reductions in production capacity where these are economically acceptable. It can also provide social cushioning, retraining as well as conversion and reorganisation assistance. The change is optimal if investment cycles are used for the transition to environmentally more applied products or processes. It makes a fundamental cost difference whether the transition follows this normal path of change or whether it is caused by sudden political interventions demanded by an alarmed public. Of course, industrial policy could also use alarming events as policy windows (whether anomalies, accidents, illnesses) if restrictions cannot be overcome otherwise. The best way would be to use this option as an argument during "negotiations in the shadow of hierarchy" (Scharpf 1991). A more general approach to achieve environmentally friendly structural change could be the reduction of environmentally harmful subsidies. As the OECD has shown, "the economic sectors with the largest share of global subsidies – agriculture / fisheries, transport, and energy, which account for 81 % of world's subsidies – are also those most responsible for greenhouse gas emissions, air pollution, and water pollution" (OECD-Observer 238, 2003, 39). Experience shows that even reduction of environmentally harmful subsidies requires intensive stakeholder dialogues. Structural change through industrial policy can be recommended especially in those sectors that face both ecological and economic crisis.

Box 1: Sectoral Strategies for Environment-intensive Industries

- Sectoral strategies based on environmental policy integration within government: Political leadership defining the role of the "responsible" policy sectors
- Sectoral dialogues about long-term perspectives on a broadened basis
- "Negotiation in the shadow of hierarchy" providing alternative regulatory options to negotiations
- Scientific input I: The contribution of the sector to long-term environmental problems
- Scientific input II: Long-term economic problems potentially caused by critical environmental events (e. g. Chernobyl, BSE, weather anomalies)
- Scientific input III: Alternatives, best practice (diversification, successful change management)
- Long-term investment perspective (investment cycle)
- Compensation of negative social effects of structural change (be "creative" but prevent *destruction*!)
- Change Management: Consensus conferences, network management, reporting.

The Dutch concept of "transition management" is of special interest in this context. According to Kemp and Loorbach, "transition management for sustainable development consists of deliberate attempts to work toward social, economic, and ecological objectives in a gradual, forward-looking manner in full recognition of system dynamics and windows of opportunity to effect change. Transition management is concerned with the normative orientation of socio-economic processes and seeks to overcome the conflict between long-term imperatives and short-term concerns" (Kemp/Loorbach 2003, 22).

It seems that the most important step in transition management is the common participative dialogue of sectoral stakeholders on long-term ecological risks, which at the same time cause economic risks. The confrontation of the respective sector or branch with science-based critical information about its future may be crucial. The German coal based power industry e. g. could be confronted with questions of its long-term competitiveness taken into account the probability of dramatic climate events and global pressure from countries suffering from increased poverty caused by climate change. This dialogue strategy can only be successful if stakeholders are participants of an institutionalised, well-managed, iterative process of consensus building about problems, long-term objectives and short-term steps (Joss 2000).

As mentioned before, this is no easy undertaking compared with ecological modernisation. But industrial transformation for sustainable development will often only succeed if it is "walking on two legs". In many cases, this transition does not seem "sustainable" without structural solutions in the sense of "creative destruction" (Schumpeter). But fear of destruction may at the same time be the most important obstacle to structural change. Governance of structural change should therefore be "creative", but not "destructive".

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Section C: Sustainable Business

Transforming the Energy Sector: The Evolution of Technological Systems in Renewable Energy Technology[1]

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1. Introduction

Fossil fuels are the dominant source of energy in the world, contributing about 80 per cent (91,000 TWh)[2] of the total primary energy supply and 64 per cent (9,400 TWh) of the electricity generation in 1999. This dominance is associated with clear environmental and climate challenges. A wider use of renewable energy technology is seen as one way of meeting these challenges. For instance, the European Union aims at increasing the share of renewable energy of the supply of electricity from about 14 per cent in 1997 to 22 per cent by 2010 (Lauber, 2002). To obtain, and go beyond this share, a range of renewable energy technologies need to be diffused.

Large-scale hydropower and combustion of different types of biomass currently provide the bulk of the energy supplied by renewable energy sources. In 1999, these supplied roughly 2,600 TWh and 12,600 TWh (160 TWh of electricity (UNDP, 2000))[3] of primary energy respectively (IEA, 2001). In addition to these, the 'new' renewables - wind turbines, solar cells and solar collectors - are now diffusing at a quite rapid rate (see Table 1.1).

[1] This chapter provides a synthesis of work undertaken within the framework of the project "Shaping and exploiting technological opportunities – the case of the Swedish capital goods industry's venture into renewable energy technology". The Swedish Energy Authority kindly financed our work, which was undertaken under the auspices of IMIT. Funding was also received from Gothenburg Energy Ltd. Research Foundation for one of our case studies. The study would have been impossible to undertake without this support and without the time generously given to us by a large number of people in Swedish, German and Dutch firms, research institutes and other organisations. We are also grateful to Jan Finn, Volkmar Lauber, Ole Jess Olsen and Adrian Smith for useful comments on an earlier draft.

[2] 1 watt hour (Wh) equals the energy supplied in one hour by an device with the power capacity 1 watt (W). 1 kilo watt hour (kWh) = 10^3 Wh. 1 mega watt hour (MWh) = 10^6 Wh. 1 giga watt hour (GWh) = 10^9 Wh. 1 tera watt hour (TWh) = 10^{12} Wh.

[3] This data is for 1998.

In the 1990s, the global stock of wind turbines increased by an average of 27 per cent per annum, leading to an electricity supply of about 56 TWh in 2001. The stock of solar cells grew by 22 per cent per annum in the same period, producing roughly 2 TWh of electricity in 2001 whereas the stock of solar collectors in Europe increased by 12 per cent per annum supplying about 6 TWh of heat in 2001.

Table 1.1: Diffusion of Some'New' Renewable Energy Technologies

	Stock (gross)[i] (2001)	Average annual growth in stock[ii] (1990-2001)	energy supply[iii] (2001)
Wind power (World)	25.7 GW[a]	27 %	56 TWh[b]
Solar cells (World)	1.7 GW_p[c]	22 %	2 TWh[d]
Solar collectors (Europe)[iiii]	11.1 million m^2 [e]	12 %	6 TWh[f]

[i] Installed wind power capacity; solar cell shipments/production; solar collector area.
[ii] 'Growth in stock' is an elaboration on 'Stock' and is based on the same sources.
[iii] Wind turbine electricity supply; solar cell electricity supply; solar collector heat supply.
[iiii] Solar collector diffusion data have not been available on a global level.

Sources: [a] BTM, 2000, table 2-1; DWTMA, 2001; European Commission, 1997, table 2-2; Kåberger, 1997; Wind Power Monthly, 2002. [b] Elaboration on Wind Power Monthly (2002) and EWEA et al. (1999). [c] Curry, 1999; Photon International, 2002; PV News, 1993 & 1997; Rduber & Wettling, 2001 (minimum values). [d] Assuming that 1 W_p ⇔ roughly 1,33 kWh electricity supply. [e] Ekvall et al., 1997; DFS, 2002. [f] Elaboration on DFS (2002), Stryi-Hipp (2000) and Soltherm (2002).

Whereas the share of these technologies in the global energy supply is marginal at present (less than 0.5% of the 15,000 TWh of electricity generated in the world), their potential is considerable. There are visions of wind power accounting for ten per cent of the world's electricity supply and of solar cells supplying one per cent by 2020 (EWEA et al., 1999, Greenpeace and EPIA, 2001). The real issue is no longer the technical potential of these (and other) renewable energy technologies, but how this potential can be realised and substantially contribute to a transformation of the energy sector. The purpose of this chapter is to add to the current policy debate by synthesising a number of studies on the development and diffusion of renewable energy technology in Sweden, Germany and the Netherlands.[4]

We would like to point to three features of the energy sector which characterise the larger context in which we must place any analysis of how policy may manage the transformation process. First, the energy system is huge. Even with continued high growth rates over the next two decades, wind and solar power may only *begin* to replace the stock of conventional energy technologies well after 2020 (see Table 1.2).[5] Yet, a transformation of the energy sector post 2020 rests on a range of policy initiatives taken today, and, as early as several decades ago. Policy-making must therefore be conducted with a very long-term perspective.

4 The studies forming the core empirical base of this chapter are Andersson and Jacobsson (2000), Bergek (2002), Bångens and Sinhart (2002), Jacobsson et al., (2002), Jacobsson and Johnson (2000), Johnson and Jacobsson (2001a) and Johnson and Jacobsson (2001b).

5 Of course, with a lower increase in total electricity supply (about half of that assumed in Table 1.2), this point would be reached earlier, in about 2018.

Table 1.2: Estimated Share of the Increase in World Electricity Use of Wind and Solar Power

	2000	2010	2020
Wind power supply increase	8.2 TWh	100 TWh	368 TWh
Total supply	37 TWh	445 TWh	2,967 TWh
Solar cell electricity supply increase	0.3 TWh	3.8 TWh	72 TWh
Total supply	1.7 TWh	17.8 TWh	280 TWh
Total increase wind and solar	8.5 TWh	103 TWh	440 TWh
Electricity use increase	462 TWh	628 TWh	729 TWh
Total use	15,381 TWh	20,873 TWh	27,351 TWh
Share of increase in electricity use	1.8 %	17 %	61 %

This table is based on assumptions and data provided by EWEA et al. (1999) (wind turbines) and Greenpeace and EPIA (2001) (solar cells). The increase in electricity supply is assumed to be 3.1% per annum until 2010 and then 2.74 % per annum until 2020. The market for wind turbines (annual installed MW) is assumed to increase with 20 % per year until 2003, 30 % until 2010, 20% until 2015 and 10 % until 2019. The market for solar cells is assumed to increase by roughly 27% per annum 2000-2010 and by roughly 34% per annum 2010-2020.
Sources: Elaboration on EWEA et al. (1999) and Greenpeace and EPIA (2001).

Second, for several reasons, markets are not easily formed. New technologies often have a cost disadvantage in comparison to incumbent technologies[6] and they may not offer any direct benefits for the individual buyer or investor (but reduce society's costs in terms of e.g. CO_2 reduction). In addition, incumbent technologies are often subsidised. This refers not only to R&D subsidies in the past, which were substantial (Goldberg, 2000; Norberg-Bohm, 2000; Watson, 1997), but also to other forms of direct subsidies. For instance, UNDP (2000) estimates that 'conventional' energy received subsidies in the order of 250-300 billion USD yearly in the mid-1990s. Incumbent technologies are also subsidised indirectly as there are various types of negative external economies associated with the use of conventional energy technologies.[7] Although the size is difficult to estimate, the European Commission suggests that "the cost of producing electricity from coal or oil would double…if the external costs such as damage to the environment and to health were taken into account" (Milborrow, 2002, p. 32). In defining the incentives for investors in renewables, policy makers must give due consideration to these direct and indirect subsidies to incumbent technologies.

Third, the proponents of the established energy system often attempt to block the diffusion of renewables by influencing the institutional framework so that it continues to be to their advantage. Indeed, the current debate over the future of the energy system involves intense lobbying over both policy goals and design of the institutional framework. Policy-making is, thus, a highly political business.

The chapter is structured as follows. Section 2 contains our analytical framework. Section 3 identifies the main mechanisms that have induced or blocked the diffusion of renewables. In section 4, we turn to the dynamics of the emergence and growth of new technological systems in the energy field. The final section contains a discussion about lessons for policy.

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[6] This is much due to the fact that price/performance improvements of a new technology are closely intertwined with the process of diffusion. In the case of wind turbines, this cost disadvantage has now largely disappeared.

[7] Examples of these are air pollution, which has significant negative effects on health and on the level of acidification of lakes, emission of carbon dioxide with implications for global warming and health hazards associatated with mining of uranium, the use of that uranium in nuclear power plants and in the storage of residues from that process.

2. Analytical framework: The evolution of technological systems

As is argued in the broader literature on innovation systems, the innovation and diffusion process is both an individual and collective act. The determinants of this process are not only found within individual firms; firms are embedded in innovation systems that guide, aid and constrain the individual actors within them. In this manner, technical change becomes endogenous to the economic system.

The process whereby a specific new technology emerges, is improved and diffused in society may be studied using the concept of a technological system, which is a technology-specific innovation system (Carlsson and Stankiewicz, 1991; Jacobsson and Johnson, 2000).[8] Due to the technology-specific features of the approach, it is particularly attractive when the focus of enquiry is competition between emerging technologies and incumbent technologies (and between the associated technological systems).

A technological system is defined as "…network(s) of agents interacting in a specific technology area under a particular institutional infrastructure for the purpose of generating, diffusing, and utilizing technology…" (Carlsson and Stankiewicz, 1991, p. 21) and is made up of three main elements:

Actors (and their competencies), which may be firms, e.g. users, suppliers or venture capitalists, or other organisations. A particularly important actor is a 'prime mover' or system builder (Hughes, 1983), an actor (or set of actors) which is technically, financially and/or politically so powerful that it can strongly influence the development and diffusion process. Other notable actors are non-commercial organisations acting as proponents of specific technologies. Unruh (2000) underlines the existence of a range of such organisations and the multitude of roles they play:

> "…users and professionals operating within a growing technological system can, over time, come to recognize collective interests and needs that can be fulfilled through establishment of technical… and professional organisations…These institutions create non-market forces…through coalition building, voluntary associations and the emergence of societal norms and customs. Beyond their influence on expectations and confidence, they can further create powerful political forces to lobby on behalf of a given technological system." (p. 823).

Networks constitute important channels for the transfer of both tacit and explicit knowledge. These networks may be built around markets and may therefore be conducive to the identification of problems and the development of new technical solutions. They may also be non-market related and conducive to a more general diffusion of information or to an ability to influence the institutional set-up. Being strongly integrated into a network increases the resource base of individual actors, in terms of gaining access to the information and knowledge of other actors. Networks also influence the perception of what is desirable and possible, i.e. shape the actors' images of the future, which then guide the specific decisions of firms and other organisations.

Institutions stipulate the norms and rules regulating interactions between actors (Edquist and Johnson, 1997) and the value base of various segments in society. The roles of institutions vary; some influence connectivity in the system whereas others influence the incentive structure or the structure of demand. Institutions are important not only for the specific path a technology takes but also to the growth of new industrial clusters (Carlsson and Stankiewicz, 1991; Edquist and Johnson, 1997; Porter, 1998).

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[8] Several alternative concepts are similar to that of 'technological system'. In particular we would like to mention the concepts of 'industry social system' (Van de Ven and Garud', 1989), 'regime shifts' (Kemp et al., 1998), 'socio-technical configurations' (Geels, 2001) and 'industrial clusters' (Porter, 1998). Similar thoughts are also found within the social construction of technology approach (see, e.g., Garud & Karnoe (2001)).

A useful way to analyse the workings of a technological system is to focus on how a number of *functions* are served in the system (Johnson and Jacobsson, 2001a; Rickne, 2000). These functions constitute an intermediate level between the components of a technological system and its performance. An extensive review of the innovation system literature (Johnson, 1998; Johnson and Jacobsson, 2001a) suggests that five basic functions need to be served in a technological system:[9]

- The creation and diffusion of '*new' knowledge*[10]
- *The guidance of the direction of search* among users and suppliers of technology. This function includes guidance with respect both to the growth potential of a new technology (which may be closely linked to the legitimacy of it) and to the choice of specific design approaches
- *The supply of resources* such as capital and competencies
- *The creation of positive external economies,* both market and non-market mediated
- *The formation of markets.* Since innovations rarely find ready-made markets, these may need to be stimulated or even created. This process may be affected by governmental actions to clear legislative obstacles and by various organisations' measures to legitimise the technology.

These functions are not independent of one another, and changes in one function may lead to changes in others (Johnson and Jacobsson, 2001b). For instance, the creation of an initial market may act as an inducement mechanism for new entrants that bring new resources to the technological system.

There are two main reasons for analysing a technological system in functional terms as well as in terms of its constituent components. First, we can define the border of the system, an inherently very difficult task (Carlsson et al., 2002), by analysing what promotes or hinders the development of these functions (Johnson and Jacobsson, 2001a). Second, there is no reason to expect a particular system structure to be related to the performance of a technological system in a clear and unambiguous way. By arranging our empirical material in terms of functions, we can trace the way through which, for instance, a particular combination of actors or a specific institutional set-up shapes the generation, diffusion and utilisation of a new technology.

For a transformation of the energy system to take place, new technological systems with powerful functions need to emerge around a range of new energy technologies. Whereas our understanding of how new technological systems evolve is limited (Carlsson and Jacobsson, 1997a; Breschi and Malerba, 2001), some insight as to the roots of and regularities in the evolution of technological systems may be gleaned from the literature.

In the literature on product/industry life cycles (see, e.g. Bonaccorsi and Giuri (2000), Klepper (1997), Tushman, Anderson and O'Reilly (1997), Utterback (1994), Utterback and Abernathy (1975) and Van de Ven and Garud (1989)), it is usually possible to identify two main phases in the evolution of a product or an industry – a formative period and one of market expansion – which differ in terms of the character of technical change, the patterns of entry/exit and the rate of market growth.

With respect to the characteristics of the *formative period*, the literature emphasises the existence of a range of competing designs, small markets, many entrants and high uncertainty in terms of technologies, markets and regulations (Afuah and Utterback, 1997; Klepper, 1997; Kemp et al., 1998). We need, however, to go beyond these fea-

[9] Not all factors are specific to one technological system; functions may be influenced by factors that affect other technological systems as well. For instance, taxes may influence the size of the venture capital industry, which, in turn, affects the 'supply of resources' for several technological systems.

[10] The knowledge does not have to be genuinely new. Innovations may come in the form of new combinations of existing knowledge or in the form of imitation.

tures and understand the process in which this formative stage emerges, i.e. how all the constituent components of a technological system emerge and how the five functions begin to gain strength. We will emphasise four features of this process: market formation, the entry of firms and other organisations, institutional change and the formation of technology-specific advocacy coalitions (a particular form of network).

In the formative phase, *market formation* normally involves exploring niche markets, markets where the new technology is superior in some dimension(s). These markets may be commercial, with somewhat unusual selection criteria (Levinthal, 1998), and/or involve a government subsidy. Such 'protected spaces' for the new technology may serve as 'nursing markets' (Ericsson and Maitland, 1989) where learning processes can take place, the price/performance of the technology be improved and new customer preferences be formed.

This protective space may not be limited to the very first niche markets – the diffusion of a new technology can be seen as an exploration of a whole series of niches prior to reaching mass markets, and protection may be required and awarded by markets that act as bridges to mass markets (Andersson and Jacobsson, 2000; Geels, 2001). Such 'bridging markets' allow for larger volumes of production and a series of 'secondary innovations,' in Schmookler's (1966) terminology, both of which may be required before the new technology can become a commodity.

The formation of nursing and bridging markets has an importance that goes beyond improving price/performance of the new technology; they generate a 'space' for the elements in the technological system to fall in place. In particular, by guiding the direction of search, these markets provide an incentive for the *entry of firms* into various parts of the value chain.

Firm entry may shape new technological systems in three main ways. First, each new entrant brings knowledge and other resources into the industry. Second, they enlarge the technological system by filling 'gaps' (e.g. by becoming specialist suppliers) or by meeting novel demands (e.g. by developing new applications). In that process, a division of labour is formed and, associated with this, further knowledge formation is stimulated by specialisation and accumulated experience (see, e.g., Smith (1776), Young (1928) and Maskell (2001)).

Third, positive external economies may emerge beyond those associated with a further division of labour – a new entrant may raise the returns for subsequent entrants in additional ways. These external economies, which may be both pecuniary and non-pecuniary (Scitovsky, 1954), include Marshallian externalities (Breschi and Lissoni, 2001)[11] but go beyond these. They may, for example, come in the form of passing of information in networks or an increased availability of complementary resources. Indeed, "[e]ach successful firm … creates a demand for certain intermediary services such as legal and accounting services. Greater availability of these services also facilitates the start-up process for subsequent firms, and higher rates of entry of firms encourage venture capital to enter" (de Fontenay and Carmel, 2001, p. 26).

New entrants may also play an important role for the process of legitimisation of a new field:

> "The ecological theory of long-term organisational evolution posits that when a new organisational form appears, such as automobile manufacturing in the late 19th century, it lacks legitimation or social taken-for-grantedness. Low or absent legimitation implies that organizing is difficult: capital sources are wary; suppliers and customers need to be educated; employees may be hard to find and recruit; and in many instances hostile institutional rules must be changed. As the form proliferates, legitimation increases. Initially, when the number of organizations is low, the returns to legitimation of adding another organization is great." (Carroll, 1997, p. 126).

[11] New entrants may, for instance, strengthen a local labour market for specialists.

The legitimacy of a new technology and its actors, their access to resources and the formation of markets is strongly related to the institutional framework. If the framework is not aligned with the new technology, several functions may be blocked. *Institutional change* (and by implication its politics) is, therefore, at the heart of the process whereby new technologies gain ground (Freeman, 1977; Freeman, 1978, Freeman and Louca, 2002).

Institutional change, or alignment, is a multifaceted process. For example, supporting the formation of a new technological system involves a redirection of science and technology policy in order to generate a range of competing designs. This knowledge creation may have to begin well in advance of the emergence of markets, but it also needs to be sustained throughout the evolution of the system. Institutional alignment is, however, also about market regulations, tax policies, value systems etc. that may be 'closer' to the operation of specific firms. In particular, institutional change is often required to generate markets for new technologies. The change may, for instance, involve the formation of standards.

The centrality of institutional alignment implies that firms in competing technological systems not only compete in the market for goods and services but also to gain influence over the institutional framework. As Van de Ven and Garud (1989, p. 210) put it, "…firms compete not only in the marketplace, but also in this political institutional context. Rival firms often cooperate to collectively manipulate the institutional environment to legitimize and gain access to resources necessary for collective survival…" [12]

This is well recognised in the political science literature (see, e.g., Sabatier (1998) and Smith (2000)), which argues that policy making takes place in a context where *advocacy coalitions,* made up of a range of actors sharing a set of beliefs, compete in influencing policy in line with those beliefs (Smith, 2000). The political science literature looks at coalitions in a non-technology specific manner, which is reasonable considering that the political debate over, say, climate change, is not necessarily focused on specific technological systems.[13] However, for a new technology to gain ground, *technology specific coalitions* need to be formed and to engage themselves in wider political debates in order to gain influence over institutions and secure institutional alignment. As a part of this process, advocates of a specific technology need to build support among broader advocacy coalitions where a particular technology, e.g. solar cells, is perceived as a solution to wider policy concerns. Hence, the formation of "political networks"[14] with the objective of shaping the institutional set-up is an inherent part of this formative stage.

A coalition may include many types of organisations and actors, such as universities, private and non-commercial associations, media, politicians at different levels and elements of the state bureaucracy (Feldman and Schreuder, 1996, Porter, 1998). However, individual firms and related industry associations play an especially important role in the competition over institutions. Thus, the entry of firms into various parts of the value chain has yet another consequence for the emergence of a new technological system: the new entrants allow for the formation or the strengthening[15] of a technology specific advocacy coalition, which may gain enough strength to influence the institutional set-up. As earlier mentioned, such entries are dependent on the emergence of

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12 Similarly, Davies (1996) underscores the centrality of the political dimension in the competition between incumbents and contenders in his study of innovations in telecommunications.

13 We are grateful to Dr. Adrian Smith for pointing this out to us.

14 In the subsequent text, this term will be used synonymously with the term advocacy coalitions by which we mean technology specific ones.

15 In the environmental field, wider advocacy coalitions existed before the emergence of specialised industries supplying e.g. wind turbines and solar cells.

niche markets. An early formation of markets is, therefore, at the heart of the formative stage. As Kemp et al. (1998) argue:

> "Without the presence of a niche, system builders would get nowhere…Apart from demonstrating the viability of a new technology and providing financial means for further development, *niches help building a constituency behind a new technology*, and set in motion interactive learning processes and institutional adaptation…that are all-important for the wider diffusion and development of the new technology" (p. 184, our emphasis).

The time span involved in a formative phase may be very long. This is underlined in a recent study of Israel's 'Silicon Wadis,' which began a rapid period of growth in the 1990s after a history starting in the 1970s (see de Fontenay and Carmel (2001)). This time span is not unusual; the first commercial major market for steam ships took about 50 years to materialise (Geels, 2001) and the formative stages of the US technological systems for computers and semiconductors lasted for several decades (Carlsson and Jacobsson, 1997a). Often, the investments are substantial and seemingly without success. Breshanan et al. (2001) summarise the lessons from a set of case studies on the evolution of ICT clusters:

> "Another similarity … is the degree of investment, effort and building needed to set up the background for an innovation cluster's take off. …it takes years of firm-building and market-building efforts… sometimes these long-term investments in national or regional capabilities can grow for a long time in what seems like a low-return mode before the take off into cluster growth…" (pp. 843-844).

At some point, however, these investments may have generated a large enough system which is sufficiently complete for it to be able to 'change gear' and begin to develop in a self-sustaining way (Carlsson and Jacobsson, 1997b; Porter, 1998).

A necessary condition for a 'change in gear' to take place is that larger markets are formed – the system needs to get connected to an underlying wave of technological and market opportunities (Breshanan et al., 2001).[16] As it does so, a chain reaction of positive feedback loops may materialise which involve all the constituent components and the functions of the technological system. The linkages between functions may turn out to be circular, setting in motion a process of cumulative causation.

Indeed, as pointed out long ago by Myrdal (1957), virtuous circles are central to a development process. He even suggested that " the main scientific task is…to analyse the causal inter-relations within the system itself as it moves under the influence of outside pushes and pulls and the momentum of its own internal processes" (Myrdal, 1957, p. 18).

It is, however, not an easy task to unravel these causal interrelationships, and, moreover, to predict how these respond to outside pushes, e.g. policy. Technological systems are dynamic and unstable, and any change in a component in the system (e.g. a new entrant or a change in the institutional set-up) may trigger a set of actions and reactions in the system (Carlsson et al., 2002). Under what conditions a 'change in gear' will take place is, therefore, difficult to predict.

A process of cumulative causation can, however, only be set in motion if the technological system has gone through a formative period – without it, a response capacity to the underlying wave will not exist and, indeed, the wave itself may not be there. But, as Breschi and Malerba (2001) point out, making the required investments in the formative period is very risky. There are many reasons for expecting that the broader (not only market) selection environment is biased in favour of incumbent technological systems and that a new technological system may consequently develop very slow-

[16] For example, some ICT clusters have become successful by linking up to the US market (Breshanan et al., 2001) whilst the Nordic technological systems in mobile telephony grew into a second phase with the European GSM standard.

ly or in a stunted way – a system failure may occur (Carlsson and Jacobsson, 1997b). These reasons are found in all components of the technological system. For instance:[17]

- Institutions may fail to align themselves to the new technology – this may encompass the regulatory framework or the functioning of the educational and capital markets.[18]
- Markets may not be formed due to, for instance, the phenomenon of increasing returns to adoption, which benefits established technologies, or direct and indirect subsidies to incumbent technologies.
- (Additional) Firms may not enter due to a lack of markets or because they tend to build on their existing knowledge base when they search for new opportunities, which may restrict their search process.
- Networks may fail to aid new technology simply because of poor connectivity between actors. The proponents of the new technology may also be organisationally too weak to counteract the influence on legislation, public opinion etc. of the vested interest groups of the incumbent technology.

Such 'blocking mechanisms' may operate in a formative stage, but they may also obstruct a transition towards a more self-sustained technological system i.e. one which is to an increasing extent driven by its own momentum rather than by outside pushes or pulls in the form of policy. Clearly, we would expect powerful inducement mechanisms to be needed in order to overcome this range of potential blocking mechanisms, and we would expect the nature of both inducement and blocking mechanisms to vary between countries and technologies.[19]

In what follows, we will first elaborate on the nature of inducement and blocking mechanisms in renewable energy technology (section 3). We will then relate our understanding of the dynamics of system evolution. It is particularly unclear under what conditions a technological system manages to shift to a second phase, and we will, therefore, analyse cases in which blocking mechanisms have been overcome and a process of cumulative causation initiated, as well as cases in which system failure has occurred (section 4).

3. Inducement and blocking mechanisms in renewable energy technology

In this section, we will illustrate the wide range and different character of mechanisms that have either induced or blocked the diffusion of renewable energy technology. We will do so by relating how these mechanisms have influenced the five functions in selected technological systems in Germany, the Netherlands and Sweden (see Table 3.1). Two broad policy challenges are then formulated.

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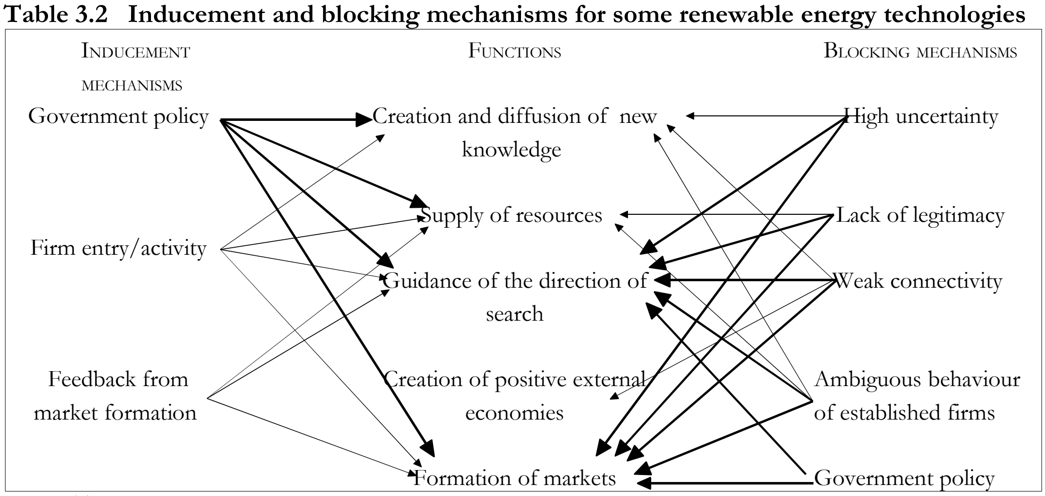
17 Jacobsson and Johnson (2000) and Johnson and Jacobsson (2001a) elaborate on various types of 'blocking mechanisms'. Kemp et al. (1998, p. 181) argue similarly " … many factors … impede the development and use of new technologies…These factors are interrelated and often reinforce each other. What we have is not a set of factors that act separately …, but a structure of interrelated factors that feed back upon one another, the combined influence of which gives rise to inertia and specific patterns in the direction of technological change." See also Unruh (2000) for an extensive review of mechanisms locking us into a carbon economy and Walker (2000) for a case study on entrapment in a large technological system.

18 Maskell (2001) provides an illustrative example of how institutions in Finland favour the wood processing industry at the expense of the wooden furniture industry.

19 Some countries and regions may get a head start, explaining not why and when increasing returns to adoption appears, but where.

Table 3.2 Inducement and blocking mechanisms for some renewable energy technologies



Note 1: These mechanisms are from different cases and this table should, therefore, only be interpreted as an overview of the most important mechanisms found in the cases.
Note 2: Line weight illustrates the main messages of this section (see the following discussion).

Government policy has been the major inducement mechanism. R&D funding has supported the creation of new knowledge, supplied resources and guided the search of various actors to the new technologies (Jacobsson et al., 2002; Johnson and Jacobsson, 2001a and 2001b).[20] Instruments such as investment subsidies, demonstration programmes and legislative changes have stimulated the formation of markets (Bergek, 2002; Jacobsson et al., 2002; Johnson and Jacobsson, 2001a and 2001b) and the creation of knowledge of applied nature (Jacobsson et al., 2002).

Firm entry/activity has led to the creation of new knowledge, the supply of resources and the development of different types of designs within each technology field.[21] Moreover, it has stimulated market formation; for example, in the German solar cell case, utilities such as Bayernwerk have introduced 'green' pricing schemes, and the entry of firms into several steps of the value chain has led to the development of new market segments for solar cells (Jacobsson et al., 2002).

Feedback loops from the formation of markets have influenced several other functions. Increased sales have generated growing resources for technology development in the capital goods sector (Johnson and Jacobsson, 2001a and 2001b) and have also guided the direction of search of new entrants into the field of renewable energy technology, bringing with them new resources (Jacobsson et al, 2002; Johnson and Jacobsson, 2001b). Finally, local energy suppliers in Sweden have through their investments in bioenergy technology stimulated further market growth by increasing the legitimacy of that technology (Johnson and Jacobsson, 2001a).

[20] In the German and Dutch wind turbine cases, the funding was, moreover, used to create and sustain variety in the knowledge base (Johnson and Jacobsson, 2001b).

[21] The latter has, perhaps, been most evident in the Dutch and German wind turbine cases (Johnson and Jacobsson, 2001b) and the German solar cell case (Jacobsson et al, 2002), but has been seen in the Swedish solar collector and pellet burner cases as well (Johnson and Jacobsson, 2001a).

The first of five major blocking mechanisms is high *uncertainty*, in technological, economic and market terms,[22] which has obstructed market formation[23] and guided the direction of search of potential entrants away from the field (Bergek, 2002, Johnson and Jacobsson, 2001a and 2001b).

The second is *lack of legitimacy* of the new technology in the eyes of different actors. This has not only guided the search away from the field of renewable energy technology, but has also blocked the supply of resources and the formation of markets (Johnson and Jacobsson, 2001a and 2001b). The most prominent example of this mechanism is the Swedish 'nuclear power trauma' (see Box 1), but lack of legitimacy was also an important reason behind the Dutch government's failure to solve the siting problem for wind turbine, which was due to difficulties to obtain building permits (Johnson and Jacobsson, 2001b).

Box 1: The Swedish Nuclear Power Trauma[a]

The Swedish 'nuclear power trauma' has its roots in the Swedish nuclear power issue, which has been discussed since the early 1970s and which led to a referendum in 1980 after the Harrisburg accident. It was decided that the Swedish nuclear époque was to end in 2010, but the issue has still not been settled.

The energy-intensive industry, the capital goods industry and the two dominant utilities formed the core of a powerful alliance to oppose the dismantling of nuclear power. In the other camp, the anti-nuclear power movement referred to the results of the referendum and wanted to begin the dismantling process. The Social Democrats in power had considerable problems to balance the demands of the two camps, which led to uncertain and unpredictable energy policies.

Over time, a 'nuclear power trauma' emerged, which reduced all energy issues to one: the issue of whether or not to dismantle the Swedish nuclear power plants. In the very heated debate, renewable energy technology was seen only as a substitute for nuclear power, and all programmes to induce further diffusion of renewable energy technology were justified in that context.

This trauma had two major consequences for renewable energy technology. First, the value of each technology was judged in relation to how many nuclear power reactors it might replace. For small-scale technologies, it was but a fraction, at least in the short and medium term, which further weakened the legitimacy of renewable energy technology and contributed to an inability to recognise its growth potential.

Second, since renewable energy technology was perceived by many as a threat to the continued availability of nuclear power, an interest in, for example, wind power was automatically assumed to involve an anti-nuclear stance and a 'betrayal' of Swedish industry, which enjoyed the benefits of nuclear power. Thus, it was not surprising that renewable energy technology did not gain legitimacy in the eyes of the capital goods industry, potential users and large parts of the media. As a consequence, the supply of resources was constrained, the market did not grow and few firms entered the industry supplying renewable energy technology.

[a] *This account is based on Jacobsson and Johnson (2000) and Johnson and Jacobsson (2001a and 2001b).*

[22] For example, it is difficult for firms to choose between different design approaches and for customers to trust that new and unproven technologies will work. Economically, the level of compensation for small-scale electricity production and the prices of other energy sources are dependent on political decisions. In the market, unarticulated demand from new customer groups makes it difficult for firms to identify markets and adapt products to customer needs.

[23] This has been true not only for large-scale process technologies such as black liquor gasification (Bergek, 2002), but also for small-scale technologies such as pellet burners and solar collectors (Johnson and Jacobsson, 2001a).

These two blocking mechanisms are common in new technological fields and have to be handled by the emerging technological systems. However, three additional mechanisms have compounded the problem.

First, *weak connectivity* in terms of weak learning and political networks between actors of the technological systems has resulted in a number of problems.[24] For example, problems have been wrongly formulated, have fallen between stools or have remained unsolved even though the knowledge to solve them exists in the system (Bergek, 2002; Johnson and Jacobsson, 2001a). A weakness of the proponents of the new technologies in the Swedish political arena has made them unable to increase legitimacy and induce the institutional changes necessary to stimulate market formation (Johnson and Jacobsson, 2001a and 2001b).

Second, the *ambiguous and/or opposing behaviour* of some established energy suppliers and capital goods suppliers has reduced the legitimacy of renewable energy technology and has, thus, blocked the supply of resources and guided the direction of search away from these technologies (Johnson and Jacobsson, 2001a and 2001b). It has also added to customer uncertainty and vulnerability, which has blocked market formation (Bergek, 2002; Johnson and Jacobsson, 2001a) and delayed important steps in the knowledge-creation process (Bergek, 2002).

Third, *government policy* has blocked several functions. In Sweden, a lack of conscious variety creation within R&D policy has guided the direction of search into an early selection of designs that have not been in demand, for example in the case of wind turbines. In Sweden and the Netherlands, inconsistent and changing policy measures have increased the level of uncertainty and resulted in an erratic demand for some technologies, which has guided the search of firms away from the field of renewable energy technology (Johnson and Jacobsson, 2001a and 2001b).

Clearly, there is a wide range of different inducement and blocking mechanisms which influence the various functions in a multitude of ways. This implies that a *first policy challenge* is to create an understanding of the functional pattern of each relevant system with the purpose of identifying its particular strengths and weaknesses. A key policy objective should then be to make sure that weak functions are strengthened (by increasing the strength of inducement mechanisms and/or reducing strength of blocking mechanisms).

In order to reduce the strength of blocking mechanisms, it is particularly important for policy to be concerned with the two functions 'guide direction of search' and 'stimulate market formation'. As is clear from Table 3.3, these functions may be blocked in many ways, and there is, therefore, a considerable risk that their potential to influence other functions through feedback loops (as described above and in the following section) will not be realised.

Designing policies that aim at influencing the functional pattern of an entire technological system obviously requires co-ordination between various ministries and agencies responsible for different parts of the incumbent and emerging systems. For example, energy policy, science policy and construction norms may need to be integrated in order for a 'roof programme' promoting solar cells or solar collectors to be realised. Achieving such policy co-ordination is *the second policy challenge*.

[24] However, in some cases, connectivity was too strong, which resulted in strategic conformity with respect to market and technology choices (e.g. the Dutch wind turbine case) and, thus, in increased vulnerability to uncertainty.

4. The dynamics of system evolution

In this section, we will turn to the dynamics of system evolution and analyse the conditions under which blocking mechanisms in some cases have been overcome, and a process of cumulative causation started, or how the evolution of a new technological system in other cases has been stunted. In the course of the analysis, we will identify more policy challenges. We will draw upon the experiences of Germany, Netherlands and Sweden in wind turbines, Germany in solar cells and Sweden and Netherlands in solar collectors.

In Table 4.1, we summarise the diffusion levels at the end of a formative period (about 1990) and in 2001 in both absolute (MW) and relative terms (MW/total primary energy consumption). Three observations can be made. First, the relative German level of diffusion was between two and seven times higher than that of the Netherlands and Sweden in 2001. Second, at the end of the formative period, the Netherlands and Sweden were ahead in wind turbines and solar collectors respectively (and about equal to Germany in solar cells) but lost their advantage subsequently. Third, the Swedish advantage in solar collectors was not only lost vis-à-vis Germany, but the Netherlands is also catching up with Sweden.

Table 4.1: The Diffusion of Wind Turbines, Solar Cells and Solar Collectors in Germany, the Netherlands and Sweden in about 1990 and 2001
(Total Stock and Stock Related to Total Primary Energy Consumption)

	Wind Turbines (MW and MW/TWh)		Solar Cells (MW_p and MW_p/TWh)		Solar Collectors (m^2 and 1,000 m^2/TWh)	
	1990	2001	1992	2001*	1990	2001
Germany	68	8,800	5.6	174	282,000	3,809,000
	0.016	*2.30*	*0.0014*	*0.045*	*0.069*	*0.994*
The Netherlands	49	519	1.3	12.8	11,000	226,000
	0.055	*0.524*	*0.0014*	*0.013*	*0.013*	*0.228*
Sweden	8	290	0.8	2.8	105,000	217,000
	0.016	*0.630*	*0.0016*	*0.006*	*0.209*	*0.471*

* 2000 for the Netherlands and Sweden.
Bold figures indicate the 'leading country' (of the ones presented here) at the end of the year in question.
Sources: Total primary energy consumption data for 1990, 1992 and 2000 (N.B.!): BP (2001). Wind turbines: BWE (2002), Kamp (2000), WSH (2002) & STEM (2001), table 5.. Solar cells: IEA (2002). Solar collectors: Bångens and Sinkart (2003).

In our attempt to explain these developments, we will begin our analysis by identifying features of the formative phase and then proceed to discuss the phase in which a market expansion begins to take place. We will argue that a necessary condition to take a lead in the transformation process is that the formative stage is characterised by certain features, but also that this is not a sufficient condition – even if a formative stage is successfully completed, the transition to a second phase is fraught with difficulties.

4.1. The formative stage

As underlined in section two, institutional alignment is at the heart of the process of transformation. In the formative stage, the institutional framework has to begin to be aligned to the new technology. *A third challenge* for policy makers is to contribute to a process of institutional alignment (in spite of eventual attempts by vested interest groups to hinder this process). Such an alignment is multifaceted, and we will point to three types of institutional adjustment, which are required for a new system to emerge: variety in 'knowledge creation', market formation and, associated with that, gaining legitimacy for the new technology.

First, science and technology policy has to induce 'knowledge creation' in renewables. In the OECD, government R&D budgets for renewable energy technology increased substantially in the 1970s and early 1980s[25] and remained broadly constant, in the order of 500-600 million USD, in the 1990s (IEA, 2000).

However, although the volume of funds matters, the manner in which policy is conducted is of great importance as well. As mentioned in section 2, the formative stage is often characterised by substantial technological uncertainty and by the co-existence of many competing design approaches. This was clearly the case for wind power in the 1980s, where designs differed greatly in terms of, for instance, size and number of blades (Johnson and Jacobsson, 2001b). In solar cells, the same variety can be seen as a whole range of so-called thin film technologies challenge the dominant crystalline technology (Jacobsson, et al., 2002).[26] Where such technological uncertainty prevails, policy makers ought to avoid thinking in terms of optima. The guiding principle for policy should instead be to contribute to the generation of a diverse set of technological options by stimulating experimentation and the 'creation of knowledge' connected to different design approaches. The creation of variety is closely connected to the number of actors within a field since these may bring different types of visions, competencies and complementary assets to the industry.[27] *The fourth policy challenge* is, thus, to induce a variety of actors to experiment with different solutions.

The German federal R&D policy consciously avoided guiding researchers and firms in any specific direction in the fields of wind turbines and solar cells. Instead, it allowed for a broad search and 'creation of knowledge' to take place by many different actors (e.g. firms and universities/institutes) over a long period of time (Jacobsson et al., 2002; Johnson and Jacobsson, 2001b). In the Dutch wind turbine case, policy and other factors induced a search in many directions as well.

In the Swedish case, however, a substantial R&D funding was channeled almost solely to very large turbines (and just a few actors) as these were seen to be the only type which could have a substantial impact on power production in the medium term (see Box 1). In solar collectors, the early Swedish pattern was the same with an emphasis on large-scale applications, one particular design approach and a few actors (Bångens and Sinhart, 2002).[28]

Second, appropriate financial incentives to invest in renewables need to be put in place in order to stimulate the 'formation of (early) markets', with the purpose of providing 'guidance of the direction of search' for a variety of firms towards the new field and stimulating the 'creation of new (application) knowledge' and the formation of prime movers. The incentives used may, for example, be in the form of capital grants for new investments in order to absorb some of the technological and economic risks for pioneering users.

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[25] So did, however, also those fossil fuel and nuclear power R&D; the approximately 700 million USD spent in IEA countries on renewable energy technology R&D in 1998 may be compared with the more than 2,800 million USD spent on conventional nuclear power R&D (excluding breeders and fusion) and 1,400 million USD spent on fossil fuel R&D (1999 prices and exchange rates) (IEA, 2000).

[26] Indeed, even in the case of the large-scale process technology of black liquor gasification, several competing technical solutions have been developed in Sweden (Bergek, 2002).

[27] On this point, see also van Est (1999). In addition, having a few, dominating actors in a field may be risky since such actors may very well become 'prime blockers' instead of 'prime movers'. This was evident in the case of black liquor gasification in Sweden, in which the mere withdrawal of a dominant actor blocked the diffusion of the new technology (Bergek, 2002).

[28] Indeed, in Sweden, a bias towards large-scale solutions at the expense of variety is easily discerned, not only in wind turbines but also in solar collectors and biomass gasification technology. In all cases, this bias was later associated with a failure to industrialise the technologies.

However, and third, a prerequisite for appropriate incentives to come into place, and for firms to enter the new area, is that renewables are seen as legitimate in broad segments of society. In Germany, the Chernobyl accident in 1986 had a permanent and major effect on the attitude towards nuclear power in the German population (Jahn, 1992) and a broad legitimacy of renewables dates back to at least 1988 when all political parties backed a Parliamentary Resolution calling for more R&D in renewables (Scheer, 2001).

Incentives to invest in renewables have therefore been widely available. Wind power benefited from several federally funded demonstration programmes, which contributed to the formation of markets in the second half of the 1980s and a demonstration programme for larger solar power applications was initiated in 1986. Moreover, the German Ministry of Research responded to the above mentioned Parliamentary Resolution with a 250 MW programme for wind energy (Johnson and Jacobsson, 2000) and a highly innovative 1,000-roof programme for solar cells (Jacobsson et al., 2002).

The market expansion for wind turbines largely benefited German suppliers – small utilities or farmers (the first customers) often favoured local machinery firms in early user-supplier relations and indeed, much of the market created by the 250 MW programme was, by various means, 'reserved' for domestic firms (Johnson and Jacobsson, 2001b). In total, the formative period saw the *entry* of fourteen German firms, which formed an industry association together with owners of wind turbines (Johnson and Jacobsson, 2001b). As for wind turbines, the early market for solar cells benefited almost only German firms.

In the Netherlands, wind power had a reasonably strong legitimacy in the late 1970s and early 1980s, and some demonstration projects in the early 1980s supported new prototypes and turbines in new applications, e.g. by fiscal incentives and capital grants (Johnson and Jacobsson, 2001b). In addition, investment subsidies were given to investors from 1986 due to a revived political interest in wind power after an energy price crisis in 1984. A Dutch market was formed which was larger than that in Germany in the second half of the 1980s and as many as 15-20 firms entered the wind turbine industry. As in the German case, these local wind turbine firms supplied most of the machinery.

In contrast, and as was elaborated on in Box 1, a key feature of the Swedish institutional context was a failure to achieve a legitimacy for renewables that supply electricity.[29] Consequently, the wind turbine market was poorly developed in the 1980s. The little market there was contained no mechanisms for favouring local suppliers with the exception of a couple of megawatt turbines. There was, however, an advanced programme for large-scale applications of solar collectors connected to district heating networks in the 1970s and 1980s, contributing substantially to the formation of an early market (Bångens and Sinhart, 2002). An early legitimacy was obtained as solar collectors were primarily seen as a substitute to oil and not to nuclear power. In this emerging market, a few Swedish suppliers were favoured (Bångens, 2002).

In summary, in the German and Dutch cases of wind power, initial markets were formed, albeit small, and firms were induced to enter into the technological system. Variety was achieved through both R&D policy and from these entrants. An early legitimacy was an underlying factor. Much the same can be said about the German solar cell case (although the number of entrants into solar cell production was lower) and the Swedish case of solar collectors (although there was little technical variety). In these cases, industrial firms strengthened the technology-specific advocacy coalitions. In contrast, in the Swedish wind turbines case there was little variety, an absence of le-

29 Interestingly, after more than a decade of intense debate, the combatants were so firmly entrenched that the Chernobyl accident had little effect on public opinion on nuclear power (Anshelm, 2000).

gitimacy, hardly any market formation, few entrants and, consequently, an advocacy coalition which lacked the strength of industrial firms (in spite of large Government R&D expenditures in this field).

4.2. Cumulative causation or system failure?

A formative stage needs to be followed by one in which the initial market space is enlarged so that volume advantages can be reaped, additional firms be induced to enter throughout the value chain and further learning is stimulated. As underlined in section two, an enlargement of markets and the related institutional alignment involves propelling the system forward in a process of cumulative causation. We will unravel the characteristics of that process where it has evolved, i.e. in the German cases of wind turbines and solar cells (4.2.1), and discuss why it has failed to occur in other cases, such as the Dutch and Swedish wind turbine cases (4.2.2).

4.2.1. Wind and solar power in Germany: Cumulative causation unravelled

The German case of wind power reveals how feedback loops may be generated from early market formation, via early entrants, to changes in the institutional framework beyond the formative phase.

Representatives of the infant wind turbine industry and independent power producers (i.e. early entrants in the form of, for instance, farmers in north-west Germany) collaborated with an association of owners of small-scale hydro electric plants (Ahmels, 1999) and with an organisation of local and federal politicians favouring renewables (Eurosolar) to get the German parliament to pass its first electricity feed-in law (EFL) in 1991 (see Box 2). The broad legitimacy of renewables in Germany meant that there was little resistance to this law– the passing of it was, indeed, seen as a 'simple thing' in terms of political effort (Scheer, 2001).[30]

This EFL gave a massive and hitherto unheard of incentive for wind turbine owners, which resulted in an 'unimaginable' market growth (Johnson and Jacobsson, 2001b). Due largely to this market growth, the German wind turbine industry was able to expand rapidly in the first half of the 1990s, and yet new firms were induced to enter into different parts of the value chain (e.g. wind turbine suppliers, financiers of large wind parks and component suppliers). These new entrants influenced the process of cumulative causation in three ways. First, they led to a strengthening of the advocacy coalition, in part because economic arguments could now be added to environmental ones in support of wind power. Indeed, the wind power coalition grew so strong that it later successfully handled challenges by the larger utilities, which wanted to change the EFL, both in the German Parliament (see Box 2) and in the court system (especially the German constitutional court[31] and the European Court (Jacobsson et.al., 2002)).

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[30] With this broad legitimacy, wind and solar power have received support not only from the federal level but also from the regional and local level (e.g. in Bavaria and North Rhine -Westphalia).

[31] We are grateful to Professor Volkmar Lauber for pointing this out for us.

Box 2: The German Electricity Feed-In Lawa

The EFL came into force in 1991. It required utilities to accept renewable electricity delivered to the grid and to pay the supplier 90 % of the average consumer price (~17 pfennig/kWh) for it.

The origin of the law was the 1989 proposal of two environmental organisations (Förderverein Solarenergie and Eurosolar) of a 'cost covering feed-in law', which was supported by an association of small-scale hydropower plant owners and the infant wind turbine industry.

Within parliament, politicians from CDU, SPD and the Greens, organised within the Eurosolar Parliament Group, worked for the acceptance of a law. With support from the majority of the CDU members (which then formed the government), the law was passed in 1991.

In the mid-1990s, the rapid diffusion of wind turbines led to a response from the larger utilities which worked vigorously to convince the German parliament that the EFL should be rescinded. Intense lobbying followed, which reintroduced substantial uncertainty, and the market stagnated. Finally, in 1997, a select committee was given the responsibility for investigating whether or not the law should be amended.

By then the German wind turbine industry had been able to grow beyond an infant stage, allowing it to add economic arguments to environmental ones in favour of wind energy. It had also formed powerful political networks that were manifested in e.g. an active industry association of turbine suppliers and owners, which through lobbying activities tried to influence the select committee.

In contrast, the utilities were neither supported by the German federation of industries (VDMA), nor by any political party.

The wind turbine lobby won the political battle, although it was a close call; in the select committee, the proponents of a continued law won the vote by eight to seven.

Second, the 'supply of resources' to the technological system by some new entrants allowed for a rapid upscaling of turbines as well as for building of large wind parks. Third, they allowed for a further division of labour to evolve, primarily between wind turbine suppliers and local component suppliers. The benefits spilled over to yet more turbine manufacturers (e.g. DeWind) since these could rely on a complete infrastructure, which reduced entry barriers.

Similar to the wind turbine case, early entrants and positive feedback loops associated with these strengthened the solar cell coalition in Germany as it tried to influence the institutional framework to the advantage of the new technology (see Box 3). The available market formation programs (the EFL and the '1,000-roof' programme) were not enough to build a growing market for solar cells (the remuneration of the former was not enough to cover the high costs of solar power and the latter was not large enough). However, through a political struggle by an advocacy coalition composed primarily of environmental organisations, solar cell firms, Eurosolar and the Green party, local feed-in laws (at the municipal level) were formed and were later followed by a federal '100,000-roof' programme in 1998 and a revised federal feed-in law (in 2000) with much higher remuneration than before (Jacobsson et al., 2002).

An expanding market for solar cells in the second half of the 1990s greatly strengthened the function 'guidance of the direction of search' and new firms and other organisations entered along the whole value chain: machine suppliers and engineering firms developing production technology, solar cell manufacturers, module manufacturers, firms applying solar cells in a large number of applications (e.g. on exhibition halls, football stadiums, parking meters, etc.), tile and roof manufacturers, facade manufacturers, builders, electricians, insurance companies, city planners and, not the least, architects. This entry strengthened the process of cumulative causation in three ways. First, some of the new entrants developed the new segments of façade and roof integrated applications. The exploitation of these segments by pioneers enlarged the market and led to a strengthening of the function 'guidance of the direction of search,' which induced yet new entrants, contributing to the 'supply of (more) resources'. Second, the solar cell advocacy coalition gained strength and is now raising the level of ambition by a call for a '10,000-façade' programme for solar cells (Siemer, 2002). Third, new entrants helped to induce further institutional changes, e.g. in the educational system. For example, the German pioneer in solar cell facades, Flabeg, spent a great deal of efforts for about a decade to engage and teach Schools of Architecture so that new architects are made familiar with solar cells and acquire competence to design buildings where solar cells constitute building components.

Box 3: The German Solar Cell Policy Process[a]

In the early 1990s, the German solar cell market could not justify investments in new production plants, and by the mid-1990s there was hardly any production of solar cells in the country. The available market stimulation instruments – the EFL and the '1,000-roof programme' – were not enough to build a larger market.

The advocates of solar power – firms and other organisations – began a struggle to stimulate market formation. In 1992, Förderverein Solarenergie proposed that more generous feed-in laws covering the full cost of electricity production from photovoltaics should be introduced for solar power by local utilities (Stadtwerke) and, together with local environmental groups and Eurosolar, managed to influence 40-45 towns to implement such laws.

Pressure built up for the federal government to follow up on the local initiatives. This pressure was augmented by an expansion of the remaining two solar cell firms in US plants and an associated threat to dismantle their activities in Germany.

In 1998, a '100,000 roof' programme started, driven mainly by the Social Democrats.

In addition, the Greens wanted to move the local feed-in laws to the federal level. They organised various environmental groups, industry associations, the trade union IG Metall, three solar cell producers and politicians from some of the states that had local feed-in laws. They also received support from SPD, which had an industrial policy interest in re-writing the existing feed-in law from 1991; they feared that the liberalisation of the energy market in 1998 would endanger the further development of the successful German wind turbine industry.

In 2000, the EFL was revised and the remuneration became fixed for a period of 20 years. The level varied though for the different renewables. For solar cells, it amounted to 99 pfennig for those who invested in solar cells in the first year of the law, a level which hardly would have been obtained without the very considerable interest in paying for solar electricity as revealed by the numerous local feed-in laws.

[a] *This account is based on Jacobsson et al., (2002).*

4.2.2. System failures: Dutch, Swedish wind power and Swedish solar collectors

In contrast to the German wind turbine and solar cell cases, the Dutch and Swedish wind turbine and the Swedish solar collector cases can be characterised as 'stunted' technological systems. The Dutch wind turbine and the Swedish solar collector cases are particularly interesting as they came out very strongly from the formative period (see table 4.1).

In the Dutch case of wind turbines, a 'change in gear' in the rate of diffusion did not occur, largely for institutional reasons; the function 'formation of markets' was blocked by problems in receiving building permits[32] and, therefore, did not increase greatly in strength in spite of the presence of different types of market stimulation instruments, e.g. continued investment subsidies, electricity taxation that favoured renewables and guaranteed access to the grid for wind power producers (Johnson and Jacobsson, 2001b). In order to attempt to solve the building permit issue in connection with a large and potentially ground breaking investment project, the central gov-

[32] The building permit procedure was slow and time-consuming – a normal project took five years to complete.

ernment made an agreement with the provincial governments as to how to distribute 1,000 MW capacity of wind power. However, the agreement did not involve the local government (which issued the building permits and which had little reason to support wind power) and wind power was apparently not a sufficiently important political issue for the central authorities to impose directives on land usage on the local authorities. This may be interpreted as a failure to further develop the early reasonably strong legitimacy (Johnson and Jacobsson, 2001b).

With a weak local market, and with poor access to the first years of the German growth, the Dutch supplier industry began to disappear, reducing the strength of the advocacy coalition.

In the Swedish case of wind turbines, an advocacy coalition of any strength never materialised, and policies favouring wind energy were hesitant. The total size of the funds channelled to the diffusion of wind turbines in the form of capital grants were limited in both time and scale (unlike the EFL).[33] Although the grants were supplemented by an environmental bonus in 1994, the incentives were much weaker than in Germany and it was not until 1996 that the utilities were obliged to buy power from independent producers at fixed price (which moreover was low (Averstad, 1998)).[34] The most serious obstacle was, however, as in the Netherlands, problems in obtaining building permits, and the government did little to alleviate the situation. The cool attitude of policy makers, in the context of the 'nuclear power trauma' (see Box 1) and the great strength of the advocacy coalition favouring the incumbent technologies, continued to block the transformation process.[35]

In the Swedish case of solar collectors,[36] an initial advantage had been created through the exploitation of large-scale projects connected to district heating networks in the 1970s and 1980s. This advantage was, however, lost in the 1990s, largely due to various mechanisms blocking the function 'formation of markets'. The bulk of the limited expansion in the 1990s occurred in the segment 'roof-mounted solar collectors for existing single-family houses.' A first blocking mechanism here was the dominance of the supplier industry by new entrants which were a) disconnected from the networks associated with large scale applications (that was the main receiver of government funding for R&D and connected to academia) and b) characterised by an underdeveloped division of labour as well as craft-like production associated with lack of scale economies. A second blocking mechanism lay in the traditional installation industry – the industry that potential customers contact when they are to invest in new heating equipment – which did not enter the technological system since the legitimacy of solar collectors was weak in that industry and other substitutes, such as pellet burners, heat pumps and electric boilers, were advocated instead. A vicious circle emerged, where high costs; poor division of labour and weak legitimacy obstructed market formation.

Other market segments failed to develop. Particularly serious has been the near absence in Sweden[37] of solar collectors applied in the construction of groups of new single-family houses. The potential of this niche is demonstrated by the Dutch case

33 This first investment subsidy was limited to 250 million SEK (approximately 25 million USD) over a period of five years (NUTEK 1993a & 1993b).

34 Suggestions for a feed-in law for wind turbines had, however, been made earlier – in 1986 by an expert group and in 1989 by the Centre party (a small party that has always favoured renewables).

35 The latest evidence of this is a Parliamentary Enquiry (see SOU (2001)), which had the task of designing a Swedish system for 'green certificates'. In the proposal, a very modest level of ambition was set for renewables, and it was explicitly stated that the expansion would take place using biomass and that any demand for additional wind turbine installations would wait until 2010 (in spite of Sweden having a large potential both on-shore and off-shore in the Baltic sea).

36 The case of solar collectors is based on Bångens and Sinhart (2002).

(Bångens and Sinhart, 2002). In a joint programme, government, municipalities, utilities and industry targeted new residential areas and implemented measures that set in motion a process of cumulative causation. Installers and local consultancy firms were made aware of the technology through campaigns and educated in training programmes. The solar collectors were almost standardised, opening up for economies of scale in production. Two solar collector firms were able to grow, exploit these economies and become strong enough to form alliances with the traditional heating industry, adding legitimacy to the technology. Annual sales have now reached about 30,000 square meters and most of it is in this project market.

In the Swedish case, policy makers did little to improve the legitimacy of the technology, nor to raise awareness or target new segments. Instead, the main policy issue was the high prices of solar collectors, which resulted in a series of subsidy programmes . These were, however, of small magnitude, short duration and on-off character and caused a roller coaster phenomenon, which the industry had difficulties adapting to.

4.2.3. Cumulative causation and challenges for policy

In sum, a central feature of the German wind turbine and solar cell cases is the unfolding of a set of powerful positive feedback loops in the second phase, the origins of which are found in investments made in the formative period. Yet, the transition from a first to a second phase is, by no means, an easy venture. As demonstrated by the Dutch wind turbine and Swedish solar collector cases, an initially successful technological system can be stunted in its further growth. *Setting in motion processes of cumulative causation is, therefore, the key policy objective and involves the fifth and greatest challenge.*

At the heart of a process of cumulative causation lies the formation of markets. A sixth *policy challenge* is, therefore, to implement pricing policies in the second phase which give investors benefits that are powerful (to provide strong incentives and to compensate for the inherently large uncertainties involved (see Section 3)), predictable (to reduce inherent uncertainties to a manageable level) and persistent (to allow for long life times of the equipment and a long learning period). In Germany, the EFL almost fulfilled these conditions. When it was first introduced in 1991, the high remuneration was a powerful incentive for investors in wind turbines. The incentive was also reasonably predictable as it was anchored in a law, but it was not persistent as it was linked to the market price. With the revision of the law in 2000, the incentive was, however, made persistent as the law guarantees a price for 20 years to investors.

The German EFL of 1991 had another drawback (in addition to not being persistent): the remuneration was too low to stimulate a demand for technologies with a higher cost level than wind turbines, in particular solar cells. The impact of EFL on the transformation of the energy sector was, therefore, initially mainly restricted to wind turbines. Whereas it can be argued that the use of a single remuneration level is efficient (in the sense of cost-efficient) it may not be effective (in the sense of inducing a transformation of the energy sector). Clearly, a transformation of the energy sector must be built on a whole range of renewables, which will have different cost levels. Each of these need to go through an extensive learning period, but as argued in section 2, this will not occur if firms are not induced to enter into various points in the value chain and firms need the incentives associated with a market to do so.[38] Forming markets is, thus, a necessary requirement for setting in motion a learning process.

[37] The exception is mainly a roof integrated solar collector developed by a Swedish municipal housing firm together with a building contractor, a university and a consultant firm.

[38] Implicit in this reasoning is that we do not have the time to wait until the presently lowest cost renewable has reached its saturation point before we foster other renewables.

Policy makers are therefore required to use market forming instruments which differentiate between renewables, although the size of the market space and the range of technologies to foster is unclear and may vary between countries,[39] A *seventh policy challenge* is, therefore, to design a regulatory framework that includes giving different prices, and price dynamics, for electricity generated by different renewables. When the EFL was revised in 2000, prices were indeed set at different levels (and with different dynamics) for different renewables (see Box 3).

Yet, economic incentives are not enough. A large obstacle to the diffusion of wind turbines in both Holland and Sweden lay in difficulties to obtain building permits. In Germany (for the north-western states where it is windy), on the other hand, it was stipulated that that if land was not designated for wind turbines, these could be set up anywhere. This had the result that wind zones were designated by local governments where it was easy to obtain permit. In the Dutch case of solar collectors, advanced building norms contributed to the expansion of solar collectors in the 1990s as did efforts to foster a broad awareness and legitimacy for that technology (Bångens and Sinhart, 2002). Institutional alignment therefore goes beyond designing appropriate economic incentives.

5. Lessons for Policy

The purpose of this chapter was to contribute to the policy debate with regards to the management of the process of transforming the energy sector. In the preceding sections, we revealed central inducement and blocking mechanisms for the diffusion of renewable energy technology and analysed the dynamics of the transformation process in both successful and in less successful cases. In doing so, we identified seven challenges for policy. In this section, we will first summarise these challenges and then discuss some problems in meeting them.

The overall policy challenge is to create conditions for processes of cumulative causation to appear in a variety of new energy technologies. Such processes are necessary for the transformation process to eventually become self-sustained, i.e. increasingly driven by its own momentum, instead of being dependent on repeated policy interventions. What these conditions may look like and how they may be created is far from evident, however, but the other policy challenges may indicate at least part of the answer.

The first of these is to create an understanding of each technological system in order to be able to specify technology specific inducement and blocking mechanisms and to influence the system's functional pattern. The latter requires, in turn, policy coordination, which is the second policy challenge. As Teubal (2000, p. 19) puts it "… the policy effort is more complex than what would seem to be the case in a Neoclassical world; and … policy coordination … is an important … aspect of such an effort."[40]

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[39] How much diversity should be fostered (given finite public resources) and how should an eventual selection between emerging systems take place are issues that go beyond the realm of this chapter. In addition, as various renewables gain ground, policy must manage a transformation of the infrastructure so that it can support a growing decentralised power production.

[40] In contrast to what is perceived in the traditional 'linear' view of innovation, the functions of a technological system have to be served simultaneously. This implies that science, technology and market stimulation policies have to be run in parallel, not in sequence. This may apply not only to a formative period but beyond it where policy may need to combine efforts to expand the space for the new technologies with efforts to maintain diversity (Jacobsson et al., 2002).

The third challenge is to begin to contribute to a process of institutional alignment in the formative stage in the evolution of a technological system and the fourth is to induce a variety of actors to experiment with different design approaches.

The final two challenges are related to the transition from the formative stage to a stage characterised by rapid and sustained diffusion of the new technologies. The fifth challenge is to implement powerful, predictable and persistent pricing policies in order to create favourable conditions for investors in renewable energy technology. The sixth challenge is to make sure that these pricing policies are technology specific so that learning may occur in different technologies simultaneously.

These policy challenges are useful in that they formulate the relevant policy problems. However, the difficulties involved in solving them should not be underestimated. We will point to three issues that policy makers will need to deal with in meeting these challenges.

First, policy makers need to achieve an understanding of the complicated and complex structure and dynamics of each technological system. It is *complicated* in that it is empirically difficult to identify, trace and assess the strength of various mechanisms, which induce or block the diffusion process. Even 'simple' relations, such as what blocks the formation of markets, may be obscure. It could be due to a lack of legitimacy, siting problems (for wind turbines), relative prices or a combination of several of these factors (see section 3). It may, therefore, be difficult to understand what to do to stimulate, e.g. market formation,[41] several factors may need to be influenced simultaneously and the outcome of any intervention is uncertain.

The *complexity* of the system is due to the prevalence of feedback loops. Such "… causal inter-relations within the system itself as it moves under the influence of outside pushes and pulls and the momentum of its own internal processes…" (Myrdal, 1957, p.18) are very difficult to predict, which implies that the properties of a new system emerge in ways that are difficult to foresee. For example, in the late 1980s, nobody could have foreseen the formidable success of the German wind turbine industry or the failure of the Dutch only a few years later (see Box 4).[42] Of course, feedback loops make the results of any intervention additionally uncertain. For instance, what effects may a particular market stimulation programme have on firm entry, and what effects will the pattern of entry have on network formation and strength of advocacy coalitions? The German case of EFL (see Box 2) illustrates this uncertainty by revealing how interventions to support one technology had unforeseen effects on other technologies. The owners of small hydroelectric plants initiated the law and gained support in parliament, but the main beneficiaries were the wind turbine owners and the wind turbine industry. Furthermore, the expansion of wind power subsequently helped to pave the way for a revision of the EFL, which provided an opportunity for the solar cell advocacy coalition to (successfully) argue for an inclusion of solar cells in the revised law (see Box 3). The outcome of policy is, thus, difficult to predict.

Second, the time scale involved is very long. In Germany, signs of a self-reinforcing process could not be seen until about the mid 1990s, i.e. after about two decades of activities. After entering into diffusion processes with self-reinforcing features, additional time is required for the emergence of complete technological systems with the capacity to significantly impact on the energy system (see table 1.2). Abatement poli-

41 This was evident in the case of black liquor gasification, in which policy was limited to R&D grants and investment subsidies in spite of the fact that lack of knowledge and economic uncertainty were not the greatest obstacles to commercialisation of the technology (Bergek, 2002).

42 For instance, who could have foreseen that by the time the EFL was questioned, the wind turbine industry would have the political strength to counteract the resistance? How could one have foreseen that the Dutch government would fail to resolve the siting problem?

Box 4: German and Dutch Wind Turbine Industry Developments in the 1980s[a]

In the 1980s, both Germany and the Netherlands developed a set of industrial firms, with experience in building a few hundred turbines. In Germany, about 15 firms entered in the mid-1980s, and 11 firms still existed in 1989. In the Netherlands, 15-20 firms entered in the late 1970s and early 1980s. In the late 1980s, many firms left the industry, and in 1989 the industry consisted mainly of five firms.

On the market side, the German market remained weak throughout this phase; the total installed power was less than 20 MW by the end of 1989. In the Netherlands, an investment subsidy was introduced in 1986, which resulted in a small market expansion. By the end of 1989, the total installed power was 33 MW.

Around 1989, both Germany and the Netherlands designed market formation programmes of similar sizes. In Germany, the federal *100 MW programme* aimed at installing 100 MW of wind power. The Dutch electricity suppliers initiated the *Windplan* project, aiming at installing 50 MW per year over a five-year period. Both these projects were huge in comparison to the then current stock and market size.

At this point in time, the Dutch industry must have seemed as likely to succeed as the German (if not more). The Windplan project was much larger than the German 100 MW programme, and over 90 percent of the first 75 MW were reserved for Dutch firms.

However, whereas the 100 MW programme successfully induced virtuous circles of market growth, increased industry resources and growing political strength,[c] Windplan ended abruptly (in part due to the siting problem) and most Dutch firms failed. Had instead the Dutch been successful with their programme (as many Dutch and foreign firms expected them to be) and the German programme failed (something which was entirely conceivable), the Dutch today could be the ones catching up with the leading Danish industry.

[a] *This account is based on Johnson and Jacobsson (2001b).*

cies, aiming to substantially reduce the emissions of CO_2, must therefore include policies that aim at fostering the formation of new technological systems.[43] Building these new systems requires patience – in order to allow for cumulative causation to appear – and flexibility – in order to be able to adapt to conditions that are bound to change but without unduly increasing uncertainty.[44]

Third, the political struggle over the institutional framework may be intense. Thus, policy makers need to find a strategy whereby they can eventually challenge and overcome opposition from incumbent actors in order to align the institutional framework to the new technologies. Part of this strategy needs to deal with how to foil attempts by incumbent vested interests to capture the state and hinder an institutional alignment simply by having more resources at their disposal than the representatives of infant industries and underdeveloped markets.

Whilst these institutional changes are vital, their scope is limited in a formative period; since the scale of activities is low, incumbents may not see the new technology as dangerous and may, therefore, choose not to obstruct the formation of the infant technological system. In Germany, resistance from utilities emerged only after wind turbines had begun to diffuse rapidly in the first half of the 1990s. This resistance was met by an increasingly powerful advocacy coalition in favour of wind energy, drawing strength from a combination of broad legitimacy for renewables and their growing economic importance. Although it was not an explicit strategy, the German policy used small steps to build an embryonic technological system before the incumbents were challenged.

43 Of course, there are other ways of reducing emissions, such as energy savings. Moreover, the length of the learning period may be shorter for some other technologies, such as biomass fuelled combine heat and power plants.

44 Kemp et al. (1998) underline the role of learning and adjustment in their approach of 'transition management'.

In contrast, in the Swedish case, renewables were put forward as substitutes to nuclear power, not only by environmental groups but also by two political parties, which advocated a closure of newly built nuclear plants. The subsequent referendum on nuclear power held in 1980 (see Box 1) had the clear effect of heightening the awareness of the coalition favouring nuclear power to a perceived threat of renewables, long before these had developed into realistic substitutes. Henceforth, fierce resistance met any policy measure, which could benefit renewables and the 'small thing' of the German EFL could in Sweden well have been a matter leading to the downfall of a government.

Dealing with these three issues requires policy makers to develop a range of characteristics – high analytical competence, in-depth knowledge of relevant technological systems, co-ordination skills, patience, flexibility and political strength – characteristics which policy makers can neither automatically be assumed to have, nor be expected to develop.

Policy makers may, however, gain access to at least some of these characteristics by working with members of different technology specific advocacy coalitions, both private capital and various interest organisations. Industrial firms clearly strengthen these coalitions in terms of knowledge, power and other characteristics. This refers in particular to capital goods firms but also to firms 'downstream.' The expansion of the actor base of the technological system – its enlargement – is, therefore, a vital element in the evolution of the technological system, not only in terms of learning, but also in terms of developing these characteristics within the technological system. Indeed, several German organisations worked with industry representatives as well as with local and federal politicians to strengthen the function 'formation of markets' and, thus, proved to be critical for the evolution of the technological systems centred on wind turbines and solar cells – together they formed *coalitions of system builders*.

Policy makers may, therefore, find it useful to strengthen existing advocacy coalitions by creating favourable conditions for private capital, in particular in the capital goods industry, and to support the work of various interest groups associated with the new technology. Perhaps the main 'output' of the formative stage lies, therefore, in a technology-specific advocacy coalition that can support elements of the state in overcoming various blocking mechanisms. Here lies a strategic role of a national supplier industry. It is strategic not only in that that it can help to educate local customers (Carlsson and Jacobsson, 1991), but also in that it strengthens the advocacy coalitions. With a supplier industry, the 'green' is 'industrialised'.

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The Governance of Transformation in Utility Systems: Challenge and Practice

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1. Introduction

How can the dynamic relationship between society, technology and nature be understood in order to derive operational concepts for sustainable development? How can long-term structural change in socio-ecological systems be intentionally shaped? These are central questions for industrial transformation research. They also form the background to this chapter which discusses some conceptual issues that have emerged from currently ongoing research on the transformation of utility systems in Germany.[1]

The conclusion of this chapter leads into an outlook to a set of new research questions. These questions focus on the process of governance transformation and strategies for governance innovation. The background is a concept of sustainability that is not focusing on questions about the *right state* of production and consumption but on *new ways to deal with uncertainty and complexity* in socio-ecological change. Sustainable development thus refers to the processes through which strategies are generated rather than to their specific content.

I argue that sustainable development requires specific capacities of societal problem treatment which are not supported by a modernist paradigm of problem-solving which is enshrined in the institutional arrangements for management and policy-making in contemporary industrial societies. Conceptual advances that propose ways to achieve policy integration, long-term orientation and learning strategies therefore find it hard to be taken up in practice. These kind of innovations don't seem to fit a dominant pattern of governance, a *governance regime* as it is, which is based on specialisation, short range orientation, prediction and control. The focus of sustainability thus shifts from system innovations in production and consumption systems towards system innovation in the realm of governance.

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[1] The research is conducted within the TIPS-Project (www.tips-project.de) and the MICROSYSTEMS-Project (www.mikrosysteme.org). Both are funded by the German Federal Ministry for Education and Research within its programme on "socio-ecological research" (www.sozial-oekologische-forschung.org).

The argument is developed by first having a closer look at the object of sustainable development: socio-ecological systems and their co-evolutionary dynamics (section 2). This leads me to formulate the problem of shaping sustainable transformation as specified by the complexity of system dynamics, ambiguity of goals and distribution of societal control capacities (section 3) and derive a set of process criteria for sustainable governance (section 4). In combination, these features pose a need to drop the fiction of prediction, clear goals and possibilities of control in problem-solving. Process requirements for sustainable development are contrasted with the rationalist paradigm of management and policy-making which is dominant in modern society (section 5). From this I conclude that processes and institutional arrangements which allow to actively deal with the pluralism of perspectives, interconnectedness of problems and the ubiquity of unintended effects are more important for sustainable development than blueprints of sustainable production and consumption pattern. The final section of the chapter (6) collects some points in sketching out further research on the *innovation of governance* as a prerequisite to introducing sustainable governance practices in the context of currently established governance regimes.[2]

2. Socio-ecological transformation

A first step of research on sustainable development is a conceptualization of the object that we are dealing with. What is it that is supposed to develop sustainably? I propose a few selected conceptual building blocks in this section in order to illustrate the nature of the problem that is at hand when we talk about sustainable development. A starting point for doing this is to have a closer look at the relation between society, technology and nature. How can reality be understood as a compound of elements from these heterogeneous dimensions? How do they hang together and how do they change in mutual interaction?

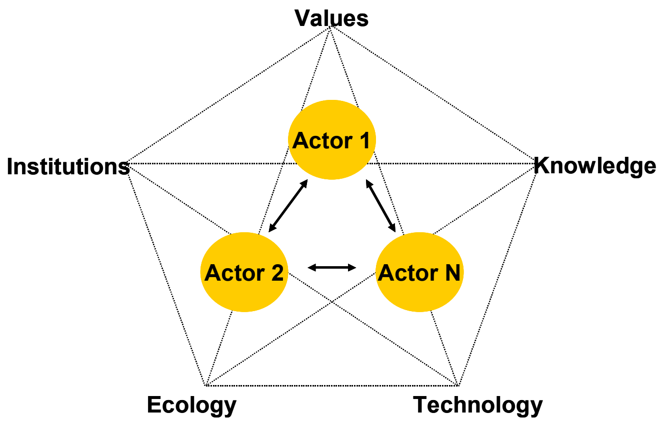
A concrete example is the transformation of utility systems in Germany. It is a process of fundamental structural change which is importantly influenced by a shift in the concept of "public service" and respective liberalisation and privatisation policies which have been implemented in the German telecommunications, electricity and natural gas system in the nineties of the last century and are currently under discussion in the system for water provision and sanitation as well. The transformation process entails far reaching changes in market shares, corporate structures, strategic orientations of consumers, production and consumption technologies, network architecture, institutional arrangements of governance and many other aspects. These ongoing developments are highly interdependent and collectively work towards "heating up" the socio-technical configuration of utility provision and opening possibilities for further change. This happens at a time when, in Germany, about 40% of generation capacity for electricity has to be replaced by 2010, demand for natural gas is forecasted to grow by about one fourth within the next 20 years, investment needs for maintenance of water infrastructure pile-up to 67-100 billion EUR and the volume of data transfers is expected to double within three years. The situation is one in which the regime of postwar utility provision is breaking up when at the same time functional requirements demand a massive build-up of capacity over the coming decades. It is largely unknown where this will lead up to, which structures of utility provision will emerge, which paths of future development will be taken. At the same time, the transformation has a strong impact for the sustainability of industrial society, because utility systems are closely entangled witch broader social, technological and ecological structures. They provide an important infrastructure for production patterns and lifestyles, account for a big portion of economic activity, channel important energy and

[2] These questions form starting points for a PhD project that I carry out at the University of Twente, NL. I appreciate inspiring discussion with Arie Rip and Maarten Arentsen in this context.

substance flows, entail considerable environmental and health risks and comprise some of the most powerful actors in the national governance system. There is a need to shape the course socio-ecological transformation and the resulting structures of utility provision. But how to do it?

For the purpose of having an integrated perspective on the variety of heterogeneous aspects that play a role for long-term structural change in the utility systems we developed a heuristic approach to socio-ecological transformation with elements from co-evolutionary theories of socio-technical change (Rip/ Kemp 1998; Geels 2002b), social ecology (Jahn/ Wehling 1998; Fischer-Kowalski/ Weisz 1998) and ecological economics (Norgaard 1994; Costanza et al. 1999). These theories are connected through a model of social interaction that explains social change in terms of a recursive relationship between agency and structure (cf. Giddens 1986; Mayntz/ Scharpf 1995; Hernes 1995; Ostrom 1999; Coleman 2000). In modification of the standard social science concept of "structuration" where the focus is on institutions (Giddens 1986), it is here assumed that structuration also takes place within the purely symbolic dimensions of societal values and cognitive frames and within the materially bound dimensions of technology and ecology. Thus, a basic framework is constituted for the analysis of socio-ecological transformation that is based on a specific set of actors who are situated within a specific socio-ecological context that is structured along the dimensions of societal values, knowledge frames, institutions, technology and ecology/nature (Figure 1).

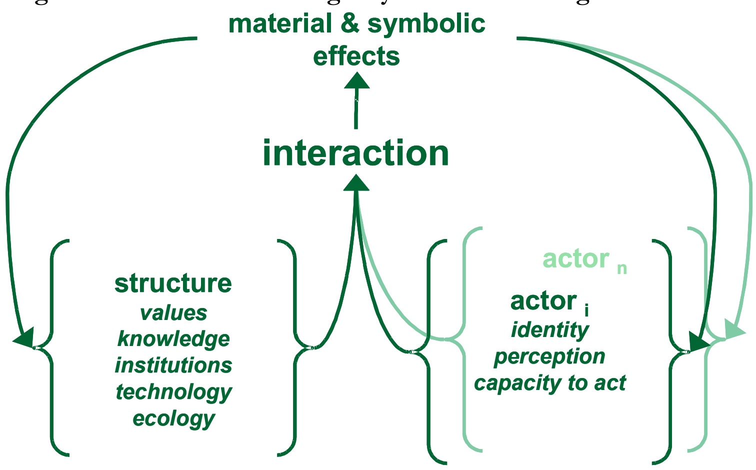
Figure 1: Basis framework for the analysis of socio-ecological systems



For the understanding of change it is important to note that the socio-ecological context structure enables and constraints human agency. There is a cause-effect relationship going from structure to agency. At the same time, however, the structure is being reproduced and transformed by as a result of human interaction. Through this there is a cause-effect relationship also from agency to structure. Observable interaction patterns can thus be thought of as being determined by constellations of interdependent actors (with individual identities, perceptions and action capacities), on the one hand, and socio-ecological structure (consisting of combinations of socially accepted values and knowledge, institutional and technical structures and bio-physical conditions), on the other hand. Within this basic framework socio-ecological change is understood to be caused by the aggregated symbolic and material effects of human interaction. These feed back on the actors themselves (e.g. make them learn) and on the socio-ecological structure. Effects that cause change are mostly unintended results of interaction, e.g. side effects of technology development, public interpretations of scientific findings, delegitimisation of institutions through individual misbehavior etc. Intended steering activities which are pursued by some actors with a view to shape socio-ecological transformation are part of the interaction process and they influence its effects, but due to the complexity of influential factors they cannot control them (cf. Czada/ Schimank 2000). The time, speed and actual course of social-ecological transformation must therefore be understood as an emergent result, that comes "from behind the back of the actors" (see Figure 2 for illustration).

The circular causalities that are involved in the recursive relation between agency and structure constitute the systemic nature of socio-ecological entanglements. The ubiquity of positive feedback relations gives rise to the self-organisation of socio-ecological systems, momentum, inertia, path-dependency and other dynamic patterns which are known from the study of complex systems (Kauffman 1995; Holland 1998; Axelrod/ Cohen 2000).

Figure 2: Recursiveness of agency and socio-ecological structure



The outlined model can serve as a heuristic framework for the analysis of structural change in socio-ecological systems, no matter if they are defined functionally or regionally. For the purpose of our project on transformation in utility systems we focus on the provision of electricity, gas, water and telecommunications in Germany as functionally defined socio-ecological systems. In analysing change we concentrate on the sector level, or "regime level" (Rip/ Kemp 1998) of these systems. But we see that utility regimes are embedded in broader social, technical and ecological macro developments which exert influence on the regime level (e.g. European integration, discourse of Deregulation, spread of ICTs, climate change) and that regime change can also effectively be induced from developments on the micro level of functional niches and particular organisations (e.g. decentralised service provision in remote areas, procurement policies in the public sector).[3] On the regime level we further distinguish between three action fields which have primary relevance for transformation processes: production, consumption and regulation.[4] The fields are not sharply delimited but each comprises a specific network of actors that is aligned under a common func-

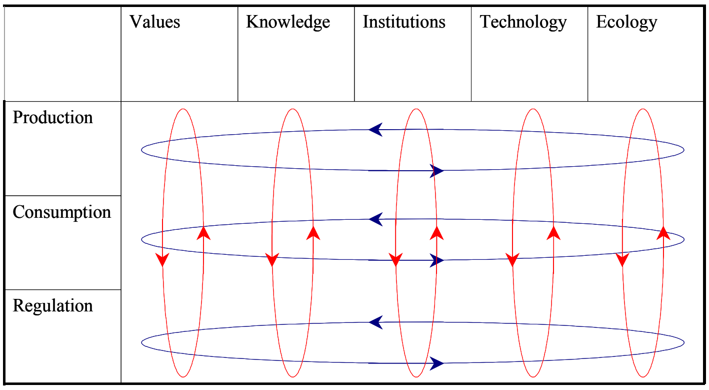
3 That means we only "zoom in" for micro processes within organisations or local niches of provision, or "zoom out" for macro processes on the landscape level of global ideas, institutions, demography, technology or ecology when we find that these are relevant to explain processes of structural change that are going on at the sector level. We believe that a multi-level concept of structural change as presented by Rip/Kemp (1998) and elaborated by Geels (2002b) is useful for studying socio-ecological transformation. Here, we restrict our presentation of the conceptual framework to the regime level.

4 We deliberately put other action fields like e.g. science and media "in the second row", because we believe that they only indirectly influence transformation in the utility systems (through e.g. changing mental frameworks of consumption) or actors from these fields directly take part in production, consumption or regulation.

tional orientation: producing utility services, making use of utility services or regulating the production and usage of utility services. Each field is structured by a specific sub-set of values, knowledge frames, institutions, technology and natural material conditions. As such, the action fields expose autonomous structural dynamics but they are embedded in and part of the socio-ecological structure of the sector as a whole. Their autonomous dynamics are coupled. The provision of utility services, technological innovation or the governance of sector performance comprise interactions between and across the differentiated action fields. The development of new production technologies, for instance, is linked to changing consumption patterns and both are linked to, say a stronger reflection of ecological risks in regulation. Novelty and variation in the established practices of one action field need to find complementary practices in the other action fields to be successfully established. Structural changes in production, consumption and regulation can therefore be observed to unfold in mutual adjustment. The transformation of regimes of utility service provision can be understood as a result of this co-evolutionary process.

Going back to the multidimensional structure of socio-ecological systems we find that co-evolution actually takes place in two different directions. In the first direction it is the various structural elements from the dimension of values, knowledge, institutions, technology and ecology that co-evolve as a result of the interaction processes within a specified action field. An example is the value change from "universal service provision" to "efficiency" in the regulation of utility services which co-evolves with a change in the cognitive framing of "natural monopoly", institutional changes towards the establishment of independent regulatory agencies and technological change towards a more decentralised network architecture. This co-evolutionary process constitutes structural dynamics within the action field of regulation. But co-evolution also and at the same time takes place in a second direction: Structural changes in one action field, e.g. regulation, are coupled with structural changes in other action fields, e.g. production. For the above example it can be stated that value change with respect to universal service is not confined to the field of regulation only, but that it is coupled to complementary value change in the field of production and consumption. In this direction co-evolution constitutes a specific dynamic of value changes that cuts across action fields. Taken together, it is this overlapping pattern of agency-structure dynamics within and across action fields that is behind the transformation of utility systems.[5] We attempt to capture this understanding by using the term "entwined co-evolution". Figure 3 visualizes the concept.

Figure 3: Entwined co-evolution in regimes of utility provision



[5] We have not explicitly looked at multi-level dynamics, yet. If we include the interaction of co-evolutionary processes across scale levels of socio-ecological systems we find that besides a horizontal overlap, there is a vertical coupling into nested processes of co-evolution.

I cannot go into more depth or detail with respect to the dynamics of socio-ecological transformation within the confines of this chapter. Here, the purpose is only to show that socio-ecological transformation is an object of study that easily escapes standard concepts and theories that exclude circular causality, multi-dimensionality, overlap and nested structures from reality in order to arrive at models that can be easily handled. The general characteristic of socio-ecological transformation is that it is a truly complex process that comprises abundant linkages between very heterogeneous elements. It could be said that science is about finding ways to tidy up this mess of real world entanglements in order to present models that allow for a clear definition of elements, cause-effect relationships and prognostic statements since, at last, it is to solve problems for what we do science. My point is, however, that this kind of problem-solving knowledge which tells us what to do in order to reach a given outcome is not available for the problem of shaping socio-ecological transformation. To ignore the complexity and uncertainty that is involved in long-term structural change across the boundaries of society, technology and nature would mean to produce knowledge that simply not adequate for getting the grips on the problem. Indeed, I suppose that overly simple models of reality, strategies that have been derived from them and their forceful implementation is one of the main roots of the problem of sustainable development. For illustration one can refer to examples such as the "green revolution" for solving food problems, nuclear power for solving energy problems, suburbial social housing to solve housing problems etc. (cf. section 3.2 of this chapter).

3. Shaping sustainable transformation

The above outlined concept of socio-ecological transformation provides a backdrop for elaborating the specific challenge of sustainable development as problem of shaping complex structural dynamics. This is taken further in the following section. In particular, three specific features will be highlighted as being constitutive for the problem of shaping sustainable transformation: complexity, ambiguity and distributed control. An unvarnished view on these characteristics reveals particular process requirements that are necessary for adequately dealing with the problem. These are summarised at the end of the section to build a set of process related criteria for the governance of sustainable development.

3.1. Complex system dynamics

3.1.1. Heterogeneous interactions

As briefly exemplified with respect to utility systems, the understanding of socio-ecological transformation implies knowledge about the heterogeneous dimensions of socio-ecological systems such as social values, knowledge, institutions, technology and ecology. It is further important to know how they are related to each other, how they change and how they interact while they change. Conventional disciplinary science does not deliver this kind of knowledge about the "interlinked and complex nature of reality" (Gallopín et al. 2001:228). Instead, it concentrates on analytically constructed "slices" of reality, such as molecular processes, problems of technical construction, social discourse etc. In reality, however, there is no clear borderline between these categories as part of the same world. Each of the specialised perspectives, consequently, defines away the systemic embedding of the analytical abstractions they are dealing with. In specific cases this may be methodologically justifiable because causal linkages are insignificantly weak so that parts of reality can be looked at in isolation without loosing important effects that determine processes in reality. In most cases, however, especially in the area of sustainability problems, linkages will reach well beyond the scope of disciplinary defined problems and models to understand them (Funtowicz/ Ravetz/ O'Connor 1998).

But this does not only relate to the restrictions of disciplinary scientific perspectives, it also relates to the restrictions of science in general to grasp the full set of factors and interactions that are relevant for understanding any specific real world problem-setting. Knowledge production about problems of sustainable development can thus not rely on scientific knowledge that is produced within the institutions and along the methodological guardrails of the science systems. It needs to integrate the perspectives of societal actors outside of the science system. This includes practical knowledge which results from experiences made in daily interactions with reality. This kind of knowledge is often tacit and cannot be used by conventional methods of scientific enquiry. It can only be generated in interactive settings, in which knowledge is co-produced by scientists and actors from respective fields of societal practice.[6]

A first process element of effective problem treatment for sustainable development therefore is to pursue ways of integrated knowledge production which transcend the boundaries between disciplines and between science and society. Practical and methodological steps in this direction are taken under the heading of "transdisciplinarity" (Gibbons 1994; Nowotny/ Scott/ Gibbons 2001; Bechmann/ Frederichs 1996; Thompson Klein et al. 2001; Mogalle 2001; Bergmann 2003).

3.1.2. Uncertainty

If socio-ecological transformation is understood as a process of co-evolution of social, technological and ecological structures, which are constitutive elements for action fields such as production, consumption and regulation, and if these action fields are at the same understood to co-evolve with each other, we face a highly complex compound of interdependent processes. The overall process cannot be analysed by linear models of cause and effect anymore, because feedback is a common appearance. If the process of socio-ecological transformation is further understood as a process which takes place within a multi-level structure of nested subsystems (e.g. local, regional and global level) the interaction between dynamics on each level adds to the complexity of the overall dynamics of socio-ecological systems. The result is that socio-ecological transformation cannot be predicted. The occurrence of positive feedback loops which give rise self-organisation dynamics or destructive resonance is multiply conditioned and may pop up here and there without possibility for safe predictions (e.g. topics in public discourse, social movements, BSE, strategic action under regulation, stock market crashs). The thresholds for catastrophic changes cannot be defined by a single parameter but are determined by a confluence of many factors which cannot all be traced down in order to determine safe levels of activity (e.g. ecological pressure causing a breakdown of ecosystem resilience, social injustice causing upheaval, tax level rises leading into an economic depression). This is a fundamental constraint because of the impossibility to measure all incremental factors (especially the human factor) that play together and because of non-linear system dynamics which may give exactly those apparently minor factors a large say on where the system will go ("butterfly effect") (Gleick 1998).

At the same time this is also the reason why we cannot, for pragmatic reasons, rely on simpler models of the causes which are behind sustainability problems. If we do so, we externalise complexity in our cognitive models while the world stays as complex as it is (Dörner 1989). Inadequate problem constructions then come back in form of unexpected consequences when strategies are implemented in the real world (Böhret 1990). That means that, for processes of socio-ecological transformation, we

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6 An important methodological questions that follows is about who is take part in such processes of interactive knowledge production, which disciplinary scientists and which societal actors.

face fundamental uncertainty about the effects of deliberate interventions by policy or management decisions (Dobuzinskis 1992; Stacey 1996; Walker/ Rahman/ Cave 2001).

The only way out of this dilemma is to stay in it, but do it reflectively: accept that there will always be a high degree of ignorance and uncertainty connected to societal action within socio-ecological systems. Unintended consequences will prevail, because no comprehensive and exact model for the prediction of socio-ecological dynamics can possibly exist. With growing impact linked to increasing scale and depth of human intervention a high probability of unintended consequences needs to be taken as a central condition of problem-solving strategies. This would mean that ignorance and uncertainty are actively dealt with and are not blocked off in order to pretend to have a practicable solution at hand (Stirling/ Zwanenberg 2002; Dobuzinskis 1992).

Because no secure knowledge can be acquired to predict socio-ecological system behaviour and the effects of human intervention, a second process requirement for the adequate treatment of sustainability problems is an adaptive design of strategies and institutional and technological structures. This would entail the capacity to respond to unexpected developments. Strategies should feature experimentation, monitoring and evaluation in order to systematically work with new experiences, altered interpretations and changed circumstances.

3.1.3. Path-dependency

While effects of human action are not entirely predictable they occur all the time and they feed into a continuous process of socio-ecological transformation. It is human action that shapes socio-ecological transformation, even if not intended. This happens through ongoing structuration processes which are not only linked to policies or other strategies that are explicitly aimed at inducing structural change but also to the daily conduct of production and consumption routines.

Changes in one element of socio-ecological systems are accompanied by changes in other elements. Within and across social, technological and ecological subsystems there is a constant generation of novelty and adaptation which induces further novelty and adaptation in response. This process may sometimes be so incremental to be non-conceivable, sometimes it may be very radical and rapid. A certain degree of stability is maintained as long as a specific configuration of elements play well together in bringing about systemic performances which meet the capacities and requirements of components within the system and outside of it. The System is then in dynamically stability because it produces outcomes which reproduce its structure (Geels 2002a).

An example are electricity systems. They comprise a specific configuration of culture, organisational rules, technology, geographical conditions and different types of actors. These elements play together in specific process patterns and deliver a certain performance with respect to service provision and side effects. The electricity system in Germany showed 40 years of relative stability after the second world war. Only towards the end of the last century turbulent changes occurred. An important source of this fundamental transformation are institutional changes which introduced competition to the market. This change has triggered other changes, e.g. in investment behaviour and technological innovation as well as the cultural meaning of electricity and consumer behaviour. Further changes in actor constellations, corporate organisation, technology, resource requirements and ecological impact are to be expected. Yet, it is highly uncertain how they will look like. These changes may again induce adaptations of regulatory institutions. At the end they may lead into another stable configuration which only changes gradually and very slowly over some decades - as it was the case for the phase after the second world war. But they may as well perpetually feed into new structural adaptations and not find a new dynamic equilibrium. The crucial point is that the future structure of electricity provision, be it relatively stable or fluent, emerges from present processes which receive their dynamics from societal action. The future structure of electricity provision is being shaped by what we do today. Depending on how this structure will look like it will entail specific social and ecological impacts. And it will entail specific opportunities and restrictions for actions to deal with these impacts. What we now do about electricity - buying electricity, drafting regulations, investing in technology, discussing public concerns etc. – thus shapes the future performance of electricity provision and the conditions under which problems can be treated that appear later on. This is an example of the path-dependence of socio-ecological transformation. It puts large weight on decisions and actions that seem to be of minor importance today, because their aggregated and accumulated effect may be of major importance for what is possible tomorrow. The point is that, in the course of socio-ecological transformation, we are constantly shaping the future, consciously or not. Future developments which are induced by today's problem solving are not easily discernible, but they are largely irreversible.[7]

Sustainable development therefore requires a careful anticipation of the long-term effects of present actions. Due to the complex dynamics of socio-ecological transformation these effects cannot be predicted with certainty. Anticipation rather refers to an explorative evaluation of alternative development paths that may be spurred by the actions that are taken today. The general aim is to explore future opportunities and to avoid lock-in to trajectories which withstand the achievement of sustainable development. Such processes can, for example, be based on scenario construction, participatory modeling or policy exercises (Godet 1987; Ringland 1998; Asselt et al. 2001; Elzen et al. 2002).

3.2. Sustainability as a strategic goal

Sustainable development is often referred to as a normative orientation. Generically, however, it refers to a functional relation. Sustainability can be defined as a state in which something can be sustained, can be kept in existence. Sustainable development thus is a type of development that does not erode its own fundaments. In this perspective, sustainable development is a normative criterion only in so far as it implies a value decision to sustain societal development on earth rather than to annihilate it. Sustainability can hence be defined as "the long-term viability of socio-ecological systems".[8] On this level, not surprisingly, there is overwhelming social consensus. The crucial question then is: *How* can societal development be sustained? In order to know which practices can serve to sustain societal development it will be necessary to assess their *long-term systemic consequences*. This requires knowledge about social and ecological systems, the ways in which they are coupled, dynamics of their develop-

[7] For an example from the electricity system one could speculate that a forceful promotion of distributed generation could eventually lead into a gradual dismantling of the long-distance transmission grid. From today's perspective this may seem to be a sustainable path of transformation. It may be, however, that within a few decades solar power generation in North African deserts turns ot to be the most cost efficient and ecologically sound way to provide electricity to Western Europe. The social and technical infrastructure which would be needed to implement high voltage power import would not be at hand anymore so that this option for electricity provision would effectively be locked-out by then consolidated structures of decentralized electricity provision.

[8] Also the political operationalisation of the concept by the Brundtland Commission with its reference to inter- und intragenerational justice: "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" can be interpreted in functional terms. The fulfilment of needs, self speakingly, is something that is needed for the continuation of society. If needs are only fulfilled for some, the resilience of social system is endangered by distress and conflict. Open questions, however, still are: What are the relevant needs, what will they be? How are they met? Which factors comprise the ability to meet them?

ment and the factors that influence it. As such, sustainability is clearly an analytical question, not a normative one.

In spite of the analytical content of the concept of sustainable development, however, specific practical problem features impede an "objective" scientific clarification:

(a) The fundamental limits to predict socio-ecological system behaviour mean that there can be no secure knowledge about the dynamics (and resilience) of societal systems and ecosystems. It may be possible to determine ranges of parameters within which system behaviour can be predicted with satisfying probability. These may be used to define "corridors of sustainability" within which dangerous system change can be avoided (for e.g. emissions, rate of inflation). In practice, however, sustainability assessment almost always deals with parameter changes at the fringe of so defined sustainability corridors. On these issues uncertainty is high and risk evaluations become decisive. The readiness to take risks, however, is a subjective disposition which differs between actors and different situations and cannot scientifically be decided.
(b) The dynamic stability of social systems depends on subjective evaluations of the actors who constitute the system. Societal systems, be it nation states, organisations or families are stabilised if the perceived situation of actors matches their identity and values. Values are thus an endogenous component of socio-ecological systems. Values changes, on the other hand, can shift requirements for sustainability.
(c) People hold different values and decide differently if they evaluate options. Even if everybody generally agrees on what is good and what is bad there will be differences in the weight that is given to certain values. This is particularly relevant for sustainability assessment since equally legitimate goals (such as social justice, reduction of environmental risk, economic viability) can only seldom be achieved at the same time and to the same degree. Value trade-offs are a common characteristic in the daily practice of sustainability assessment. The different ways to make these trade-offs effectively feed social dispute about what is sustainable and what is not. These disputes, however, can less be solved scientifically but rather through social discourse or political decision.

Taken together, sustainable development necessarily remains a contested concept. Its substantial content (i.e. definition of the parameters of socio-ecological systems that have to be met to sustain development) cannot scientifically be determined as "objective knowledge" but will always incorporate normative valuations which are ascertained in processes of social interaction. To a certain degree political institutions may have the legitimacy to decide on matters of values and risk. But when it comes to actions with potentially irreversible and large scale impacts, decisions which in fact have an existential meaning for human life on earth, the legitimizing function of democratic government may indeed be overstrained. When sustainability is taken as an orientation for societal action it will therefore not be lend itself to be resolved into a clearly defined goal but always deliver a variety of ambiguous goals. It may not be possible to eliminate the inherent discrepancies that exist between different goals or to define a clear ranking order by way of rational argumentation and empirical evidence. Social conflicts are inherent to the concept and need to be carried out with it.

Another aspect is that sustainability goals cannot be determined once and for all. Because substantial notions of sustainability are build on the basis of uncertain knowledge and social evaluation, they must be expected to change over time. Knowledge about socio-ecological system dynamics changes with scientific progress and new experiences being made. Values, on the other hand, are endogenous to the process of socio-ecological transformation. They may change, exactly because they are successfully being followed. And there is no way to know, what the needs of future generations will be.

Sustainability thus is a "moving target" which can only be followed through processes of iterative participatory goal formulation. Sustainability goals and assessments cannot be determined by principle once and for all, but only through iterative processes. The broad participation of affected societal actors in the process of goal formulation is necessary because their values are constitutive to the sustainability of social development.

3.3. Strategy implementation

A third feature of shaping sustainable transformation is related to the implementation of strategies. Even if certain predictions about socio-ecological system behavior and clearly defined goals were given, so that "best strategies" of intervention could be derived, there would still be specific difficulties with the implementation of strategies to shape transformation. These refer to the fact that capacities to influence the speed and direction of socio-ecological transformation are distributed among many different actors. In order to take effect their actions would need to be coordinated along the lines of a collective strategy. There is no one point from where processes of socio-ecological transformation can be steered.

The distribution of control capacities is surely not an exclusive feature of sustainability problems. It is a general characteristic of governance in modern societies. The shift from government to governance in talking about societal management reflects growing awareness for the fact that capacities to take influence are distributed between different governance levels (e.g. nation states and the EU) as well as between functional domains, such as production, consumption and political regulation, and between different actors within these domains (Kooiman 1993; Schneider/ Kenis 1996; Rhodes 1997; Mayntz 1998; Kohler-Koch/ Eising 1999). These conditions have to be taken as a starting point for strategy formulation and implementation. There are situational differences in how dispersed capacities of governance really are and in how far one actor (e.g. the head of government) or a small coalition of actors disposes over sufficient power to make other actors follow certain strategies. The situation is, however that the coordination of actors cannot be taken for granted, but that it needs to be established for any specific problem anew.

Problems of shaping sustainable transformation are a kind of problems for which a very high degree of distributed control capacities can be stated. The reason is that innovation and structural change are highly contingent upon a multitude of different factors. These are in the hands of many different actors. Overarching competencies and procedures for shaping structural change are not established. Public actors are but one type of actor among others, albeit equipped with democratic legitimacy as a special source of power. Moreover, the competencies of the state are fragmented into several agencies such as governmental departments, regulatory agencies, political parties etc.

The "de-factor" governance of transformation thus appears to emerge from the daily interactions between consumers, producers, policy-makers and various other actors such as researchers or journalists – without anyone controlling it (cf. Rip/ Groen 2002). The diverse actors involved in transformation follow their own vital interests, partly in cooperation and partly in conflict. And they each dispose over specific resources to enforce their strategies. Transformation, finally, is the result of the intended and unintended effects of these interactions. In contrast to "normal" policy or management arenas the governance of transformation is neither an instutionalised policy field nor are stabilised policy networks in place, yet, which comprise the relevant actors who have influence on transformation.

Due to the many roots of socio-ecological transformation distributed control capacities have to be taken into account in strategy development. For the shaping of transformation processes it is necessary to coordinate the action of a broad range of heterogeneous actors. Such coordination cannot rely on hierarchical modes of control but takes place in heterogeneous governance arrangements which comprise elements of negotiation, market and hierarchy. Problem perceptions, interests and practical knowledge of the various stakeholders need to be linked together in processes of interactive strategy development.

4. Criteria for sustainable governance

The above mentioned specifics of the problem of shaping sustainable transformation and derived strategy requirements can be compiled into a set of criteria for sustainable governance. Such criteria do not refer to specific targets that should realised or to the substantial content action strategies but to the very process and the institutional arrangements through which strategies to shape transformation are developed.Table 1 gives an overview on the criteria that have been derived in course of the above discussion.

Table 1: Process criteria for sustainable governance

Aspect of Problem treatment	System analysis			Goal formulation	Implementation
Specific problem features of sustainable transformation	Co-evolution of social, technical, ecdological elements across multiple scales	Uncertainty about system dynamics and effects of intervention	Path-dependency of structural change, high societal impact	Sustainability goals involve value trade-offs, are endogenous to transformation	Capacities to influence transformation are distributed among actors
Strategy require-ment	**Integrated knowledge production**	**Experiments and adaptivity of strategies and institutions**	**Anticipation of long-term systemic effects of measures**	**Iterative, participatory goal formulation**	**Interactive strategy development**

If the complexity of socio-ecological systems, ambiguity of sustainability goals and distributed control capacities are taken as unavoidable starting points for the development and implementation of sustainability strategies, there occurs a shift in focus from questions directed at defining the right way of energy or water provision, agriculture or transport to questions about the design of processes which provide effective guidance in searching for sustainability (Minsch et al. 1998). This leads us to ask if we have the right institutions in place that create integrated and long-term problem perceptions, abilities to respond to unexpected dynamics, learning from experience and foster capabilities of self-adaptation. The set of criteria for sustainable governance can be used as orientation for the development of methods and institutions to shape transformation, and they can be used to assess current governance processes with respect to their adequacy for the problem of shaping sustainable transformation. They are briefly worked out in the following paragraphs.

4.1. Integrated knowledge production

Treatment of sustainability problems needs to be based on integrated concepts of the problem itself and the system context in which it is embedded. This refers to scientific knowledge production across disciplines and consideration of practical knowledge held by societal actors. It also refers to the development of integrated perspectives in defining policy problems, conceptualising its causes and effects and assessing possible intervention strategies.

4.2. Adaptivity of strategies and institutions

Because of the impossibility to predict socio-ecological transformation there can be no best solution defined ex ante. A strategy needs to be seen as a hypothesis about the problem and its solution. Policies should therefore be designed to test this hypothesis. This entails that the test is thoroughly monitored and that policies can easily be adapted according to test results. Responsiveness and adaptivity of strategies and institutions could serve as procedural criteria for sustainability assessment.

4.3. Anticipation of long-term systemic effects of action strategies

Within socio-ecological system dynamics effects may appear detached from their causes. Important repercussions often occur where they have not been expected and long after the triggering actions have been carried out. Narrow problem definitions and short time horizons are therefore likely to exclude important effects. A specific aspect with respect to socio-ecological systems are lock-in effects which may be the result of a neglect of the path-sensitivity of decisions at points where small interventions may cause large results. Sustainable governance systematically needs to anticipate the indirect and long-term effects of pursued action strategies, especially with respect to structural lock-in. Explorative scenario methods can be a method in case where complexity forbids analytical modeling.

4.4. Iterative participatory goal formulation

Sustainability goals can for generic and practical reasons not be defined "objectively". The ascertainment of the necessary conditions for long-term viability of socio-ecological systems involves subjective risk perceptions and value trade-offs that cannot be decided by scientific methods or political decision but only through social discourse. Moreover, values are themselves a constitutive element of the resilience of social systems because they determine social needs. As such they may change in course of transformation processes. Sustainability goals thus constitute ambiguous and moving targets. This needs to be taken into account by way of participatory processes for formulating sustainability goals. Goals need to be regularly revised in order to adapt to changing values and knowledge in course of transformation.

4.5. Interactive strategy development

Socio-ecological transformation is an outcome of dispersed social interactions. Interactions cut across institutionalised policy fields and action fields such as production, consumption, regulation, research or the media. A broad range of heterogeneous actors is involved who follow their own interests and dispose over specific resources of influence. Government and other public actors are but one type of actor among many, albeit equipped with political legitimacy as a special source of influence. In order to shape transformation diverse actions have to be aligned for a collective strategic goal. Strategies therefore have to be developed in interaction with relevant stakeholders in order to integrate their know how and assure support for implementation.

5. Rationalist problem-solving and modern governance

The process features of sustainable governance that have been outlined pose specific requirements to institutional arrangements. When looking at institutional arrangements and the status quo of problem treatment in industrial societies it appears, however, that they follow quite different lines. The difference becomes clear when the criteria for sustainable governance which have been elaborated above are contrasted with currently established patterns of management and policy-making and their underlying paradigm of problem-solving.

The ideal of the modern approach to the world is to strive for rational coherence based on the assumption of a uniqueness of truth and universality of knowledge. If these assumptions are taken for granted it is a matter of clarification of goals, thorough analysis and choice of right instruments that makes problem solving successful. Great achievements are built on the cultural victory of the rational approach. It provides a common bottom-line and a stable reference framework for scientific and technological exploration, political discourse and even the handling of personal relationships. As such it helped to civilise society and gain control over large parts of nature.

But rationalisation also has a price. Rational order is not a generic feature of the world but it needs to be constructed by human cognition. The vast network of causes and effects which constitutes the real world beyond human perception must be shrunk and sliced in order to make it rationally accessible. Finally, this leads to the construction of problems in a way that they can actually be solved in a rationalist way. This orientation has obvious advantages in developing powerful levers to take effect on nature, motivating straight forward action and, not least, providing a common frame of reference for reasonable discourse. This modernist ideal proved to be appropriate for very many problems. However, it also has its specific limitations. Rationalist problem construction essentially works by externalisation: The order inside of a cognitive model is the result of leaving out the vast majority of factors that take effect in the real world. This holds true for physics as well as economics and psychology and it also holds true for more practical models such as those underlying the farmer's weather forecast or the politicians campaign strategy. The cognitive externalities only show effect when strategies which are derived from the model are actually implemented in the context of the real world. Then they appear in form of unintended or even unexpected effects. These may cause new problems or even turn against the original problem-solving intention. The paradox of rationality thus is that the motivation of getting the grips on the world may turn against its own ends: When the ambition to make things clear leads to ignorance and neglect of relevant aspects of reality, it may trigger actions which cause even more disorder. Such an approach is apt to produce new "second order" problems at the same time as it intends to solve problems (Jahn/ Wehling 1998). When these second order problems become more severe than the ones that are actually solved, it deems that there is something irrational about rationalist problem-solving. Global environmental change, soil degradation, poverty and adverse effects of globalisation and other issues of sustainable development are examples of second-order problems. They are caused by rationalist approaches to solve problems of energy and food provision and economic development. The ideal of rationalist problem-solving is starting to crumble in light of these experiences. But it is still deeply rooted in social expectations towards policy-makers and managers and in institutionalised procedures of societal problem treatment.

5.1. Functional differentiation

A general pattern of modern societies is functional differentiation (Luhmann 1990; Mayntz et al. 1988; Schimank 1996). From the early separation of the church and the state the momentum of differentiation takes effect. It leads through to the departmentalisation of policy-making, the disciplinary split of scientific knowledge and branching of ever more specialised professions. Differentiation is essentially a process of slicing up the world. Its main cognitive driver is that it allows for a reduction of complexity to be considered in carrying out professional communication and action. As such it allows to extend the application of rationalist problem-solving approaches.[9]

The patterns of differentiation are deeply rooted in the structures of society and they are difficult to transgress. Experiences with policy integration, inter- and trans-disciplinary research and economic innovation networks exemplify the practical difficulties in crossing the boundaries. These are linked to differentiated theories, language and habitual styles, differentiated perceptions of relevance and feasibility of strategies, competition over resources and other factors. In many cases it is indeed two or many different social "worlds" that incompatibly stand beside each other.

5.2. Short-term orientation

Another structural aspect of modern society are loosened personal bondages and increased mobility compared to traditional forms of living which were prominently structured by clan membership and local residence. People move across space and social networks, live in different cities on different continents, change friendships and work with different organisations. This means a higher degree of personal freedom and a reduced obligation to stick with certain social relationships. But with it comes a general loss of liability and the need to introduce more sophisticated means of social control than communal norms and trust. For professional roles specific procedures of evaluation have been developed. Politicians are assessed through elections, managers through the shareholders of their company. This works to make them accountable and control their work to a certain degree. However, it also introduces a short-term perspective to their strategic behaviour. Against the background of the paradigm of rationalist problem-solving they are expected to deliver solutions within the time-frame of their assessment period, usually not more than 5 years. If they do not succeed, they are out.

Another aspect feeding the short term orientation in professional decision-making is that, in order to make rationalist problem solving possible, it is necessary to reduce uncertainty. The array of unexpected things happening, however, increases rapidly with the time horizon taken that is taken into account. This is a factor that systematically favours problem definitions and strategies that cover only short time periods. The more strategies are built on linear implementation plans without allowance for adaptation but only the possibility of failure, the stronger is this effect. Especially in the economic system, but also in the domain of politics and social relations, strategies thus tend to be concentrated on projects with short pay-back periods.[10]

Beyond both features, functional differentiation and short-term orientation, and their linkage to the paradigm of rationalist problem-solving many more structural specifics of the current governance regime in modern societies could be highlighted. These are, for example, competitive orientations in party politics or markets which work to impede the realisation of cooperation benefits, veto positions in informal

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9 The more aspects of the real world are excluded from theories about human behaviour, for instance, the more encompassing and sophisticated models of economic development become possible and instruments appear feasible to control it.

10 Financial interest itself is another institutionalised form of the short-term as it systematically diminishes values when they occur in the future.

policy networks which are occupied by powerful actors who can dominate collective action, sovereignty of nation states contrasting the global scale of problems etc.

At first sight it appears that the dominant patterns within the configuration of governance in modern society contradict the criteria for sustainable governance in some important respects. Most clearly is the opposition of the modern paradigm of rationalist problem-solving with the uncertainties involved in complex socio-ecological transformation. Specifically, the momentum of functional differentiation contrast with the requirements for integrated knowledge production, participative goal formulation and interactive strategy development. The institutional embedding of short term perspective in political election cycles, management perspectives and interest rates hints at a mismatch with the anticipation of long-term effects in strategy development.

6. How to innovate governance?

Against the background of the rationalist paradigm of problem-solving and the structures of current governance regimes it deems important to have a closer look at the realistic prospect of sustainable governance. Which are the conditions for sustainable governance to gain ground and become implemented in the daily practice of societal problem treatment? How can new modes of governance be introduced within the context of existing regime structures? From this perspective sustainable development appears as a challenge to innovate governance.

Several approaches have been developed over the last years with the aim to improve societal problem treatment for sustainable development. Many of them follow similar lines of reasoning as contained in the criteria discussed above. Some of these approaches are not yet more than vague programmatic strategies like policy integration, transdisciplinary research, integrated assessment etc. Some of them, however, are already quite elaborate with respect to specific methods and procedures through which they can be applied. In some cases implementation experiences have been made. Examples of the latter are green cabinets and sustainability councils for integrated long-term strategies, participatory research methods like focus groups and scenario workshops, interactive technology assessment and new forms of prospective strategy processes such as foresighting and transition management.

Some of the experiments that have been carried out on the basis of these conceptual approaches can be observed to work quite well. In these cases it seems possible to implement sustainable modes of governance under the conditions of the prevailing governance regime, at least to a certain degree. The Dutch transition management programme, the British sustainable energy policy network, the German socio-ecological research initiative, European foresight exercises etc. could be cited as successful examples of introducing more integrated, learning oriented approaches – although all of them are pretty recent and only have a short record of experience. Many other attempts fail at different stages of the innovation process. Either the problems with established ways of dealing with sustainable development do not even become a topic of discourse or alternative approaches cannot gather sufficiently strong actor networks for further development or they become frazzled in the course of implementation. The success of governance innovations for sustainable development obviously depends an many factors from the cultural, institutional and technological context, the actor constellations and on the innovation strategies that are pursued by the actors in each case.

As a hypothesis from the briefly outlined characterisation of modern governance it can be expected that many unsuccessful attempts at innovating institutional arrangements of societal problem treatment suffer from a lack of fit with the dominant governance regime. Yet, there is little knowledge on these aspects of innovating governance. Institutional and policy innovation for sustainable development is either simply referred to as something that ought to happen or it is merely being reported as a phenomenon that appears in comparative studies. Very few studies go into the details of the respective innovation processes, so that little is known about the evolution of innovation strategies for sustainable governance. Some work in the area policy studies dares a closer look at the birth and lifecycle of political reforms, but the analysis usually is restricted to a set of variables that is limited by the disciplinary perspective of political science which cannot sufficiently grasp the entanglement of governance in the context of socio-ecological transformation.

I therefore end the contemplations of this chapter with a brief outlook to further research on governance innovations for sustainable development. For this purpose I present possible directions that this kind of research could take.

- Research on governance innovations takes into account the embedding of processes of societal problem treatment in socio-ecological system contexts. An analytical framework that is restricted to actors and institutions, as is dominant in political science, may not be able to adequately consider the influence of cognitive frames, technology development and ecological conditions for changing governance patterns.
- For a dynamic understanding of governance, steering activities need to be seen to be endogenous to socio-ecological transformation. Governance is not somewhere outside or above the socio-ecological systems in which transformations take place (e.g. electricity systems, food production, geographical regions) but it is part of it. This is important for not to overlook how governance itself is conditioned by the social, technological and ecological structures of the area to where it applies. When governance induces changes in these structures it also induces changes in the conditions for its own working.
- Dynamic concepts of governance should not focus too much on the identification of general patterns or even universal theories of change. They should rather be open enough to give due recognition to the many contingencies that are involved in social and institutional change processes.
- The study of governance innovations may be able to make use of co-evolutionary concepts and theories from the field of innovations studies and socio-technical change. By drawing analogies between technological and institutional innovation some helpful concepts may be derived and interesting hypotheses may be generated.
- It could, for example, shed new light on the conditions under which institutional innovations occur, if they were, similar to technology, be conceptualised as "configurations that work" (Rip/ Kemp 1998). This would mean that they comprise a specific combination of values, knowledge, institutional rules, maybe also technology and elements from the natural environment. Innovations processes would then require complementary changes within these heterogeneous dimensions to be successful.
- Against this background "innovation journeys" of new governance arrangements can be traced by detailed case studies which could work with concepts that are known from technology studies such as "alignment", "momentum", "reverse salient", "hot phase and cool phase", or possibly a phase heuristic that comprises invention (idea), development (concept) and diffusion (implementation).
- It could be worthwhile to apply a multi-level framework of niches, regimes and landscape which has been developed for analysing socio-technical change (Rip/ Kemp 1998; Geels 2002b). An adapted concept of "governance regime" could be helpful in explaining institutional path-dependency and lock-in, but also patterns of governance transformation. This concept could be linked up with existing con-

cepts from political science such as policy style, political culture, political system etc. and add a dynamic component.

- Finally, various strategy recommendations which have been drawn from a multi-level, co-evolutionary analysis of socio-technical change, could be used to explore the ways in which societies could reflexively innovate their own governance. Among these are
    - A general orientation towards learning and modulation rather than achieving prediction and control
    - Active experimentation, management of niches in which a diverse portfolio of governance modes is tested and further developed
    - Contextualisation of governance innovation processes by establishing nexus arrangements for the integration of perspectives of various stakeholders. This would help to take socially robust paths of governance innovation.
    - Participatory formulation of performance criteria for sustainable governance and development of long-term visions, road maps of how to get there, including monitoring and a regular revision of criteria, visions and road maps.
    - Establishment of a "social innovation policy" including social science R&D, support for social innovation networks which comprise researchers and "institutional entrepreneurs", support for niche experiments and adaptation of framework conditions, institutional innovation impact assessment.

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Resource Ownership in Drinking Water Production. Comparing Public and Private Operators' Strategies in Belgium

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The increased demand of goods and services based on water resources - be it for production (e.g. industrial process), direct consumption (e.g. drinking water), absorption of pollutants (e.g. dilution of wastewater) and other immaterial (e.g. river landscape) or ecological services (e.g. habitats for fauna) - has resulted in competing use, increasing scarcity and reduction of renewability. Any number of examples can be provided to demonstrate the ongoing degradation of water bodies and, in particular, aquifers (Gleick 1993; Postel 1997; European Environmental Agency 2003; World Water Development Program 2003).

Water management is influenced by various institutional rules and social norms, which represent both constraints and opportunities for the behavior of rival water appropriators. In this chapter, we focus especially on formal property rights (PR), on specific water bodies and on public policies (PP) regulating sector-specific exploitation (e.g. irrigation) or protection (e.g. pollution from agriculture) of water resources. We analyze how these two types of institutional rules (PR and PP) influence the strategic behavior of public and private water operators producing drinking and mineral water from an aquifer and, thereby, the sustainability of past and current water management. From a theoretical point of view, we adopt the perspective of actor-centered institutionalism (Scharpf 1997). In other words, we pay close attention to the capabilities of water operators to mobilise, in a given hydrological context, institutional rules in order to secure water provision.

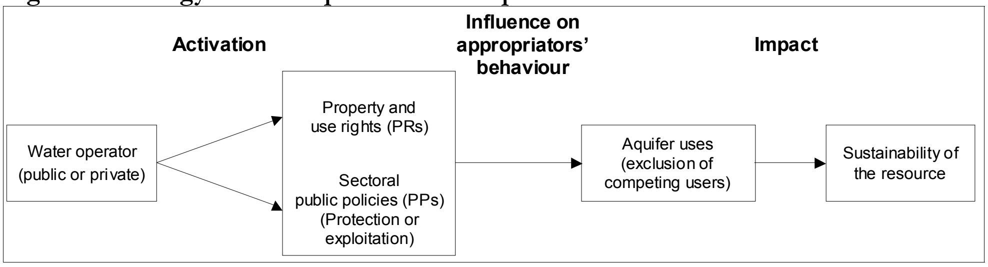
This article asks if the ownership status of the water operator determines its strategy of access to the resource. More concretely, what are the strategies implemented by water operators to secure drinking water provision in the long-term? Does the public or private status of these operators influence them directly? Do operators mobilize property rights and public policies in a similar way? What are the impacts of this mobilization on the resource exploitation, on the exclusion of competing users and, in the end, on resource sustainability? Such questions are very touchy as they trigger a vivid political debate about the liberalization and privatisation of water services (Finger and Allouche 2002). Furthermore, they feed theoretical debates about the respective effectiveness and efficiency of resource regulation through tradable property and use rights, regulatory policy instruments (e.g. permits, bans) or voluntary tools (e.g. negotiated agreements).

As we intend to assess the relative importance of PR and PP on the sustainable use of water resources, we first review the main hypotheses formulated on these topics (Part). Then we analyse two concrete cases of aquifer exploitation in Belgium from 1880 onwards (Part): drinking water production by the public-owned Brussels Water Company and mineral water production by the private company Spa Monopole. The systematic comparison of these two historical cases studies (Part) sheds a new light on the influence of the operators' ownership on resource use and sustainability. The comparison shows that the operators' strategy is identical. Whatever the ownership status (public or private), they attempt to privately appropriate the resource. The key objective of the operators is to maximize their security in resource provision, by systematically excluding all other local users. The theoretical implications of such a finding are that a combined theoretical approach (PR and PP) is necessary to analyse water users' behavior as well as a dynamic perspective on institutions, including the informal arrangements that facilitate their mobilization and enforcement.

1. Institutional rules orienting operators' behavior (in Belgium)

An aquifer provides different goods and services: drinking water, water for irrigation, water for industrial process, water as a sponge for pollution, etc. Thus, each aquifer's situation can be characterized by the number and type of (potential) beneficiary groups. It is quite obvious that socio-economic and socio-cultural factors play a key role in what is and what is not defined as – a good and service of - an aquifer. Furthermore, it is very common for different users to compete for heterogeneous goods and services provided by the same aquifer (e.g. conflict between farmers and drinking water companies). In order to collectively solve these rivalries and to tackle the problem of resource scarcity, several institutional mechanisms have been gradually defined and implemented by the State or directly negotiated between the water users themselves. From an institutional perspective, it is therefore crucial to identify these rules-in-use and to examine their impact on both water users and resource sustainability. Our theoretical framework relies on important contributions provided by institutional economics and policy analysis on this issue. We postulate a series of causal links between the mobilization of institutional rules by the water operators and the sustainability of the resource that we investigate in the empirical field (see Figure 1).

Figure 1: Strategy of water operators and impact on water resources



In a word, we suggest that a (public or private) water operator can choose, combine or even create various institutional rules (PR and PP) in order to exclude competing users from the aquifer exploitation. Furthermore, the sustainability of the resource management depends upon the effectiveness and efficiency (for the exclusion of rival appropriators) of the institutional mechanisms concretely at work.

1.1. Public versus Private Water Operators

The strategy of the operator consists mainly in mobilising institutional rules. The literature suggests that the behavior of the operator is influenced by its legal status. But does the legal ownership status of the water operator determine resource property? In water management studies, much confusion exists between the status of the operator and the status of the resource. The privatisation of the operator is often considered as a privatization of the resource, and respectively the public resource property is often deducted from the public status of the operator. On the one hand, the tenets of the privatization of water provision consider that a public body is unable to manage the resource efficiently (Winpenny 1994; Brubacker 1995; Anderson and Hill 2001). When considering the resource, they talk about tradable property rights on water. But when they refer to drinking water supply, they forget that the operator, be it public or private, must have guarantees on resource access. On the other hand, the advocates of the public water management are confused as well, while sustaining that only a local public authority is able to effectively protect the resource (Petrella 2001; Shiva 2002). They also forget that public water supply does not necessarily mean that the resource is under public property. These kinds of commitments must not hide the actual institutional mechanisms (PR) that guarantee access and exploitation of the resource by the water operators. The aim of this article precisely consists in breaking up this linear and widespread vision between the status of the operator and the status of the resource. It calls for a deeper analysis, historically informed, of the operator strategy towards resource access according to its ownership status[1].

Does the legal and ownership status of the water operator matter for the strategic mobilization of institutional rules? The traditional literature on public versus private (water) operators has not addressed this question very systematically. It focuses essentially on the ability of private interests to supply public services. We classify the arguments about the differences between public and private operators – and, furthermore, about the privatization of state-owned entreprises (SOEs) - into two categories. On the one hand, macro-economic rationales for privatization claim that it should improve efficiency, reduce the public sector borrowing requirement and ease price determination (Vickers and Yarrow 1989). On the other hand, micro-level discussions concentrate their arguments in favor of privatization on the implications of the type of ownership on management and output efficiency. The general assumption is that public ownership is by its very nature inefficient and unable to attain satisfact-

[1] The institutional arrangement for resource management must fit with the temporal and spatial scales of the resource cycle.

ory levels of economic efficiency (see Winpenny 1994 for the water sector). Empirical studies show that public managers lack market incentives and shareholders pressure to attain greater efficiency (Laffont 1996: 1240-42; Nestor and Mahboobi 2000: 19).

However important in quantity and quality, the economic and political literature is divided on the validity of most of the theoretical assumptions on the superiority of private property over public ownership of (water) operators. On the empirical level, many authors, having undertaken performance reviews of SOEs and private companies, often have not found clear cut evidence of the superiority of public or private ownership over the other. Rather, the institutional and market environment of the company (e.g. public regulation, degree of competition, market structure) has proven to be a much more important factor on productive efficiency than property (Brooks 1989; Vickers and Wright 1989; Hodge 1999).

To conclude, the managers of public and private water operators obviously face different situations and incentives. Accordingly, we might expect that they follow different strategies to secure the provision of drinking water. However, there are no strong theoretical arguments that clearly predict the type of institutional rules that will be mobilized by a public versus a private company. Thus we need to look in detail at PR and PP, the two pillars of institutional resource regimes (Kissling-Näf and Varone 2000; Knoepfel, Kissling-Näf, and Varone 2001; Varone et al. 2002; Aubin and Varone 2004).

1.2. Formal Property Rights on Aquifers

The first strategy for a water operator is to become the owner of the resource or, at least, to have exclusive disposal and use rights on it. Institutional economics considers property and use rights (PR) as key steering factors for resource use and sustainability (Bromley 1992; Devlin and Grafton 1998). PR must be clearly regulated to enable effective and efficient use and management of resources. PR are usually defined as social relations between two or more competing users of the same natural resource. Thus, property is not an object such a water body (e.g. an aquifer), but a right to a benefit stream derived from the resource (e.g. water for irrigation, drinking water), usually guaranteed by the State. This right is secure as long as the duty of all the other (potential) users respects the conditions that protect the stream (Bromley 1992: 2). Accordingly, the first virtue of property rights is to exclude non-owner and rival appropriators from the use of – goods and services derived from – the natural resource. It is therefore obvious that the acquisition of PR represents a first possible target for public or private water operators.

In Belgium, property and use rights on natural resources were formally set in the Civil Code (CC) of 1804. PR determine who the formal owner is and what its related disposal and use rights are. As far as water is concerned, it ties (ground-) water ownership to land ownership. According to the "accession principle", rainwater, ponds, groundwater and springs are private water, once extracted by the landowner (e.g. when rainwater falls on land, when groundwater is located under the soil and when springs stem from the land). It is obvious that the absoluteness of this organisation of PR would hamper water use by non-owners, for whom water is vital. The CC actually limits private property on water by means of easements. Easements are introduced for public utility reasons and clearly limit use rights of the formal owners. Furthermore, public laws and sector-specific regulations might restrict some disposal and use rights of the resource owner.

1.3. Public Policies on Aquifers

The second strategy that water operators can implement, especially if they are not the formal owners of the resource they intend to exploit, is to mobilise an existing – or to propose the adoption of a new - public policy. A public policy represents the response of the political-administrative system to a reality that is deemed collectively unacceptable. In order to achieve the desired effects, each policy design is based on a rationale or action logic. This comprises hypotheses on both the causal chain behind the collective problem to be solved and the possible forms of State action (Knoepfel, Larrue, and Varone 2001; Schneider and Ingram 1988; Schneider and Ingram 1997). For the illustrative example of a polluted aquifer, the causal hypothesis responds to the question as to who or what is to blame or is objectively responsible for the unacceptable use of the resource. This gives rise to the political definition of the target groups (e.g. agriculture, industry and/or households) in the policy design. The intervention hypothesis responds to the question as to how the behavior of the target groups identified can be influenced in such a way as to achieve the defined aims of the policy. In other words, it legitimizes the choice of the policy tools mix (e.g. ban of manure spreading, tax on industrial discharge and/or permit for housing). As a matter of fact, a water operator might invoke a sectoral policy in order to limit the direct or indirect exploitation of the aquifer by the specific target groups of the relevant public policy.

We must explicitly acknowledge that this strategy is possible even if the target groups are *de jure* the owners of the aquifer: the legal definition of PR clearly indicates that property is not absolute, but could be limited – with financial compensation in cases of expropriation – by public laws and regulations. De facto, public policies distribute specific (sometimes exclusive) use rights to the actors, whose behavior is to be influenced by State intervention. Thus, even if the formal property and use rights have no longer been questioned since the adoption of the CC in 1804, their material content of ownership is rendered concrete and restricted by public policies gradually adopted afterwards.

Policy analysis and evaluation show that policy designs are often incomplete or incoherent (problem of inter- and intra-policy coordination), that they are only partly implemented (due to non-adapted administrative agencies) and/or that the effects achieved only partly correspond to the defined aims. Thus, it is imperative to examine the extent to which the concrete use and management of a natural resource depend on the internal coherence and degree of implementation of such policy designs.

In the French-speaking region of Belgium (Wallonia), public policies in the field of aquifer management concern both exploitation activities and protection measures. They date back to 1889 with the Law on the protection of mineral water extraction, applied first to Spa, subsequently generalized in 1924 to all mineral water springs and then in 1990 to all drinking water sources. The underlying policy rationale can be summarised as follows: *If we set a protection perimeter around a spring with limitations of use inside, then we will guarantee its preservation*[2]. A public water distribution policy has also been developed since 1907 and is based on the practical assumption that *If we both allow towns to both collectively organize and create a national (or public-owned) company, then we will supply drinking water to the whole population and eliminate water diseases*. Regulations of industrial and domestic discharges were implemented as well. As such, public policies constitute a wide set of public interventions in water management.

It is thus important in the case studies presented below to distinguish between the status of the operator and resource ownership. This status should influence the strategy of the operator towards the resource access and protection, a strategy where

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2 It must be emphasized that this policy does not really guarantee the protection of the resource but rather, the prevention of pollution accidents, since the perimeters are smaller than the percolation basin.

the mobilization of institutional rules (property rights and public policies) are key elements.

2. Historical development of water production in Belgium: the cases of CIBE and Spa Monopole

Belgium's water resources are distributed among two international river basins, the Meuse and the Scheldt. The major aquifers are located in Wallonia, the southern and French-speaking region of Belgium. Wallonia meets 55% of the national needs in drinking water (providing Flanders and Brussels), while it accounts for only 37% of the population (Barraqué 1995: 54). The yield of groundwater is about 900 Mio m³ for the whole country, exploited at a rate of 75%. Even though some fear of water shortage appeared in the 1960s, Belgium does not face a "hydrous stress" (Cornut 2000)[3].

From the analysis of water use, we have identified two persistent rivalries (Aubin and Varone 2004). The first occurs between the high pollution levels in most water bodies and drinking water production. Pollution is due both to domestic wastewater discharge and the diffuse pollution from manure disposal. The second line of rivalry concerns economic development (e.g. construction, industrial use of water, intensive farming and flood control) and the protection of the environment.

The two historical cases presented below address the issue of drinking and mineral water production. Each case study successively discusses the aquifer characteristics, the ownership status of the water operator, the strategy put into action from 1880 onwards and the induced effects on the exclusion of rival users and on resource sustainability.

2.1. Drinking water production by the Brussels public water company (CIBE)

As pointed out above, most of Brussels' drinking water originates from the Walloon Region. Therefore, the public-owned company which supplies the urban area of Brussels has developed a specific strategy to secure 'its' water resources. This strategy is mainly based on property rights and public policies, which were reinforced with a bunch of contractual agreements and additional monitoring measures. In fact, the story of Brussels drinking water production is closely linked to the growth of the city as the socio-economic and political center of Belgium.

2.1.1. Groundwater extraction far from the place of consumption

The first water catchments of CIBE are located in the Condroz region (Wallonia), approximately 80-100 km south-south-east Brussels, where the major Belgian aquifer made of folded carboniferious limestone is. Both in Spontin (the 1890s) and Modave (the 1920s), the groundwater extracted is of high quality thanks to natural underground purification, and plentiful thanks to the limestone that is often compared to a "water highway". The system used to extract water is very simple. In the lower part of the valley, an underground permeable gallery is built in parallel of the river, just a little above its bed level, so as to collect the underground water that supply the river. The extracted underground water has percolated, for months and even years, from the plateaux and slopes surrounding the valley. The aquifer is vulnerable, though, as its permeability is mainly based on large passages between the fragmented limestone rocks. In certain areas of the percolation basin, a pollutant can

[3] Despite its very high density of population (333 inhabitants/km²), water availability is 1,900 m³/capita/year.

thus quickly migrate into the gallery. As these areas, either large or very small, are impossible to precisely locate on a map, the whole basin must be carefully monitored.

After its first developments, CIBE diversified its water catchments, both geographically and geologically. CIBE now produces approximately 140mio m^3 per year (~50mio m^3/year in 1940 and ~100mio m^3/year in 1970) from many sources, mainly in Wallonia: the Condroz limestone aquifer (~45%), the Mons chalk aquifer (~11%), the Brussels sand aquifer (~11%) and surface water from the river Meuse (~30%). The Modave and Spontin catchments remain of high importance for the company, since their cost is very low compared to pumping stations and drinking water treatment plants: there is no need for energy (both for the catchment and the adduction), the capital invested nearly a century ago has been completely amortized, and the only costs are dedicated to maintenance.

2.1.2. Historical operator of the Brussels-Capital Region

The *Compagnie Intercommunale Bruxelloise des Eaux* (CIBE) is a public company, created in 1891 by four boroughs of the urban area of Brussels in order to extract drinking water and to distribute it to their inhabitants and economic activities. In 1899, after 8 years of technical and institutional efforts, the 'Spontin catchment' supplied the four associated boroughs with 35,000 m^3 per day of fresh and high quality groundwater channelled through a slow slope aqueduct. Since its foundation, CIBE has never stopped growing, increasing both its water production capacity and its distribution area. The major part of production, groundwater, is extracted from the company premises which now total about 300 ha in Wallonia.

Today, CIBE counts 38 associated boroughs in its capital and many '*customer municipalities*': all in all, it supplies about 2mio people (1/5 of the Belgian population): upstream Brussels (along the aqueducts), Brussels itself and its periphery where it also is in charge of distribution, and downstream Brussels (as far as the Belgian coast, 110 kms away from Brussels). Recently, CIBE has also extended its activities to the sewer and sanitation sectors.

Legally speaking, CIBE is a *limited risk public company* (*société coopérative à responsabilité limitée*) whose shares are exclusively owned by boroughs of the Brussels urban area. The 1,500 employees of the public company benefit from a high social protection just as in other public companies or administrations. Originally, the public status of the Company was not so obvious, for the first project in the 1880s was to create a public-private company where the four boroughs had the majority of assets (8/15 of the shares), the remainder being the property of a private entrepreneur. The project was finally abandoned, partly because of the specific water catchment that was to be built by the projected company (see below) and partly for ideological reasons that deal with political debates on public service and privatization (Cornut 2003).

For the associated boroughs, creating a joint public company with the aim of building and managing a water production and distribution system was a risky undertaking in 1891, for no specific legislation could guarantee a legal framework for the new firm. However, CIBE succeeded in growing and building its production and distribution networks, often without any subcontracting. But at the same time, it made an efficient political lobby to enact new legislation that could give legal status to such associations of boroughs. The law, adopted in 1907 by the Belgian parliament[4], was clearly modelled on the original status of CIBE. The 1907 law gave new opportunities to CIBE, such as compulsory purchase and low interest rates on loans, but at the same time, allowed the Government to control the accounts, loans and status of such associations.

[4] *Loi du 18 août 1907 relative aux associations de communes et de particuliers pour l'établissement de services de distribution d'eau (M.B., 5 septembre).*

2.1.3. From first settlings to complete control and monitoring of the resource

The strategy used by CIBE to build its 'water empire' is complex. However, we can get the essential information on property rights by looking at the specific strategies used both to *secure access to the resource* (possibly by excluding alternative uses) and to preserve the resource. Given these limits, we can distinguish three major periods in the history of CIBE: first settlings in the Condroz region (1880-1945), expansion through the mobilization of planning procedures (1945-1990) and legalization of CIBE water protection strategy (from 1990 onwards).

Phase I (1880-1945): The first project set up by the four boroughs of the urban area of Brussels was to create a public-private company in association with a private entrepreneur who was to own 7/15th of the shares. In return for his participation in the capital and potential benefits of the company, the latter had to give the company his property rights on hundreds of hectares in Modave, a sparcely populated village located in the Condroz region, containing many springs that could produce up to 70,000 m^3 per day of high quality water, i.e. enough to supply Brussels plentifully. According to the Civil Code, property on these lands entailed the property of the groundwater, so the exchange of real-estate property with company shares allowed the projected company to exploit Modave's groundwater. This project was finally abandoned, though, notably because of the competition on water resources. The catchment of Modave's springs was actually endangering the flow of the local river, *le Hoyoux* (a tributary of the river Meuse), which was still used downstream for industrial purposes (both for hydro power and the industrial process). As a consequence, the industrial lobby actively fought against the project, both politically and legally. This well-organized lobby was clearly efficient, for the Liège Appeals Court confirmed in 1894 the rights of the industrials on the surface water flow, invoking to the Civil Code, which guarantees riverside landowners the flow of water across their land cannot be harmed by surface water extraction upstream, including springs[5]. As a consequence, CIBE had to give financial compensations to riverside landowners downstream from Modave who would have suffered from the qualitative and quantitative degradation of the water flow induced by CIBE's withdrawal.

The financial setback of the Modave project forced CIBE to find another source of water to supply Brussels, if possible in a place where competition on the resource was lower. It found it in 1892 in Spontin, a small village in the Condroz region as well, about 30 kms west of Modave. The strategy was the same there as before in Modave. First, CIBE negotiated with the village and private landowners to buy land on which many springs emerged. At the same time, it negotiated with the Belgian Government to get an authorization both to extract water from Spontin's springs and to buy the necessary lands that guaranteed its property of underground water. The Government granted the authorization in 1894, in exchange for a firm commitment of CIBE to give fair compensation to landowners and industrial users of surface water[6]. The authorization also included the ability for CIBE to carry out "*public utility*" expropriations if negotiations failed with landowners.

All in all, one can say that CIBE succeeded in Spontin because the potential opponents to the project were either too few or badly organized, so that the financial compensation were affordable for the Brussels water company. The proof came later on, when CIBE 'struck back' at Modave in 1910, when Spontin's water didn't suffice to meet Brussels' demand anymore. To get the official authorization, CIBE not only had to give fair compensation to local landowners, but also to pay a BEF 3mio compensation to industrial users of surface water downstream, and to use 1/30th of that money to build a sewer along the river for industrial discharge, in order to preserve

[5] Case-law of the Liège Appeals Court of 16th May 1894.

[6] *Arrêté royal du 10 juin 1894 portant sur « Hygiène publique ; agglomération bruxelloise ; distribution d'eau ; projet du Bocq » (M.B., 25-26 juin, p. 1997).*

the river's water quality[7]. This agreement could be compared to an early form of today's environmental 'win-win' approach: each of the parties benefits from the agreement which at the same time preserves the (local) natural environment. The story also gives clear indications of the financial power of CIBE and consequently, of Brussels' boroughs.

Despite the *modus-vivendi* officialization, not all Modave residents were happy with the project, though, for the hamlet of Petit-Modave was nearly entirely wiped out after expropriation: a psychological scar that is still perceptible today among the local population, nearly one century afterwards.

Apart from Petit-Modave's destruction, it has to be noted that, both in this early period and after, CIBE has always tried to avoid direct conflicts with local people, even if it had all the legal rights to buy the land and extract groundwater. For example, CIBE has always favored fair deals in land purchase and avoided to go to court and use its expropriation rights. It also supplied water at low cost to local inhabitants (even for free at the beginning) and hired local labor to manage its local infrastructure. As socio-political tools, these measures were essential to make the local populations and authorities accept the presence of a 'foreign' public company, even if the measures did not have any effect on the preservation of the resource.

The strategy used in Spontin and Modave to secure access to and preserve the resource has been generalized in all the other catchment places developed later on by CIBE, and is still the same today. It was enhanced, though, after WWII.

Phase II (1945-1990): The second period is not highly different in terms of resource strategy, though in some way, it shifted from a property rights-based approach to a policy design-based one. Of course, the policy of land purchase was pursued, and even geographically extended so as to include in CIBE's possessions not only the close catchment area but also lands further in the aquifer basin in order to secure the largest possible part of the percolation basin. The purchases did not proceed in a one-shot process but rather, in an opportunistic way so as to make the property map look like a *"gruyère" cheese* of which the holes were progressively filled. Most of the time, trees were planted on these lands, in order to both enhance the percolation quality of the soil and to create a physical, natural and psychological barrier against potentially polluting human activities.

But this strategy was by no means the essential one of this second period, which was marked by the mobilization of policy design rules, in two directions. It is of crucial importance to note that the two following measures are mainly based on the quality of underground water, undoubtedly because the quantity aspects were already guaranteed by the property right measures.

First, CIBE hired and trained specific employees, water workers (*"cantonniers"* in French, by analogy to roadmenders), who are in charge of watching every human activity that could endanger water quality or quantity: construction, agriculture, oil tanks, etc. When a potential danger is identified, the job of the water worker is to warn the person in charge about the danger his activity represents for water and if necessary, to remind him that he is legally (hence financially) responsible for any pollution he could provoke on CIBE's water. The monitoring of CIBE's water workers was gradually 'codified': using geological tools, informal protection perimeters were traced around each catchment. In fact, three concentric zones were defined, the observation criteria more detailed as the distance from the catchment decreased. The preservation of the resource was thus extended and more efficient.

Second, CIBE adapted its procedures to the new planning laws set up after WWII. As every important new construction or economic activity had to ask for a planning

[7] *Arrêté royal du 19 mars 1910, portant sur « Travaux d'hygiène; Compagnie Intercommunale Bruxelloise des Eaux ; Dérivation des sources de Modave » (M.B., 2 avril, pp.1883-1885).*

permission, which includes a public enquiry, CIBE's water workers could systematize their monitoring by asking the planning authority to add specific constraints in the permission to guarantee no pollution of groundwater (e.g. the double envelope of an oil tank). We can easily interpret this use of planning policy as an economic rationale: now CIBE does not have to buy as much land as possible, it can intervene in the planning procedure to protect its resource, even beyond its property. The protection process through planning was not yet fully efficient, though, for (1) the planning authority could decide not to consider the remarks of CIBE and (2) the owner could easily hide his disrespect of the planning rules. Thus the preservation was not complete.

The final strategy in this period, which did not directly affect the water resource, relied on the dramatic growth of CIBE. Upstream, it geographically diversified its groundwater sources and also developed drinking water treatment plants to treat surface water so as to assure its independence on the seasonal and annual changing capacities of aquifers. Downstream, it has convinced more and more villages to become associated in the company or customers of its water supply, giving itself wider social justification to new water extraction. This extension process, which made it the second largest drinking water company in Belgium in terms of cubic meters produced (and the first in terms of domestic supply), is probably the major asset of CIBE's power today.

Phase III (1990 onwards): The third and final period, starting in 1990, saw the Walloon Region setting up new legislation on water protection, very similar to (and in a way, officializing) CIBE's protection zones strategy. The policy is applied to the whole Walloon territory, for all water producers including Brussels and Flemish ones. A regional bill now legalizes CIBE's preservation strategy, especially the monitoring measures: landowners located in the aquifer basin are legally obliged to adopt water preservation constraints on their potentially polluting activities.

Of course, CIBE's financial capacities, formerly used to secure its access to as well as protect the resource, are largely reduced as the Region has levied a tax on each cubic meter extracted in Wallonia in order to finance all the protection measures imposed on local residents. In return, though, water producers can ask for regional subsidies for the implementation of protection measures around their catchments.

2.2. Mineral water production by the private-owned company Spa Monopole

Spa's water has been tapped for centuries. Since 1888, the communal springs have been conceded to a private company that exports natural mineral water in bottles and manages the health "spas". Protection and exploitation of the resource are closely tied. In fact, Spa's aquifers are vulnerable to human activity, but located in forest and a natural setting. The resource has remained in public hands over the whole period, belonging mainly to the village. However, the private company assists the public authorities in preserving it. As a local producer, Spa Monopole is dependent on the resource for its survival. Thus, it has developed a complex strategy to protect the resource, based on the securing of access and the exclusion of alternative uses.

2.2.1. Bottling the thermal water of the Fagnes

Located in the East of Belgium, in the Ardennes, the region of Spa is a natural area benefiting from a very specific landscape, originated from timber overexploitation before the 19th century. The *Fagnes* are high plateaux which form a collection of marshes with its characteristically muddy ground (or peat bogs), filled with abundant rain- and snowfalls. Spa water percolates from the *Fagnes* plateaux through primary quartz rocks, and emerges downstream on the slopes of the Spa valley, thanks to deep faults or impermeable primary rocks. Depending on the deepness of percolation, Spa water is either very poor in minerals (50mg/l) or poor in minerals (100mg/l).

Spa water fits with the requirements linked to the label of natural mineral water, as stated in the related European Union directives[8] and the Belgian law of transposition[9]. More than 300 springs stem from the Spa area, of which 59 are registered as mineral water springs, and exploited (it has to be noted that Spa water has been exported for more than 400 years, and since 1700 to the U.S.). Its flow is about 5 to 10 m^3/hour. Most of them are classified as natural mineral waters. This label requires very strict characteristics, viz. stability in the composition and temperature of the water over time (six months without variation). Furthermore, natural mineral water cannot be treated before bottling.

Both for the qualitative stability required by the mineral water label and because of the age of the aquifer rock, the aquifers must be carefully protected over large areas (the percolation basin is estimated at 13,000 ha). In such a context, the mineral water company fought to preserve the resource against any pressure. Over time, it had to monitor the development of housing areas in the surroundings (dispersion in rural areas), and tourism. It benefited however from a low development of agriculture and a decline in the interest in timber production[10].

2.2.2. Industrial development in the exploitation of thermal waters

As from the late 19th century, Spa water have been industrially exploited. If the water trade is much older, industrial production developed after 1888, when the Spa municipal authorities gave a monopoly of exploitation of its springs to Emile Dhainaut. His company, called the *Compagnie fermière des Eaux de Spa*, became Spa Monopole in 1921. Exports kept growing. In 1947, a holding named SPADEL headed Spa Monopole, which has remained a family-owned company over time. Today, SPADEL has a turnover of about EUR 240mio and counts 900 employees. It is the leader in mineral water production in the Benelux and this in a high growth sector (8.2% growth in Belgium in 2001).

Spa Monopole is the main subsidiary of the group with 662 employees in 2001 (out of a population of 10,000 inhabitants in the town). It accounts for about 65% of the turnover of the Group. After huge investments in 1999 (EUR 14.2mio) and the full modernization of the production plant, Spa Monopole feeds thirteen lines of production with a network of pipes running from the 59 wells under exploitation. More than 600mio litres are bottled each year. The production capacity grew from 50 m^3/hour in 1980 to 100 m^3/hour in 2000. In peak periods, i.e. during dry summers, the capacity rose to 200 m^3/hour. In the production process, the flow of water is exclusively reserved to bottling. Other water needs in the industrial process, mainly the rinsing of bottles, are provided by pumping in the lake of Warfaaz (about 500mio l/year).

Spa Monopole mainly exploits the municipal springs, under a concession. According to the contract, it pays a royalty of EUR 0.01 per litre to the town. In 1999,

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8 Council Directive 80/777/EEC of 15 July 1980 on the approximation of the laws of the Member States relating to the exploitation and marketing of natural mineral waters (OJ L229, 30.08.1980, p.1), as amended by Directive 96/70/EC of the European Parliament and the Council of 28 October 1996 (OJ L299, 23.11.1996, p.26).

9 *Arrêté royal du 8 février 1999 concernant les eaux minérales naturelles et les eaux de source (M.B., 23 avril, p.13486)*, in application of the *Loi du 24 janvier 1977 relative à la protection de la santé des consommateurs en ce qui concerne les denrées alimentaires et les autres produits*.

10 As coupled with the closing of the coal mines in Wallonia. Timber was priorily made to sustain the galeries.

the royalty amounted to EUR 5.1mio, corresponding to 40% of the income of the municipal budget. The company keeps negotiating with the town in order to reduce 'cash drains', as the production is permanently growing. This relation of dependence with the resource is combined with the absolute necessity to keep the composition of the mineral water constant as the aquifers are vulnerable to external pressure.

2.2.3. Continuous securing of industrial development

Spa Monopole has developed a strategy oriented both in the guarantee of access to the resource and its preservation. This strategy fits with the status of the resource (public-owned) and its particular vulnerability (the *Fagnes* wetland ecosystem). Throughout the period, the resource has remained the property of the town and is localized in a naturally protected environment, without permanent human activity. The strategy is in line with the industrial development of mineral water production and permanent growth in the activity. How does Spa Monopole progressively secure its resource access and exclude other users? In order to manage groundwater access and protection, Spa Monopole both secures its disposition rights (concession contract with the town of Spa) on the resource, and builds its action on the existing legislation, a strategy that limits the cost of private intervention. We distinguish three different phases in the strategy of the operator: first, a securing of the production since 1888; second, the enabling of a boom in production; and finally, the constitution of a growth potential. Spa Monopole, in its behavior, manages to straddle a permanent tension between economic growth and the absolute necessity to keep the resource intact. Overexploitation is synonymous to bankruptcy in such a context.

Phase I (1888-1967): Forecasting is one of the conditions for investment in industry. This is no exception for Spa Monopole. Security in access and quality of the resource have priority on industrial development. In 1888, Emile Dhainaut signed a concession contract with the town of Spa, the owner of the springs. The concession gave him a monopoly in the exploitation of Spa's water, materialized in 1921 when the company started its industrial development. In the early 20th century, the forests and the *Fagnes* belonged to the State, the springs to the town and Spa Monopole owned the disposition rights (concession) on Spa water. The ownership structure on the resource did not evolve much afterwards.

During the same period, Spa Monopole relied on public law in order to protect the resource. In 1889, a protection perimeter (the first in Europe!) was established by law around the main mineral water spring[11]. The spring was declared public utility. All around it, in a perimeter of 34.6 ha, prospecting and exploitation of mineral water were prohibited, as well as digging at more than two meters' depth. Monopoly in exploitation was thus confirmed by the law. The protection perimeter is progressively extended to the other Spa springs. It reached 3,409 ha in 1937. The production of mineral water was more and more regulated[12]. Any public work that could alter the flow and quality of mineral water was strictly forbidden, as well as the trade of mineral water without prior authorization. Competition was restricted, which limited risks of over-exploitation, and the resource was subject to protection measures. The context for the industrial development of Spa Monopole was in place.

It is also important to note that Spa Monopole soon developed a research strategy. In 1931 it created the Henri-Jean Institute, specialized in hydrogeology. It monitored in situ the evolution of the resource and controlled the quality of the products. It determined the level of flow subtractible from the aquifers without altering the resource.

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11 *Loi du 31 juillet 1889 déterminant le périmètre de protection des eaux de Spa.*

12 *Loi du 1er août 1924 concernant la protection des eaux minérales et thermales (M.B., 22 août)* and *Loi du 14 août 1933 concernant la protection des eaux de boisson (M.B., 31 août, p. 4326).*

Phase II (1967-1990): An industry under expansion needs a growing flow of raw materials. That was the case for Spa Monopole. However, the necessity to keep constant the composition of the resource forbade over-pumping. Thus, the rise in the capacity of production was organized around the exclusion of other uses, particularly drinking water provision. At this time, the town kept drinking water provision from the springs of Spa. The situation led to a confrontation between the town authorities and Spa Monopole at each re-negotiation of the concession. In 1974, a new concession was signed for a period of 65 years (1974-2039), which entails the exclusion of drinking water provision from the springs. Since then, the regional water company (*Société wallonne des Eaux*, SWDE) has operated in the town of Spa with water from the reservoir of Eupen, located at a distance of 25 km in the neighbouring river basin. The long-standing rivalry between mineral water production and drinking water distribution was solved through an 'exclusive' concession. Also, Spa water is no longer used in the industrial process of Spa Monopole (for bottle rinsing). The company signed an additional agreement with the town to extract surface water in the Warfaaz lake. From the monopoly on the mineral water produced from the flow of the resource (i.e. aquifers), Spa Monopole obtained a monopoly on the whole resource.

In the same period, Spa Monopole expanded its strategy of protection of the aquifers. It paid particular attention to activities going around the *Fagnes* and put pressure to limit their potential effect on the resource. Agricultural activities were interrupted. In 1972, Spa Monopole bought the farm of *Bérinzenne* located at the edge of the *Fagnes de Malchamps* in order to avoid any risk of manure or pesticide spreading. Also, it surveyed the forest management carried out by the national forestry office (*Division de la Nature et des Forêts*, DNF). DNF manages both the State and the communal forests. In 1978, Spa Monopole signed a *modus operandi* with DNF. The contract consisted in giving priority in forest management to the protection of the aquifers. For instance, DNF commits itself to limiting the planting of pine trees. Spa Monopole compensates the financial loss in timber production. The foresters also limit and monitor recreation activities in the public forests. In order to enable its expansion, Spa Monopole developed its strategy of guaranteeing access and resource protection and completed it with contractual agreements with other users.

Phase III (1990 onwards): In recent times, Spa Monopole has been consolidating its expansion strategy with the goal of constituting a growth potential. It has conducted hydrogeological studies above the protection perimeter in order to search for new mineral water springs, with a composition equivalent to Spa water. The survey delineated the aquifers more precisely. The outcome led to a proposition for an extended protection perimeter, according to the regional law of 1990[13]. The Walloon government agreed on the new perimeter (13,177 ha) in December 2001[14]. The new law made the restrictions on activities inside the protection perimeter more severe. Digging activities deeper than three meters were prohibited as well as any activity that could modify the flow and composition of the mineral water springs. In closer perimeters, all activities are severely restricted, with particular attention paid to oil tanks. Spa Monopole bases its strategy on the law on the protection of wells. It gives advice to the town in the permission of building or exploitation. Its own patrols (or water workers) work in the public forests. It visits individual properties and inform the

13 *Décret du 30 avril 1990 sur la protection et l'exploitation des eaux souterraines et des eaux potabilisables (M.B., 30 juin).* According to the regional law, the perimeter of protection is divided into three zones : the extraction zone, a radius of 20m around each well and spring where all activities are excluded; the prevention zone, 1 ha around each well where activities are severely restricted; and the monitoring zone covering the whole catchment.

14 *Arrêté ministériel du 13 décembre 2001 relatif à l'établissement d'une zone de surveillance pour la protection des eaux de Spa et environs (M.B., 1 mars 2002)* and *arrêté ministériel du 13 décembre 2001 relatif à l'établissement des zones de prévention rapprochée et éloignée des ouvrages de prise d'eau souterraine de l'administration communale de Spa, de la S.A. Spa Monopole et de la S.A. Exirus, sis sur le territoire des communes de Spa, de Theux, de Jalhay et de Stoumont (M.B., 1 mars).*

owners about the legislation, particularly their duty concerning oil tanks. Wastewater discharges are severely restricted, even for individual households. If the risk is too high, they buy lands and property. Spa Monopole wants to avoid any risk of pollution of the aquifers. This attitude is connected to the vulnerability of the resource.

The strategy is coupled with land purchases. Spa Monopole (or its real estate tributary Exirus) buys both springs and wells that were formerly in private hands and sensitive areas where the threat on the wells is high. This acquisition strategy leads to a diversification of the ownership structure of the springs. The town of Spa is no longer anymore the sole owner of Spa water as new springs or aquifers have been discovered. Today, Spa Monopole holds one third of the wells. This purchasing strategy gives it more leeway to (re-)negotiate the concession with the town and puts pressure on the commune to reduce the royalties.

Instead of a strengthening of the legislation and a strategy of land purchasing, Spa Monopole has continued to settle contractual agreements with other users. In 2001, the company renews its *modus operandi* with DNF (now attached to the Walloon Region). The aim is to balance the protection of the aquifers and the forest management. At the same time, SPADEL mentioned the financial burden ('cash drain') that the royalties represent and negotiated with the town of Spa to soften it.

Finally, the local anchorage of Spa Monopole has enabled negotiation and bargaining with the local authorities. Spa Monopole has succeeded in securing both the constant quality of mineral water it exploits and its growth potential in a highly competitive market. Such an environment was created to the disadvantage of other local, be they indirect, water users. Many activities ceased or were put under restrictions in order to guarantee the viability of the resource. However, substitution solutions were found out and the mechanism of transfer of property rights seems to be efficient for the community.

3. Comparison of the case studies

On an empirical basis, we have analysed two cases of water production from an aquifer occurring over a similar time period (from 1880 onwards) and a similar legal environment (CC and public laws), gradually establishing the institutional framework (PR and PP) that the operators mobilize. The problems that both operators faced, as well as the objectives they attempted to reach, are similar. Initially, they wanted to obtain (exclusive) access to an aquifer that they did not own and, afterwards, they wanted to secure their access and preserve resource renewability, in order to guarantee the economic growth of the company. These elements are deemed constant in the analysis.

Conversely, the two above-mentioned cases are to be distinguished on at least three aspects: the status of the operator (public for CIBE and private for Spa), the nature of the good produced (drinking water for CIBE and mineral water for Spa), as well as the initial ownership status of the aquifer (private for CIBE and public for Spa). These contrasting characteristics suggest that the strategies of the two operators would diverge. In fact, if the status of the operator is interpreted as an explanatory factor for the strategies followed, then one should expect divergences in the institutional rules mobilized as well as the impacts.

Surprisingly, the systematic comparison of both cases shows a rather high convergence in the strategies followed (see Table 1). Similarities clearly appear from the analysis:

1. CIBE and Spa Monopole both mobilize property rights as well as public policies. These two categories of institutional rules must then be combined in an analysis of users' behavior[15].
2. Concerning PR, CIBE becomes the formal water owner. It bought the land above the aquifer, with the authorization of the State to expropriate for a reason of public utility. In the case of Spa Monopole, the company did not seek formal property on water, as the village of Spa is the single (public) owner. Rather, Spa Monopole signed a concession contract that granted them of the (exclusive) disposition and use rights on the communal resource. Land purchase to individual landowners came much later and remained residual in the operator's strategy. As a result, both operators got exclusive appropriation of the resource. Another common point is that quantity problems of water management were solved with a mobilization of property rights[16].
3. Concerning PP, both the case of CIBE and of Spa Monopole are exemplary. In fact, the public laws that set protection perimeters around springs and wells reproduce former voluntary practises of these operators. In a way, the strategies of CIBE and Spa Monopole constitute "local laboratories" for the elaboration of exploitation[17] and protection[18] policies. Also, it clearly appears that voluntary protection measures, as well as the mobilization of institutional rules, evolve with the development of scientific knowledge on the resource. Finally, we note that the mobilised PP contribute mainly to resolve qualitative aspects of water management.
4. Above PR and PP, the strategies of CIBE and Spa Monopole are implemented with additional mechanisms. On the one hand, contractual agreements with the locals improve the effectiveness of institutional rules (e.g. the *modus operandi* on forest management in Spa, free water supply for locals in Spontin), and contribute to the social acceptability of the economic expansion of the two operators (e.g. hiring local people for CIBE). On the other hand, we observe that the operators adopt tight monitoring and control programs. Their own 'private patrols' guarantee the respect of the protection laws in force (e.g. participating in all public enquiries) and even substitute the tasks of the police or public administration.
5. Convergences between the strategies of both operators are also quite obvious concerning the exclusion of competing users and the sustainability of the resource use. Both operators adopt 'winning' strategies (Strategy = Access (1) > "Monopoly" (2) > Protection (3)), as all other users are deliberately excluded from any appropriation or (even indirect) use of the aquifer: farmers, individual landowners wishing to construct, industrial users downstream, etc.[19]. The systematic exclusion of all potential competing uses has allowed both CIBE and Spa Monopole to manage 'their own' resource very rationally relative to their own (homogeneous) use. As these two companies are highly dependent on the renewability of the aquifer to assure their economic growth and survival, they carefully avoid any over-exploitation of the resource. In fine, this situation has led to a very high environmental sustainability of the resource use. Nevertheless, the economic (efficient allocation) and social (equality in access) aspects of sustainable development are far from satisfactory, or perhaps in a very indirect way through financial compensations that CIBE and Spa pay to some excluded users (e.g.

15 We noted elsewhere that the two categories of institutional rules together form an institutional resource regime (Knoepfel, Kissling-Näf, and Varone 2001; Varone et al. 2002; Aubin and Varone 2004).

16 We note here that other case studies conducted in France, Switzerland, Italy, Spain and The Netherlands also demonstrate that quantitative aspects in water management are generally addressed with PR (Bressers and Kuks 2004).

17 See the Law of 1907 on the inter-communal associations.

18 See the Laws of 1889 and 1990 about the protection of wells.

19 Even the local drinking water consumers in Spa are supplied from other sources than the local aquifer, which formally belongs to the town (or municipality)!

royalties to the town of Spa, free drinking water provided by CIBE to local residents). As a consequence, we conclude that "private appropriation of the resource" occurs whatever the status of the drinking water operator[20].

6. The scope of these empirical results must however be tempered by the strong local anchorage of these two operators. Both are vitally dependent on the local resource, a situation that is a pre-condition for sustainable resource management (Ostrom 1990). In both cases, places of production and distribution are local. Any depletion, particularly in the case of Spa Monopole would lead the company to bankruptcy[21].

Beyond these empirical findings, many theoretical implications can be made from the former comparative analysis.

[20] A private appropriation corresponds to a *de facto* privatization, as opposed to a *de jure* privatization, i.e. a privatization process explicitly backed by the law.

[21] Such a situation, that leads them to secure their water provision, is perhaps not paralleled by multi-national (e.g. Ondeo-Suez) and multiple-brand water companies (e.g. Nestlé and Danone) which are so diversified that they can abandon a production location or an activity in case of problems without much prejudice for the company's finances (e.g. Ondeo-Suez which resigned from water distribution supply in Atlanta (see www.waternunc.com, January 2003)).

Table 1: Development phases of CIBE and Spa Monopole water productions

	Phases		Strategy (mobilised institutional rules)	Limitations and exclusions (of goods and services)	Impact on the local resource
CIBE	1. First settlings in Spontin and Modave (1880-1940)	**PR**	-Purchase of communal and private lands -Expropriation of lands -Financial compensations to downstream users	Agriculture **Construction**: destruction of houses **Production:** industrial process and energy **Purification:** self-purification in the river	*Quality*: Prevention against any aquifer pollution in the close catchment area *Quantity*: Minimal flow for industries downstream
	2. Expansion and mobilization of planning procedures (1945-1990)	**PR**	-Geographical extension of land purchase	**Agriculture** **Construction**	*Quantity*: Prevention against any aquifer pollution in the catchment area
		PP	-Systematic use of public inquiries and consultation provided in land-use planning procedures -Legal responsibility of polluters in case of pollution	**Agriculture**: punctual pollution sources **Discharges:** industrial and domestic **Mining:** limestone and sand **Oil tanking**: farms, SMEs, housing, petrol stations	*Quality*: Prevention against any pollution risk in the larger aquifer
	3. 'Legalization' of the protection strategy (1990 onwards)	**PP**	-Definition of official protection zones around water catchments -Systematic use of public inquiries and consultation provided in land-use planning procedures -Legal responsibility of polluters	**Agriculture**: diffuse and punctual pollution sources **Discharges**: domestic and industrial **Production**: Limitation of manure spreading **Gardening**: careful use of pesticides **Car parks**: restriction on car parks (>5 vehicles)	*Quality*: Prevention against any pollution risk in the larger aquifer
SPA	1. Securing of industrial development (1888-1967)	**PR:**	-Concession on the communal springs: monopoly in exploitation of the mineral water production	**Production**: Exclusion of alternative mineral water producers	*Quantity:* No depletion risk due to competing extraction
		PP	-Protection perimeter and springs declared of public utility	**Construction**: limitation of public works in the city center (prohibition to dig)	*Quality/quantity:* Prevention against pollution risk depletion due to public works
	2. Expansion of production (1967-1990)	**PR**	-Renewal of the concession contract. -Monopoly on the aquifers -Purchase of a farm	**Drinking water**: provided from the Eupen dam **Agriculture**: stop of activities	*Quantity:* Whole flow to mineral water production. Renewability secured *Quality:* no risk of manure spreading
	3. Reserve of production (1990 onwards)	**PR**	-Purchase of land and new wells -Re-negotiation with the commune of the royalties attached to the concession contract	**Oil tanking**: SMEs and housing (tightness/ thickness of oil tanks)	*Quantity:* Exploitation of the full potential of the aquifers *Quality:* Avoid settlements above the aquifers
		PP	-Geographical extension of the perimeter of protection and strengthening of the restriction measures	**Discharges**: stricter measures **Construction works**: limitations **Oil tanking**: SMEs and housing	*Quality:* preserve renewability

4. Conclusion

Given the results of our comparison, we can answer our initial research questions without much ambiguity. The status of the operator (public versus private) does not influence the strategy adopted to gain resource access and maintain the resource status. In fact, neither the types of mobilized institutional rules, nor the pressure put on the resource, significantly differ between CIBE and Spa Monopole. The mobilization of PR by both operators depends more on the initial ownership status of the land where the resource flows.

Concerning the hypotheses about the privatization of the operator or the resource and the links implicitly formulated between both, we will provide some empirical findings. First, we observe a "private appropriation of the resource" whatever the status of the operator. In both cases, the local community is dispossessed of the resource. The inhabitants of Spontin or Modave do not directly profit from the water distribution in Brussels. Those of Spa do not consume the 500mio bottles of mineral water produced each year. Some compensations partially cover the externalities created by the "private appropriation of the resource". As such, the necessity to distinguish between the operator's status and the resource property is verified.

Second, the public operator does not protect the resource more or less than the private one. Moreover, its behavior is not more or less sustainable. Both of them bring optimal protection to the resource as they vitally depend on it. The public ownership structure of CIBE does not make it more sensitive to political pressure in favor of a diversification of the resource use. In contrast, Spa Monopole responds favorably to local demands, e.g. about the development of tourist activities on communal land, such as walks in the forests and visits to the famous springs of Spa. As a result, the public operator does not manage the resource in a less nor more efficient way than the private one.

If we link our results with the macro-scale, we observe that the behavior of water users highly influences the overall water system. PP do not necessarily produce the desired effects and are not uniformly applied. A study limited to formal institutions gives a partial view on how things work and cannot foresee evolutions in behaviour. In our case, we clearly observe that individual users effectively protect the resource, but at their own benefit. These kinds of exclusive appropriation of the resource, with strategies combining activations of PR and PP, hamper the goal of a sustainable water use, at least in its social aspect of sharing access. As such, an integrated water management should consider the users' strategies and assess them. Furthermore, this chapter shows that "more attention needs to be paid to the relationship between property rights regimes and natural resources management" (Klug 2002: 693). PR are determinant in water management, but they do not always fit with the reality of the water cycle. This especially holds true with groundwater. A policy of integrated water management should attempt to reform PR in order to align them with its objectives. Finally, a twin analysis of PP and PR effects is necessary to understand how water management works.

In order to more precisely identify the different mechanisms that make the strategy operational and decisive, we should do further research on these cases in four different areas:

(1) From the point of view of the State, the consideration of the liberalization of the resource access would hamper the strategies presented above. These strategies are effective and profitable when there is a monopoly on the resource. If other users competed on the same aquifer, the logic would change. In fact, the creation of a monopoly is the key point of the operator's strategy[22]. In a situation of competition on mineral resources exploitation, users can hardly self-regulate in order to collectively assume resource sustainability (Libecap 1989). They fall in a public choice dilemma that is hard to overcome.

(2) In a State-centered perspective, we should then look more closely at the sectoral regulations that co-ordinate the behavior of competing users. The different water users are regulated by different sets of legal dispositions usually designed on a sectoral basis and producing contradictory outputs and negative outcomes. More co-ordination should then be required in a true resource perspective. Furthermore, a pro-active co-ordination of PR and PP is also required, with the same end. With respect to practical utility, the combining of PP and PR gives rise to an enlargement or broadening

[22] CIBE searched for unexploited aquifers and, about Spa, the elimination of the competition was a pre-condition to its industrial development.

of the steering potential of natural resources. As a result, it helps to conceive new directions for the sustainable use of natural resources (comprehensive and integrated resource management). The innovative concept of Institutional Resource Regime (IRR) would be useful in the elaboration of integrated water policies, pointing to gaps and weaknesses in the current water policy and as a result bringing internal coherence between PP and external coherence between PR and PP (Varone et al. 2002).
(3) From the point of view of the locals, we should examine the mechanisms of "social reproduction". The local anchorage of the operators allows for the development of particular relationships with the other inhabitants, who get used to being constantly controlled in their behavior. The public and private management rules, that the beneficiaries enforce directly (e.g. 'private patrols') have 'performative effects' (Bourdieu 1980). They are embodied by the residents. Private rules become respected norms after time has had them penetrate into the locals' minds[23]. Anthropological and sociological studies could reveal these performative effects in more detail.
(4) At last, from the point of view of the resource, we can wonder if reaching renewability is possible while at the same time respecting the principles of sustainable development. In the case considered, water use is renewable, but not really sustainable if sustainability includes economic and social aspects. Reaching sustainability within the same good or service is far from obvious. Could we not rather create complementarities between different goods and services, from an inter-resources perspective, to transform these renewable (but exclusive uses) into more sustainable practises?

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A Methodical Approach to Multi Criteria Sustainability Assessment of Water Pricing in Urban Areas[1]

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1. Introduction

Drastic changes in water pricing policies are likely to occur in the coming years in particular in the fast growing urban areas all over the world. Urban populations are growing as never before. While today 45% of the worlds population live in urban areas those population is likely to increase to 61% by 2025. (GWP 2000)

Large financial resources will be required for maintaining and renewing the existing water service infrastructure or to construct new infrastructure at all to comply with the environmental needs, but also with the needs of the urban poor.

To expand privatisation of water supply and of water and wastewater treatment facilities is often seen as a need to ensure their appropriate, adequate, development and modernization through increased reliance on private capital. The World Bank recently adopted a policy of water privatisation and Full-Cost water pricing. Many developing countries now fear that than water will not be affordable anymore. To pay for water became a common objective even among the critics and opponents of privatisation. Water has an economic value.

Water pricing itself has an direct impact on water use[2] and pollution and therefore on water resources. A sustainable water pricing policy can lead to a reduction of pressure on water resources by reduction of over-abstraction of groundwater resources and a recharge of aquifers, the increase of flows in rivers and the restoration of ecological status of rivers or wetlands. Efficient water pricing also ensures that water infrastructure is adequately designed and that sufficient resources for operating and maintenance are collected. Water pricing, that builds on sustainable principles and therefore influencing local and socio – economic conditions can provide strong incentives for a more sustainable use of water.

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1 The research was funded by Klaus Tschira Foundation, Germany, Heinrich-Böll-Foundation, Germany, BMBF, Germany and MOS, Israel.

2 To measure the influence of water pricing on water demand is rather difficult. An important factor in being able to manage metered water effectively is knowledge of its price elasticity of demand. Price elasticity of demand measures the respond of customers to changes in price of demand (E= percentage change in quantity demanded/percentage change in price) In international case studies the residential price elasticity (short run) of demand for total water usage range from -0.1 to -0.26. To measure price elasticity of demand needs to take into account several factors influencing the water demand, which are not only directly related to water pricing but also to altering social and economic condition. For an overview of studies and values of price elasticity of water demand for domestic users see Bartoszczuk, P. and Nakamori, Y. (2002). "Modeling sustainable water prices". Handbook of Sustainable Development Planning: Studies in Modelling and Decision Support. M. Quaddus and A. Siddique. Cheltenham UK; Northamton, MA, USA, Edward Elgar Publishers (to appear).

2. Minimum elements of a sustainable water pricing[3] concept: Multiple and competing policy goals

Sustainable development has many definitions but the perhaps most commonly quoted within the science community is the description given in the report "Our Common Future", known as the Brundtland Report:(WCED 1987)

"Development that meets the needs of current generations without compromising the ability of future generations to meet their needs and aspirations"

Sustainable development is classical portrayed as the interface between environment, economic and social sustainability, but the detail of what this implies in practice of water use and especial of water pricing and tariff setting has been open to much debate.

The concept of sustainable development is used in the management of renewable water resources to ensure that the rate of harvesting a resource is smaller than the rate of its renewal. The availability of water in adequate quantity and quality is a necessary condition for sustainable development. Water, the basic element, is indispensable to sustain any form of life and virtually every human activity. The need of constraining human activities within the carrying capacity of the Earth system has been widely accepted and is written down in the "UN action program for sustainable development" (Agenda 21), which contains a full chapter only devoted to freshwater resources. Dealing with urban water issues the program area "Water and sustainable urban development" was proposed. It clearly states that a better management of urban water resources, including the elimination of unsustainable consumption patterns, can make a substantial contribution to the alleviation of poverty and improvement of the health and quality of life of the urban and rural poor. Furthermore a continued supply of affordable water for present and future needs and to reverse current trends of resource degradation and depletion are mentioned as the most important targets. (UNCED 1993)

Following the approach described above minimum elements of a sustainable water pricing system have been identified to meet the challenge of the water needs of the recent and future generation: [4]

1. Resource use efficiency including ground waters and surface waters;
2. Full Cost Recovery, including Supply Costs, Opportunity Costs and Economic Externalities;
3. Economic viability of the water utility;
4. Equity and fairness for different uses and users.

Obviously, these criteria describe partly competing water policy goals. A sustainable water pricing system aims to achieve a balance among these competing goals reflected by a consent between several different stakeholder groups.

2.1. Resource use efficiency

Water is a scarce resource in both quality and quantity. Efficient use of the water resource is not an end itself but an enabling mechanism to promote a more sustainable use of water. It refers at once to a reduction of total resources costs and a way to

[3] Please note that the term "water pricing" refers to both price level and tariff structure

[4] The scientific literature knows other concepts of sustainable water pricing, but all of them comprise at least the following criteria: viability, efficiency, equity, optimality, see: Dalhuisen, J. M., et al. (2001). "Thematic Report on the Economics of Water in Metropolitan Areas". Metron Project Report. Vrije Universiteit Amsterdam, the Netherlands., Beecher, J. A. and Shanaghan, P. E. (undated). "Sustainable water pricing". http://www.uwin.siu.edu/ucowr/updates/pdf/V114_A4.pdf., Boland, J. J. (1993). "Pricing urban water: Principles and compromises". Water Resources Update. 92(summer).

contribute to an improvement of water quality and quantity, supply reliability and the quality of service and environment. Key attribute is the level of water resource exploitation: Only as much water might be used as naturally recharge within a defined short time horizon.

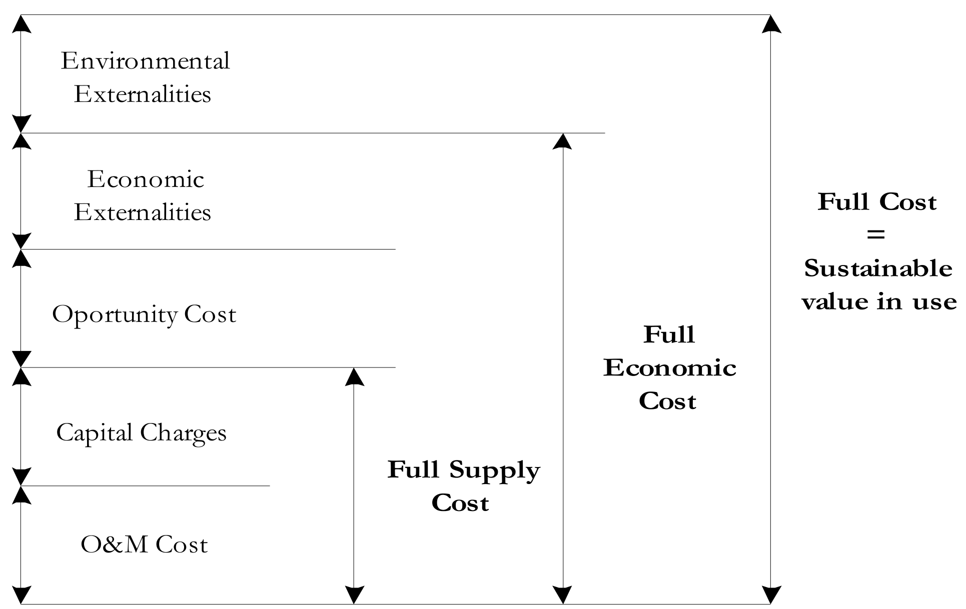
2.2. Full Cost recovery

Regardless of the method of estimation, the ideal for the sustainable use of water requires that the sustainable value of water and the Full Costs should balance each other. Various components have to be added to make the Full Costs of water: The Full Supply Costs and the Full Economic Costs, to which Environmental Externalities have to be added.

Each of these is composed of separate elements: The Full Supply Costs include the costs associated with the supply of water to a consumer without consideration of either externalities nor alternate uses of water. They are composed of Operation and Maintenance Costs and Capital related Costs. The Full Economic Costs of water are the sum of the Full Supply Costs, the Opportunity Costs associated with the alternative use of the same water resource and the Economic Externalities[5] imposed upon others due to the consumption of water by an specific sector. Opportunity Costs address the fact that by consuming water the user is depriving another user of water. If that user has a higher value of water, then there are some opportunity costs experienced by society due to this misallocation of resources.

To the Full Economic Costs the Environmental Externalities have to be added. These costs have to be determined based on the damages caused or as additional costs of treatment to return the water to its original quality.(Rogers et al. 1998)

Figure 1: General principles of Full Cost of water, modified (Rogers et al. 1998)



[5] The most common externalities are: The impact of an upstream diversion of water or the release of pollution on downstream users and over-extraction from or contamination of common pool resources

2.3. Economic viability of the water utility

In general the economic theory serve guiding principles to calculate Full Costs grounded in Marginal Cost Pricing theory. An important issue in estimating the marginal cost of water service is where the next increment of supply comes from and the cost of this supply increment. Marginal cost estimation is a forward looking process, involving forecasts of future costs and future use. Marginal costs can vary within time and location. Unfortunately they may not always generate revenues that match the utility revenue requirements due the fact that long run Marginal Costs typically exceed embedded costs. (AWWA 2000)

At least the Full Supply Cost of water must be covered to guarantee the economic long time financial, managerial and technical capacity of the water utility. (Bhatia et al. 1999), (OECD 1999)

2.4. Equity and Fairness

Most economists assert that economic efficient solutions are equitable[6]. The political definition of equity also takes into account justness, fairness and affordability of water. As far as water is a minimum element of life every human being must be able to access a reliable and affordable minimum of water in quality and quantity. The criteria of affordability does not necessarily undermine efficiency goals or the viability criteria and the criteria of full costs recovery. Efficiency is a necessarily but not a sufficient criteria of sustainability.

This concept of sustainability raises the issue of subsidies, often the only possibility to make water affordable to the urban or rural poor. Subsidies can be paid as internal subsidies amid different users and uses within a water supply system and to a supply system as extern subsidies. External subsidies can be paid as financial assistance to the water system by the government or payment assistance to individuals by governmental or charitable organizations. Most common subsidies are those amid different uses: the urban sector subsidies the agricultural sector, the industrial sector subsidies the urban households. Subsidies between users comprise payments from the economical viable customers to the rural or urban poor. Main target of subsidies should be to make the crucial amount of water for everyday life affordable for everybody, even the very poor:

- The average person needs a minimum of 50 litres of water per day, with 5 litres for drinking, 10 litres for cooking, 15 litres for bathing and 20 litres spent on sanitation needs. (Gleick 2000)
- The water expenditures of a family should not exceed 2 % of the family income. (AWWA 2000)

That also might indicate that external subsidies would have to be paid to the water system by a government or charitable organization to cover Full Supply Costs.[7]

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[6] For competitive goods and services, the concept of economic efficiency encompasses equity in terms of willingness to pay. The equilibrium price reconciles supply and demand, which in turn reflects the producers willingness to produce and the costumers willingness to pay for a good or service.

[7] For a contrary position see Beecher, J. A. and Shanaghan, P. E. (undated). "Sustainable water pricing". http://www.uwin.siu.edu/ucowr/updates/pdf/V114_A4.pdf.

3. Measuring the immeasurable: Indicators for sustainable water pricing

Based on the sustainability criteria mentioned above appropriate indicators for the assessment of water pricing policy were selected.

The use of indicators has many potential benefits and uses:

- Provision of key information related with water pricing;
- Monitoring of the effects of water pricing management decisions;
- Highlight of strength and weakness of water pricing policy and support for the formulation of policies;
- Assistance in assessing investment priorities, project selection and follow-up:
- Providing of an appropriate framework for identifying the main asymmetries between different urban areas.

The indicator system incorporates 3 thematic groups of indicators. Integrated pricing management, water pricing policy and Full Cost recovery. Each of these is composed of separate elements.

The assessment of a water pricing policy cannot be done without taking into account the context information of the water supply system, as well as the characteristics of the region. Therefore, in additional context information indicators were defined to collect all necessary information needed for the assessment indicators which partly derive from. The indicators proposed take into account the actual experience working with indicators in the water sector[8] by analysing case studies.

To describe each indicator and its relation to the comprehensive system the following indicator characteristics are defined:

- The concept to give a definition of the indicator with a concise meaning and unique interpretation;
- The unit of measure;
- The reference value to define a sustainability range by meaning that, if the indicator lies within the value the sustainability criteria are met;
- The critical value to mark a limit value of sustainability;
- The sustainability criteria to identify to which extent the indicator contributes to value of sustainability[9];
- The sustainability weight to represent how important the indicator is to achieve sustainable water pricing[10].

Indicators needs to refer to a well defined time period and geographical area. The model uses one year as the basic assessment period and the urban area as the geographical assessment area. Latter attributes to the political boundaries of urban administration.[11]

For a list of the assessment indicators and their characteristics see the Appendix.

4. Sustainability assessment and decision making: A strategic approach

The model shows that the basic principles of sustainability assessment are being applied to other than purely environmental or purely economic issues. The demand

[8] One of the most developed indicator systems for water supply services was developed by IWA, see: Alegre, H., et al. (1999). "Performance indicators for water supply services". Manual of best practice. IWA.

[9] ++ -high contribution, + - low contribution, 0 - no contribution

[10] 6 - high effect, 3 - average effect, 1 - low effect

[11] In contrary to the urban area the metropolitan area refers to a conglomerate of small urban areas gathered around a large urban area.

for sustainability assessment at higher levels of planning and policy making and strategic planning has given rise to a discussion about the need for an appropriate assessment method or reference framework. This discussion is linked to the question of how sustainable development principles can be introduced in the decision making process.

4.1. Sustainability assessment

Applying the model to a real world water pricing policy for each indicator an evaluation can be made, whether the parameter falls within the reference value or exceed the limit value of sustainability. Once the process has been performed

- a classification can be given for each indicator and as percentage output for each (sub) thematic group;
- fields of needful activity can be identified;
- a first appraisal of for which field urgent actions are needed can be done by taking into account the sustainability weights.

The theoretical aim is to alter the actual water pricing policy in that way that each indicator falls within the sustainability value. The practise will be rather difficult. There is no solution optimising all criteria at the same time. A decision has to be made by finding a compromise solution taking into account the different sustainability weights of each indicator.

4.2. The decision making process

The norm in policy making is that a single criterion is not sufficient. A large number of multi-criteria evaluation methods have been developed and applied for different policy purposes in different contexts. In general, a multi-criteria model presents the following aspects:(Paruccini et al. 1997)

- There is no solution optimising all the criteria at the same time and therefore the decision maker has to find compromise solutions.
- The relations of preference and indifference are not enough in this approach, because when an action is better than another one for some criteria, it is usually worse for others, so that many pairs of actions remain incomparable with respect to a dominance relation.

With a multiple criteria decision aid the principal aim is not to discover a perfect solution, but to create a basic agreement between different stakeholder groups taking part in the decision making process.

Once the fields of activity are identified outranking methods can be used to decide which alternative results in the best compromise. The outranking methods have been recommended for situations with a finite number of discrete alternatives to be chosen among. The number of decision criteria and decision makers may be large. An important advantage of outranking methods, when compared to other decision support techniques is the ability to deal with ordinal and more or less descriptive information on the alternative plans to be evaluated. Furthermore, the uncertainty concerning the values of the criterion variables can be taken into account using fuzzy relations, determined by indifference and preference thresholds. The difficult interpretation of the results, on the other hand, is the main drawback of the outranking methods.(Kangas et al. 2001)

4.3. Moderating conflicting policy goals of different stakeholder groups

Conflicting policy goals have been identified and therefore procedures for consensus building and conflict management are central to a successful sustainable water pricing policy. In general conflicts can occur for many reasons including independence of people and responsibilities, jurisdictional ambiguities, functional overlap, competition on scarce resources, differences in organizational status and influence, incompatible objectives and methods, differences in behavioural style, difference in information, distortions in communication, unmet expectations, unmet needs or interests, unequal power or authority, misperceptions and other. (GWP 2002)

Gaining a shared version of a sustainable water price of different stakeholder groups a moderating process were initiated. The identified indicators of the sustainability assessment model were assessed by different stakeholder groups by appraising the sustainability criteria and the general sustainability weight for each indicator.

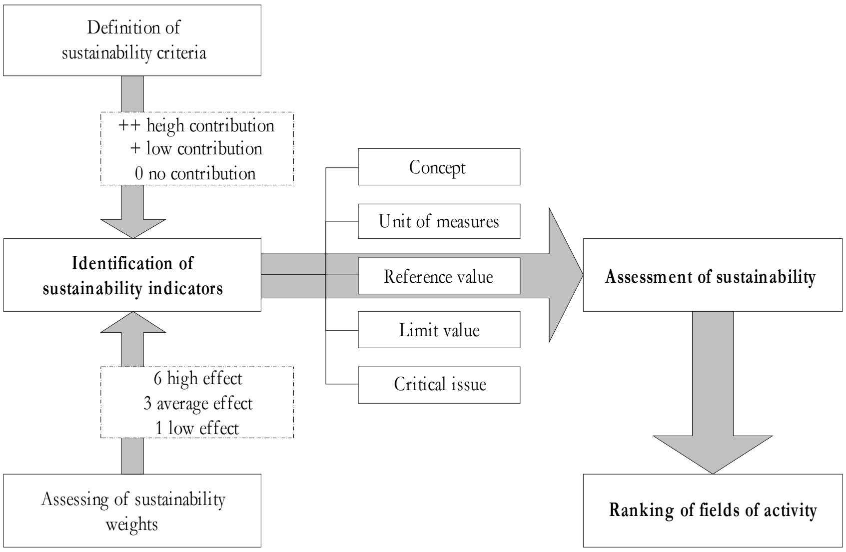
Out of the four identified sustainability criteria for water pricing the following areas for potential conflicts have been identified: [12]

- Full cost recovery;
- Economic viability of water utility
- In assessing the general sustainability weight for each indicator differences occurred within the following indicator fields:
- Analysis and demand of water;
- Use of subsidies and incentives;
- Full economic cost.

Differences in objectives are seen as the main reason. Managing these conflicts means for all stakeholders to move beyond possible bargaining and the claim/counter claim process. By identifying differences and possible conflict areas it becomes possible to understand which interests lie behind each sides position. Furthermore, win-win situations can be identified, that meet as much as possible of the interests of all the stakeholder groups. It has to be stressed, that especially in the field of water pricing issues, not all situations can be resolved with win-win situations in a short term. Trade off and compromises are often a necessary outcome.

[12] The following method has been applied in practise: In a structured email interview for each indicator the influence of the identified sustainability criterion had to be assessed and a general sustainability weight had to be named by different stakeholders summarized in two main groups: Lobby group of economics and lobby group of environment. Please note that out of 50 stakeholder asked only approx. 40 % answered were received and evaluated. The evaluation doesn't claim to be a universal categorization, but shows a possible method of stakeholder participation and conflict resolution by managing disputes

Figure 2: Strategic approach



5. Putting the model to a practical use – first steps

5.1. Overview about water pricing in urban Israel – the case of Tel Aviv-Jaffa

5.1.1 The water tariff: Increasing Block Rates

All fresh water served in Israel by the national water supplier MEKOROT is paid by Increasing Block Rates charging Increasing Volumetric Rates for increasing consumption. Increasing Block Rates require metering. By law all water served in Israel is metered. Increasing Block Rates need to define consumption blocks over which rates increase. The rates usually are designed by costumer classes (residential, agricultural, industrial). Theoretically, properly designed Increasing Block Rates recover class specific cost of service while sending a more conservation oriented price signal to the classes. Therefore Increasing Block Rates have been favored in relatively water scarce regions.

But the price signal of Increasing Block Rates will only be sent, if the water price is calculated in economic terms, not by administrative policy decisions as it is still the situation in Israel

5.1.2 The water prices: Volume rates per administrative sectors

In Israel two water price types have to be distinguished: The water price the municipality has to pay to MEKOROT getting water from the national water supplier and the water price consumers have to pay for their uses. Water prices for urban water uses for the different administrative sector of the last years are represented in .

If there is no residential consumption at all but a water meter is installed a very small Minimum Charge of NIS 16.20 per billing period is requested. Large families have a discount (Levi 2002).

Table 1: Tel Aviv – Jaffa urban water prices, 1997-2002, in NIS[13]

MEKOROT water price, which the municipality has to pay					
				2000	2002
Residential				1.474	1.53
Industrial				1.436	1.492
Agricultural				0.89	0.857
	1997	1998	1999	2000	2002
Residential customer water price, 2 month billing period					
0-16 m^3	2.32	2.35	2.54	2.69	2.69
16-30 m^3	3.42	3.47	3.76	3.99	3.99
>30 m^3	4.97	5.04	5.45	5.78	5.78
Industrial					
Per quota	1.20	1.39	1.40		
Agricultural (urban)					
Per quota	0.85	0.88	0.92		

The difference between what the municipality of Tel Aviv–Jaffa has to pay to MEKOROT is supposed to be used for operating and maintenance expenses, taxes and capital related costs of the water system, but in reality most of the municipalities deserve a certain income used for general purposes of the municipality. So the additional income is used similar to a general tax income. In 2000 the additional income of the municipality of Tel Aviv-Jaffa amounted to NIS 1.924 Mio. Therefore in general every municipality has no economic interest that its customer saves water, but on the other hand the possibility to make some profit also engages the municipality to operate efficiently.

5.1.3 Supply and consumption behaviour and affordability of the water price

The supply network of Tel Aviv - Jaffa today is asked to meet the need of about 350,000 inhabitants and some 700,000 commuters working in the city or coming as a tourists daily. All water for institutional, public, commercial and industrial purposes has to be added. Following the overall water policy of Israel the actual urban water policy of Tel Aviv-Jaffa is supply oriented.

Water in Israel is defined per law as a public property. So far every municipality in Israel gets as much water as the municipality asks for water from the governmental supply company MEKOROT [14].

The general level of the total urban water consumption[15] in Tel Aviv-Jaffa is much higher compared with the consumption in other developed countries. The same picture can be drawn for residential water consumption only. But assessing the data one has to take into account the large number of commuters and illegal workers, which redoubles the number of urban consumers. In 2000 the residential water consumption amounted for 201.61 Litre/capita/d.

Providing water to all customers at an affordable price is a basic requirement in every society. Less affluent households have less flexibility in their budgets to absorb water bill increases. Due to the fact that there are no substitutes for portable water the customer can not choose a lower priced alternative. When customers have difficulties paying their bills, the cost to the utility is raising, too due to late payments, disconnec-

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13 Due to the economic situation the Israeli currency varies strongly: Annual Exchange Rate for US$ 1: 1999: NIS 4.14; 2000: NIS 4.0773; 2001: NIS 4.2056; 2002: NIS 4.8867, Source: http://www.bankisrael.gov.il/deptdata/mth/average/averge.htm

14 Water for agriculture and industry is served by means of quotas.

15 The urban consumption is here defined as the total water consumption in the urban area (residential, industrial, agricultural, public, trade and commercial) for a specific year, divided by the number of residents in the city in that year.

tion notices and service terminations etc. This associated collection costs and bad debt write-offs increase all other costumer bills.

Compared to other developed countries the water price in Tel Aviv-Jaffa is moderate. But to assess the affordability of water one has to take into account the income of the customers, the general consumption expenditures and the consumption behaviour, too.

In 1999 only 0.19 % of the average monthly consumption expenditures were used for water, but e.g. 18.6 % for transportation.

Assessing a water price needs to orientate towards affordability issues. For the group of households, whose family head is employed only 1.31 % of the minimum wage has to paid for water. (Tal 2000) As mentioned above special assistance to households is only needed, where the water bill exceeds 2% of the average income (AWWA 2000).

In the group of family whose head is unemployed are approx. 16,800 families (out of 349,045 in urban total) The cost of water represent in this group amounts to 2.6% of their income.

As shown above the water price not only accounts for a minimum of consumption expenditures, but also represents an easy affordable percentage of the average income. Rising the water price could send an important signal to reduce the urban water consumption. Special assistance is needed for low income families on the basis of their real income (e.g. low income affordability rates).

5.1.4 Use of subsidies and incentives

Every water supplier is asked to charge its costumers to cover the Extraction Levy. The municipality of Tel Aviv – Jaffa on whom an Extraction Levy has been imposed is entitled to collect the same amount of money per water unit supplied from the water consumer, but at the same time the municipality is only allowed to charge prices posted by the government. Furthermore it is questionable if the municipality charges their consumer cost recovery fees at least for the water produced from their own wells.

The water prices of MEKOROT, calculated on an average cost basis, are very low and don't reflect the scarcity of water at the present time. The first step was done with the recently introduced Extraction Levy. But, if the Extraction Levy is collected at all, the amount of money received is simply entering the general national budget and is not used for environmental purposes. Hopefully it will cover at least the 20% the government is paying to MEKOROT to fill up the public company's deficit. Today the public company only covers approx. 80-85% of its costs, the difference is covered by the state by general taxes (Kislev 2002). In 1994 the Cost Plus method used by MEKOROT to calculate water costs was replaced by a more Supply Cost oriented method in which the fixed and variable costs were defined, and a 2.5% efficiency factor was imposed on the company's performance. An increase in water prices coupled with improved performance (saving in energy costs and other variable and fixed costs) have resulted in a significant reduction in the Government's subsidy from 40% to 20% over the last years. Under the current water price and tariff structure, water supplied to the most urban and industrial consumers covers the Supply Cost, while water supplied to agriculture and urban costumers in remote and hilly areas is partially subsidized. Since the agricultural price is much lower the urban consumers subsidize the water for agricultural purposes. The costs of water which is being supplied over long distances or to hilly costumers are much higher than municipalities have to pay for it. The intention to subsidize water for certain administrative sectors was and still is to serve national policy goals. Nearly self-sufficiency in food production is still an important national target although the number of imported products has been raising permanently over the last years. The foundation of new settlements far away from urban centres or in the dessert is still an important goal. Both examples require the transport of high values of water over long distances. But at present time the national agricultural policy goals are changing resulting in smaller water quotas for the agriculture sector and higher prices.

To reduce leakages every municipality will be punished with a fine if it has more than 12% water losses a year. A special water administration was set up to monitor and collect the contributions to the Water Networks Rehabilitation Fund, which is managed by the Municipal Waterworks Association The money is used to assist municipalities in investments and renewals of their water networks. In 2000 water losses in Tel Aviv-Jaffa amounted to 11.9 % of the system input volume. The average water loss in Israel accounts for 10%.

5.2. Is the current water price sustainable? An application of the assessment model to the water pricing policy of Tel Aviv-Jaffa

In a large number of personal interviews and by a comprehensive literature survey data for all indicators were collected to evaluate the current water pricing concept of the urban area of Tel Aviv-Jaffa. It has to be mentioned that, as far as every urban area in Israel can get as much water as it wants to get from the national water supplier MEKOROT, for an assessment of the availability and use of water resources national resources and use were taken into account.

By applying the model different fields of activities have been identified. Several indicators exceed the critical sustainability value: (see Appendix: yellow marked indicators)

Table 2: Selection of indicators with a critical sustainability value (Tel Aviv-Jaffa, year 2000, sustainability weight: 5 and 6)

Critical indicator	**Critical sustainability value**
Use of natural water resources	Recently Israel utilize more natural water than naturally recharged (103%)
Level of water bill in relation to consumption expenditures per household	Only a very small interest of consumption expenditures (0.19%) is used for covering the water bill. The water price is to low.
Level of water bill in relation to average family wage	Only 0.48% of the average family wage has to be paid for water. The water price is to low.
Marginal Cost pricing in use	Due to the fact that no marginal cost pricing is in use no accurate price signal is send to the customer.
Full supply cost coverage	Supply costs of water are not fully covered. Economic viability of the water utility is questionable.
Operating cost coverage	No operating costs are covered. Economic viability and efficiency of the water utility is debatable.

As far as several indicators weighted with a high effect on sustainability are affected the actual water pricing system can not be named sustainable and urgent actions are needed to improve the urban water pricing system of Tel-Aviv-Jaffa. By using one of the outranking methods mentioned above it can be decided which alternative action would lead to the best compromise.

Appendix: List of Indicators, their characteristics and a first practical application

Indicator	Concept	[Unit of measure]	Reference value	Limit value	Critical issue	Sustainability criterion: Resource use efficien-cy	Full cost recovery	Economic viability of water utility	Equity and Fairness	Sustainability weight	year 2000 Tel Aviv-Jaffa
Integrated Pricing Management											
Analysis of Economic Setting, Development Objectives and Policies											
Metropolitan Water System Profile											
Differentiation of water supply source	Water supplied from different sources	% of the vol. produced from a single source	<50%	<80%	Quantity of drinking water not guarantied in the event of a water supply crisis	++	0	+	0	2	85%
Central water supply	Water supplied by a central system	% of population with access to central water supply	80-100%	<80%	Minimum quantity of drinking water not guarantied	++	0	+	++	3	100%
Full time supply	Reliable full time supply 24h a day	yes/no	yes	no	Minimum quantity of drinking water not guarantied	+	0	0	++	4	yes
Water Resource Assessment											
Availability and Use of Water Resources											
Use of natural water resources	=Real annual water abstraction / Reliable annual yield of natural resource x100	%	<100%	>100	Level of water resource exploitation: A value of more than 100% means that more natural water is being used than naturally recharged.	++	+	+	0	6	103%
Analysis of Demand and Supply of Water											
Water Balance for a Water Supply System											
Inefficiency of use of water resources	=Water losses / System input volume x 100	%	<40%	<60%	Sub-optimal performance and achievement of infrastructure, future level of investment, absence of gua-ranties of water supply	++	+	++	0	3	8%
Revenue water by volume	Value of revenue water as % of system input volume	%	>60	<60%	Absence of guaranties of economic viability of water utility	+	++	++	0	5	88%
Non revenue water by volume	Value of non-revenue water as % of system input volume	%	<40%	>40	Absence of guaranties of economic viability of water utility	+	++	++	0	5	12%
Consumption and De-mand											

Total per capita consumption	=System input volume / Population served/365	l/capita/d	<300	>300	Wastefulness use of water	++	+	+	0	5	373,59
Consumption per type of customer-residential	=Residential consumption / residential customers / 365	l/capita/d	<120	>120	Wastefulnes use of water by residential customers	++	+	+	0	5	196,34
Costumer Analysis, Metering and Billing											
Residential customer meters	as % of Customers for residential use	%	80%-100%	<80%	Management difficulties, sub-optimal tariff setting and billing	++	+	+	++	5	100%
Residential customer meter reading frequency	pre-defined frequency of meter readings per residential customer meter targeted within the water undertaking per year	number/a	6-12	<6	Absence of information and incentive signal to customer	++	+	+	++	4	6
Residential customer billing frequency	pre-defined frequency of billing per residential customer targeted within the water undertaking per year	number/a	6-12	<6	Absence of information and incentive signal to customer	++	+	+	++	4	6
Type of residential customer meter	apartment meters as % of residential customer meters	%	80	<80%	Management difficulties, Limited possibilities to set specific water conservation oriented tariffs	++	0	0	++	3	no data
Industrial/agricultural customer meters	as % of Customers for industrial/agricultural use	%	100%	<80%	Management difficulties, sub-optimal tariff setting and billing	++	+	+	++	5	100%
Industrial/agricultural customer meter reading frequency	pre-defined frequency of meter readings per industrial/agricultural customer meter targeted within the water undertaking per year	number/a	6-12	<6	Absence of information and incentive signal to customer	++	+	+	++	5	6
Industrial/agricultural customer billing frequency	pre-defined frequency of billing per industrial/agricultural customer targeted within the water undertaking per year	number/a	6-12	<6	Absence of information and incentive signal to customer	++	+	+	++	5	6
Public/institutional meters	as % of Customers for public/institutional use	%	100%	<80%	Management difficulties, sub-optimal tariff setting and billing	++	+	+	++	5	100%
Public/institutional customer meter reading frequency	pre-defined frequency of meter readings per public/institutional customer meter targeted within the water undertaking per year	number/a	6-12	<6	Absence of information and incentive signal to customer	++	+	+	++	5	6
Public/institutional customer billing frequency	pre-defined frequency of billing per public/institutional customer targeted within the water undertaking per year	number/a	6-12	<6	Absence of information and incentive signal to customer	++	+	+	++	5	6

Coverage of large volume users	Identification of large volume users	yes/no	yes	no	Absence of information and incentive signal to customer	+	+	+	0	3	yes
Coverage of large pollution users	Identification of large pollution users	yes/no	yes	no	Absence of information and incentive signal to customer	+	+	+	1	3	yes
Social Impact Assessment											
Demographic analysis											
Population with access to safe water	=Resident population within the supply area supplied by the undertaking	% of resident population	95-100%	<85%	Reduced hygienic and sanitary safety, Pricing policy and management difficulties, future level of investment	0	++	0	++	5	100
Population with access to adequate sanitation	=Resident population within the supply area with adequate sanitation	% of resident population	95-100%	<85%	Reduced hygienic and sanitary safety, Pricing policy and management difficulties, future level of investment	1	++	1	++	5	100
Population growth	Forecasted average yearly growth of resident population	%/a	0.5-1%	>2%	Absence of guaranties of capacity of water supply infrastructure	0	++	+	++	2	1
Water Pricing Policy											
Analysis of Tariff Level											
Water price and demand											
Average water price per type of customer-residential	Water price per unit	$/m³	1-2 (given a central supply system)	<1	Level of water price to give a price signal (Please see also Price elasticity)	0	++	++	0	3	0,66
Price elasticity of residential water demand	=Change in use as % of original use level/Change in price as % of original price level	negative ratio	>-1	<-1	Sensitiveness of water use relative to changes in the price of water	+	+	+	0	3	<-1
Level of water bill in relation to consumption expenditures per household	Expenditures for water as % of consumption expenditures	%	10	>10	Level of water price to give a price signal	0	+	+	++	5	0,19
Level of water bill in relation to average family wage	Expenditures for water as % of average family wage	%	<5%	>5%	Affordability of water not guaranteed	0	+	+	++	5	0,48
Analysis of Tariff Setting											
Rate design											
Design by customer class	Rate design by customer class	yes/no	yes	no	Identification of customer classes, customer specific cost allocation	+	+	+	++	5	yes
Fixed charge	Partly fixed payment for water supply service	yes/no	yes	no	Full Supply Cost, Coverage of fixed costs	+	+	++	+	3	no

Water conservation rate in use	Use of rate to motivate to save water	yes/no	yes	no	Water conservation	++	+	0	0	5	yes
Marginal cost pricing in use	Added cost of producing or acquiring incremental supplies or capacity	yes/no	yes	no	Optimal rate to send the accurate price signals to customer, Typical mismatch of revenues to actual costs	++	++	++	0	5	no
Use of Subsidies and Incentives											
Subsidies											
Cross sector subsidies	Subsidies for a specific sector	yes/no	no	yes	Subsidisation of water use by one sector, Accurate price signal, Cost coverage	+	++	+	++	3	yes
Subsidies for the poor	Subsidies for low income families	yes/no	yes	no	Affordability of water use by the poor	0	-	-	++	3	yes
Full Cost Recovery											
Full Economic Cost											
Full Supply Cost											
Full supply cost coverage	=Total revenue/(Total O&M expenses +Total capital related costs +Total taxes)	ratio	1.5	<1	Economic viability of water utility	0	+	++	0	5	1,01
Operating cost coverage	=Total revenue/ Total O&M expenses	ratio	>1	<1	Economic viability of water utility, Efficiency of water utility	0	+	++	0	5	1,24
Level of capital related costs	as % of Total revenue	%	20%-50%	>50%	Economic viability of water utility, limited economic elbowroom	0	+	++	0	3	11,58%
Opportunity Cost											
Coverage of costs due to misallocation of water resource		yes/no	yes	no	Undervaluing of water, Misallocation of water resource, which needs to be shared between different users	0	++	0	++	3	no
Economic Externalities											
Coverage of costs due to the impact of an upstream diversion of water		yes/no	yes	no	Undervaluing of water	0	++	0	++	3	no
Coverage of cost due release of pollution on downstream users		yes/no	yes	no	Undervaluing of water	0	++	0	++	3	no

Coverage of cost due to over-extraction from common pool resources	yes/no	yes	no	Undervaluing of water	0	++	0	++	3	yes
Coverage of cost due to contamination of common pool resources	yes/no	yes	no	Undervaluing of water	0	++	0	++	3	no
Environmental Externalities										
Coverage of costs of public health and ecosystem maintenance	yes/no	yes	no	Up keeping of public health and ecosystem quality	0	++	0	++	3	yes
Sewage treatment charge in use	yes/no	yes	no	Additional costs of treatment to return water to its original quality	0	++	0	0	3	yes

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Time Strategies of Transitions and the Transformed Role of Subsidies as Environmental Innovation Policy Instrument

A Policy Framework Demonstrated by the Comparison of Innovation in Iron Production and Housing

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1. Introduction

Fostering innovation is often seen as important for policies inducing a transition towards sustainable development. Yet, given the ambitious environmental targets implied by sustainability, often it is not be sufficient to stimulate incremental innovations alongside established technological trajectories. Due to economic and institutional path dependencies, however, such policies aiming at innovations which change those technological trajectories are difficult.

A broad collaborative empirical research effort on the topic of fostering environmental innovation processes in Germany has established that a simple incentive-response relation between certain economic instruments and innovative effects does not hold generally, but is context specific (e.g. Klemmer et al. 1999, Jänicke et al. 2000, see also Kemp 2000). The general result is a multi-impulse theory in which the same instruments can have different impacts in different circumstances as well as different instruments may have similar impacts.

If the relevant contexts cannot be specified further, however, these results are neither scientifically nor politically satisficing. The research project "SUSTIME - Innovation, Time, and Sustainability. Timing Strategies of Environmental Innovation Policy" (Nill and Zundel 2002, Zundel et al. 2003, Erdmann 2004, Sartorius/ Zundel 2005, see also the contributions of Zundel and of Sartorius in this volume)[1] is based on the hypothesis that time and the dependency of innovation dynamics on time provide a promising systematic context for environmental innovation policy analysis. It is part of everyday's knowledge of entrepreneurs and policy makers that not only the content but also the timing of decisions is crucial. Windows of opportunity play an important role, in particular if the type or consequences of the decision are not only incremental. Nevertheless, striving for generality and simplicity, science has hesitated to transfer this knowledge systematically into theoretical reflections.

[1] Project co-ordination: Prof. Stefan Zundel, University of Applied Sciences Lausitz; other scientific partners: TU Berlin, IÖW, MERIT Maastricht) within the RIW research programme on "Frameworks for Innovations towards Sustainability" funded by the German ministry of research and education (www.riw-netzwerk.de).

Hence in the next section a conceptual framework for the appropriate timing and instrumentation of political transition strategies is introduced, which has been developed in the SUSTIME project. In section 3 particular attention is payed to the role of subsidies as one instrument of time strategies that try to prepare and utilise techno-economic windows. Section four applies the policy framework in a comparative way to two empirical cases: iron and steel production and housing. The last section concludes that time strategies are a promising but politically challenging way to enhance transitions towards sustainability. Time limited Subsidies could play an important role if they are conceived as one element of such strategies.

2. A time strategic conceptual framework for innovation policy

2.1. A taxonomy of time strategie

Modern evolutionary economics depicts the creation and implementation of innovations as an unsteady process. Phases of radical change of technological paradigms alternate with stable phases of incremental improvement in given technologies (Dosi 1982). During times of change, i.e a critical phase of technological competition in which the old paradigm becomes unstable due to external factors or internal problems and competitive new solutions are available, opportunities for a transition towards environmentally more sound technologies are better, at least if they are appropriately supported by environmental innovation policy. Such instable phases can be conceptualised as "time windows of opportunity" (David 1987, Erdmann 1993). We can define a techno-economic window of opportunity or *time window* as an instable phase of (market oriented) technological competition in which actors such as firms or policy actors have a greater opportunity to change the direction of trajectories in a significant way than during stable phases (for a detailed presentation of the conceptual framework see Zundel in this volume and Zundel et al. 2005).

What makes the distinction between stable and instable phases of techno-economic systems interesting from a political point of view is that the success conditions for policies which attempt to alter the direction of development paths change over time.-Techno-economic windows provide an opportunity for a more effective or lower cost environmental innovation policy and make thus transitions towards more sustainable technologies easier. A time-strategic approach to environmental innovation policy designed for a change or a transition of the given path of technological development should make use of that.

For political time strategies building on these dynamics, however, also the success conditions in the political system are important: First, the system cannot be completely separated from society. In democratic societies policy reacts – as it should – to public interests. On the other hand, the political system is not completely free in adapting public interests; it has its own institutional and social momentums. These mechanisms operate like a filter and influence whether and to what extent external impulses are picked up by political actors and are transformed in political concepts and actions. In particular in the competition between old and new technologies, also (attempts of) institutional and political stabilisation of the old path by the incumbents have to be systematically taken into account. Here it makes a difference if the path changing innovations can easily be driven or adopted by established firms or whether they are disruptive for the established actors because they involve discontinuities in competencies, organisation and markets (Christensen 1997). In the latter case, a strong incentive arises for political bargaining instead of R&D in order to prevent a transition. The political system can then be inert and impede external impulses for change. In such cases, the political system also has to move in an unstable phase for making a transition possible, a political window of opportunity is necessary (Nill 2002).

Time strategies should reflect the specific conditions and dynamics in the techno-economic system. In the SUSTIME project, a taxonomy of time strategies has been developed (see the contribution of Zundel in this volume). In this contribution, we focus on the strategies of window preparation, when the techno-economic system is still stable but promising alternative solutions exist, and window utilisation, when an instable phase has been reached.

2.2. Policies for window preparation

The phase of window preparation is characterised by a *stable* old path, but there is at least one *promising new solution*. The main targets for policies which *prepare* the emergence of future techno-economic windows for a transition are creating diversity by improving search and development processes and stimulating firms to develop at least one competitive solution, for example by organising learning curves.

Government should make best use of market forces; here this involves mainly searching for new promising solutions and developing new solutions until they become competitive to some extent. For window preparing policies expectation management is important. Weak signals such as long-term targets also play a role. Mechanisms may e.g. include the creation of niches for or the support of new alternatives, such as argued in the concept of strategic niche management, see Kemp et al. 1998). Also economic instruments may play an important role. If budget is limited or if strong increasing returns are involved, a trade off between development of a particular promising solution and diversity is possible. Additionally, we must keep in mind that environmental policy requirements can also hinder window emergence, e.g. delay investment cycles (retrofitting), thereby increasing sunk costs especially if end-of pipe treatment is involved. In this case a transition is obstructed by environmental policy itself.

Political-economic constraints are probably of less importance - except if the policies are expected by relevant actors of the dominant path to be in fact window-creating policies. However, c.p. the result may be rather a restriction of feasible instruments than of the policies as such: While policies with direct negative impact on dominant path actors are difficult to achieve, policies which rather support new alternatives should remain feasible - also the influence of new path actors may help here.

2.3. Policies for window utilisation

If at least one alternative solution becomes competitive to some extent, the situation may be generally characterised by the following features: the old path is *unstable* or at least a techno-economic window can be anticipated, and there is competition between different new solutions. At least one of the new solutions is *competitive* in principle. In short, we face a combination of *new/new* competition and *old/new* competition. Fundamentally a transition is now possible and the government's target now is to facilitate this transition, for example by abandoning discriminating mechanisms for the new solution.

For examining appropriate policies which *take advantage of* or *utilise* such a techno-economic window for a transition that has emerged or will emerge in the techno-economic realm, it is helpful to first regard two subcases separately, namely dominant old/new and dominant new/new competition, before looking at the general, but not always relevant, old/new/new case. If one takes the specific background of time strategies, namely increasing returns, serious, it should be rarely the case that the *utilisation* of old/new and new/new windows have to be dealt with simultaneously, i.e. that in both sub-constellations the dynamics are highly unstable. Usually, such windows should rather emerge in sequences (old/new (promise of solution) - new/new –

old/new (if old is not ruled out politically)), thus often only one of the two types is actually time critical.

For policies which *utilise* techno-economic windows of the *old/new* type (case *3a*) sometimes a relatively small and perhaps even temporary political impulse is sufficient. The main political task is to grasp the situation and have flexible and well measured out instruments available to deal with the dynamics. However, in this situation window utilisation usually tends to imply selection. Due to the different dynamics of old and new technologies, it is difficult to manage a fair and result-open old/new competition; this is also normally not the environmental aim.

However, the utilisation of such a window by policy is supposed to be subject to political-economic constraints only under particular conditions. The criterion proposed is a *disruptive impact* of window utilisation on actors of the old path. This may be the case if it implies

a) a probable decision of the technological competition (and not only the ensuring of window openness), and
b) this decision would have a significantly negative impact on politically important economic actors, for example due to competence- or cost-based constraints to utilise the techno-economic window successfully themselves.

Due to these (expected) disruptive effects, the result often is a blocking of the political system so that a political opportunity to utilise the techno-economic window is supposed to be tied to other change facilitating conditions in the political or social system, for example political windows (Nill 2002).

Sometimes the necessity of a transition is clear due to internal limits of the old path. As a result, new/new dynamics come to the forefront (case *3b*). For policies which *take advantage of* or *utilise* these new/new techno-economic windows, "utilise" can also mean "keep the window open" for a sufficiently long time. Political responsibility is also high here: environmental policy may act as the "small historical event" within the selection environment important for the increasing returns models, e.g. biases competition. This may reinforce or even lock-in first mover advantages. Under some conditions, it may be necessary to extend the duration of the techno-economic window by means of political intervention (David 1987) in order to ensure that political discrimination of ecologically superior better solutions does not occur.

In some cases of phase 3 the situation is more complicated than in 3a or 3b: besides the competitive solution there are other solutions that are merely promising and have not yet attained competitiveness. The development of their potential can be strongly impeded by simply following the target of transition. If some new solutions can use network effects and early economies of scale, they can gain an advantage, and cannot be overtaken by other promising solutions with a possibly greater potential. In other words, in this case there is a trade-off between diversity and facilitating transition. In this situation the government must keep the window open by suppressing the selection function of markets until the most promising solutions have developed their potential. If this is too costly or not feasible and the old/new window can only be used by the more advanced technologies, a lock-in of new solutions must be avoided at least, e.g. through reservation of niches etc. This is not easy for political reasons, the promoters of the available solution might press to secure their future market.

2.4. A new, time strategic perspective on instrument choice

From a dynamic point of view, it must be emphasised that the usual treatment of instruments in economic textbooks is misleading to some degree. In a dynamic context also framework instruments such as taxes or tradable permits have a "technological content" depending on the time of implementation. If a given techno-economic system is in a stable phase and there are no promising solutions, these instruments mainly induce an improvement of dominant technologies. This contributes to explain why empirical findings on the impact of taxes and tradable permits on the stimulation of research and development of new solutions are not very convincing (Kemp 2000). If the system is unstable, even a weak use of instruments may give the system's development a new direction. Hence timing, design and dosage of instruments may be more important than the question of choice of instrument. The vivid debates also on the implementation procedures of economic instruments such as taxes and emission trading are a case in point. This confirms some aspects of the multi-impulse-hypthesis, but puts them in a systematic context: The dynamic efficiency or innovation impact of policy instruments is a function of techno-economic dynamics in time. This implies a change of perspective: from "regulation to innovation" towards "innovation to regulation". A precondition for appropriate time strategies is the identification of the relevant features of techno-economic dynamics (as described in table 1 above) and the adaptation of instruments to these.

Moreover, a time strategic analysis of policy instruments involves the following aspects:

- instruments should contribute to keep a balance of clear overall transition signals and adjustment flexibility to new developments
- instruments should be techno-economically and politically feasible and accepted by society

Both aspects lead to the conclusion that often a combination of general framework instruments and temporary specific impulses is appropriate. For the latter, a set of additional, process-oriented criteria is important:

- Is it possible to design the instrument according to the techno-economic dynamics and to time its beginning and finish of implementation appropriately?
- Is it possible to treat different solutions inequal?
- Is it suitable to the political system so that a quick and flexible implementation are possible?

Given these criteria, appropriately designed subsidies can be an attractive policy instrument within a time strategy for environmental innovation policy.

3. The transformed role of subsidies as policy instrument

3.1. A reappraisal of the debate on subsidies as innovation policy instrument

Especially in the economic literature, subsidies have a bad image. They contradict the polluter-pays-principle, are expensive, politically difficult to remove and there is the danger of windfall profits. The neoclassical theoretical literature states that the innovation impact of subsidies is lower than of taxes or tradable permits (e.g. Milliman and Prince 1989). The more recent, empirically underpinned literature is less categoric. Kemp (2000) emphasizes the importance as well as the limits of subsidies as instrument. R&D subsidies may be important for variety creation if uncertainty prevails as well as if a technology switch is costly and no market exists. In his view, investment subsidies are more problematic, and the empirical success is limited, albeit there are counter examples if they are managed appropriately. In their broad collection of empirical studies, Klemmer et al. (1999) discover a bigger impact of subsidies than assumed in advance. They highlight the role subsidies may play for the first market introduction of an innovation. This study is also a first attempt to relate the impact of instrument to innovation phases. But Klemmer et al. (1999) rather focus on individual decisions of innovators (invention, market introduction, diffusion) than on the dynamics of techno-economic and political systems. From the latter perspective, the potential role of subsidies - as well as their limitations - emerge even more clearly.

3.2. Subsidies as instrument of window preparation strategies

At first glance, there are two different strategies for window preparation conceivable. Either a strategy based on a general framework changing instrument like environmental taxes as main element which destabilises the old path and improves the economic perspectives of new pathes. Or, in particular when product or system innovations are aimed at, strategic niche management (e.g. Kemp et al. 1998) which cares systematically for the development of different alternatives by securing niches for experimentation. In both approaches, however, subsidies will often play an important role. It is a well established empirical result that at least regarding to path changing innovations, the innovative effects of taxes are limited (Kemp 2000, Linscheidt 2000). There is at least a complementary role for R&D subsidies. This holds particularly, if more radical and hence more risky and often also more costly solutions are strived for. Moreover, subsidies for pilot demonstration projects ore demand creating investment subsidies are one important instrument to provide for niches.

The advantage of subsidies is the easy targeting and the possibility to treat different solutions inequal. To reach the window preparation goal, a degressive or temporary way of implementation is crucial, as for example in the German renewables act. Moreover, they have at least two important political advantages. A successful demonstration of feasibility of a new solution paves the way for a more stringent regulation, a historically well known dynamic pattern of the interplay of process innovation and regulation in Germany. Second, from a political economy perspective, they are easier to implement than more general instruments like taxes if established actors fear the new path to be disruptive. While policies with direct negative impact on dominant path actors are difficult to achieve, policies which rather support new alternatives should remain feasible - also the influence of new path actors may help here. Hence, implementation may be feasible without the need for a political window of opportunity.

3.3. Subsidies as instrument of window utilisation strategies

It is useful to regard the two subcases of window utilisation, 3a and 3b (see table 1) separately. In the case of dominant old/new competition, and if no economic instrument such as taxes or permits is already in place, a time limited environmental standard, which destabilises the old path, or temporary investment subsidies may be instruments of choice. For both instruments, however, institutional limits are important to consider (see cases below). Taxes and tradable permits are also be well or even better suited, because they allow for flexibility in the firm decisions to make the technological transition, but difficult to dose and to implement quickly.

In the case of dominant new/new competition, taxes or tradable permits are well suited to let the new/new competition play in an innovation-enhancing way. However, there is the danger that promising solutions which are still on a higher point of the learning curve are locked-out, especially if are no big and resourceful actors behind this path. In such situations, subsidies or, if a regulatory framework is dominant, also innovation waivers could play an important additional role to keep technological competition and thus the techno-economic window open or at least to secure a niche for future solutions. As a general instrument, however, they are too costly.

Taken together, temporary subsidies can play an important role in window utilisation strategies, in particular if other economic instruments are not available or if the most promising solutions are in different stages of technological development.

4. Empirical application: a comparison of two cases

In the following, the policy framework presented is applied to two empirical cases and the window preparation and utilisation strategies are compared. The chosen cases, iron and steel production and low energy housing, share some similarities but also differ in important respects so that a comparative analysis is instructive. In both cases, the old technological paradigm is confronted with environmental problems and new promising technical solutions emerge. Hence, techno-economic windows are anticipated by at least some actors. Another similarity is that both cases are not "high tech", thus the pace of technical change is rather slow. The first case represents a technologically radical innovation of a capital intensive process situated in a market with substantial entry barriers. Moreover, in this case supra-national dynamics and competition play an important role. The second case rather deals with a functional or system innovation of a capital intensive product supplied by markets with low entry barriers. One implication is that in the first case time strategies before window realisation, i.e. window preparation strategies, are of paramount importance while in the second case appropriate window utilisation policies are the key challenge. The focus of the presentation is on old/new competition.

4.1. The case of iron and steel production

Steel production is one of the most energy and environment consuming industrial activities. Today steelmaking is dominated by two production routes based on different technologies. The still dominant *coke oven - blast furnace - basic oxygen furnace route* and the originally by and large complementary *scrap - electric arc furnace route*. The first route takes place in so-called integrated steel mills at a quite high production scale while the latter is typical for so-called minimills, which work on a much lower scale. In the last years the ironmaking stage has seen important invention and partly also innovation processes. The new smelting reduction technology (SRT) is a technologically radical new process of ironmaking which skips the coke oven stage and substitutes for the blast furnace. SRT is one of the very important energy efficiency increasing process technologies in industry, it is expected to reduce specific energy consumption by more than 20 per cent and CO_2 emissions by 15% (and other emissions even to a higher degree). For the use in integrated steel mills, SRT has to compete with the old blast furnace route of ironmaking (for a detailed analysis see Luiten 2001 and Nill 2003).

A main driver introducing dynamics into these R&D processes since the middle of the 1980s was the anticipation of a window of opportunity for innovation in the sense of market introduction due to the replacement necessity of obsolete coke ovens and blast furnaces in integrated steel mills (ISM). For example, in the Netherlands as well as in Japan, important replacement necessities of coke ovens or even blast furnaces were anticipated for 2000 to 2005. At the end of the 1980s and the beginning of the 1990s relevant prototypes emerged and the construction of small pilot plants of several SRT types was the next step envisaged.

However, the dominant trajectory did not stand still. The existing capital stock was being continuously improved and upgraded and thus its lifetime extended so that the need to replace the existing coke ovens became less pressing. One impulse for this was environmental regulation. Moreover, the incremental innovation of direct pulverised coal injection in the blast furnace, combined with the increasing availability of coke imports, reduced the need for coke production (EC 2001, 319). And finally, cleaner coke ovens were developed. All in all, the cost advantages of SRT became smaller and smaller and some producers reinvested into the traditional route, thus losing interests in alternatives (Luiten 2001). As a consequence, the anticipated window did not materialize (yet).

One result was that only in the Netherlands and in Japan integrated producers seriously pursued possible market introduction and thus the anticipation of a techno-economic window stabilised. The technical processes being patented and published in the mid nineties, and pilot plants being put into place, now the step to a demonstration plant was on the agenda. Due to the investment scale, and costs as well as the risk involved, this step in effect proved to be already a very time critical stage, because it would be only taken if a serious success chance for market introduction were perceived. The Dutch example nicely illustrates this point: Including the pilot plant Hoogovens had invested up to this point 6.5 million US $ into SRT development (Moors 2000, 244). From 1996 on Hoogovens planned for its SRT technology a demonstration plant of industrial scale, i.e. 700.000 tons a year. The costs were estimated at 125 million US $, which is above the costs of an *isolated* replacement of a blast furnace which is reported to cost 100 Mio US $ (Hogan 1994, 186).

Finally, the techno-economic window did not materialise yet, although the Dutch government wanted to support the facility (see below). Due to the overall economic situation and other investment priorities, Hoogovens first postponed and two years later, in 1999, stopped the development (Moors 2000). Also in Japan a demonstration plant was not build up to now. Probably, market introduction of SRT in integrated mills will at least be postponed for five to ten years. In the meantime, there is a certain probability that SRT will be introduced in minimills, substituting hot iron for scrap in the electric arc furnace route. Some attempts are on the way, but it is not clear if the critical investment amount hurdle, which is beyond usual investment capacities of minimill producers, will be successfully taken. One first generation SRT, COREX, however, which is less promising from an environment perspective and of which the use is only possible in newly built steel mills, has successfully exploited a local niche and diffuses now in some emerging countries[2]

4.2. The case of housing

In Germany, conventional housings have been gradually improved towards a kind of low energy standard, now defined by the energy saving ordinance of 2002 (about 70-110 kwh per m^2a end energy for heating purposes). But in parallel, at the innovation frontier much larger steps are in sight. Technical concepts such as solar housing, zero heat energy housing or plus energy housing can be mentioned. But in particular passive housing emerged as a potential new paradigm, enabling much lower energy consumption for heating at a reasonable cost (for more details see Haum and Nill 2004).

Technologically, a passive house is a a system innovation or functional innovation, a combination of technologies which reduce the end energy use for heating purposes to less than 15 kwh per m^2a and hence make the omission of conventional heating systems feasible. To achieve this, a combination of strong thermal insulation, an utilisation of passive solar gains by solar-oriented windows and internal savings, a special type of three-layer windows and a ventilation system with heat recuperation which provides for the necessary rest of energy are used (Feist 1996). The prototype was constructed 1991 in Darmstadt-Kranichstein. The main actors were outsiders to the

[2] Seen on a global scale, this process contains also interesting aspects of new/new competition. For more details, which go beyond the scope of the present chapter, see Nill (2003).

construction industry, and strongly motivated by environmental concerns. The main component innovations required were integrated planning approaches by architects and better insulated three-layer windows.

To a certain extent, passive housing can be described as a disruptive innovation (Christensen, 1997), because at least in the beginnings, a reduced product performance was accepted by the environmentally motivated lead users. Since 1995, important component innovations of windows and integrated ventilation and heat recuperation systems followed. At the end of 1998, there have been some 120 passive house flats. In 1999 there was a first boost of the new trajectory. Policy reacted and supported the new solution (see below). The investment cost difference has been reduced to about 15 per cent. The number of houses increased markedly, the necessary window technology became commercially available and important technical problems had been solved. Expectations rose that there could be a techno-economic window for successful competition with conventional housing, mainly based on three pillars: cost reduction due to the omission of the conventional heating system, learning and scale effects in component development, and raising energy prices. Incumbent actors such as constructors of prefabricated houses and component suppliers began to react to the dynamics and to offer passive houses as part of their portfolio, while still perceiving the passive house as a niche. At the same time, they explored more incremental steps of optimising conventional low energy housing towards "three litre houses" (30 kwh per m^2a), keeping the conventional heating systems.

Until today, these dynamics have resulted in quality improvements and a rising market share. As of end of 2002, there more than 2500 passive house accomodation units. The market share, however, is still well below one per cent of new housing. There have not yet been significant further cost reductions. The price of passive houses is still about 10 to 15 per cent higher than in conventional houses, and slightly higher than in three-litre houses (Schulze-Darup 2002). The cost saving potential is estimated at nearly 50 per cent for windows and about 30 per cent for ventilation and recuperation units. Recently, some policies which could be termed window utilising are visible, but their effects remain to be seen (see below).

4.3. The empirical role of subsidies in transition strategies - window preparation

In the iron and steel case, governments were substantially involved in window preparation, though their activity alone was not sufficient for window emergence. Luiten (2001, 186) estimates that about 25-30 per cent of the total expenditure for SRT development, up to now between 600 and 700 million US $, was provided by governments. In most industrial countries general R&D efforts in the steel industry were supported by governments; in the European Community of Coal and Steel financed by a levy on steel prices. In the SRT case, it played a supplementary but sometimes rather substantial role. In the Netherlands, the European subsidies were at the beginning of the 1990s complemented with a covenant in the framework of the National Environmental Policy Plan. The base metal industry agreed to increase its energy efficiency between 1989 and 2000 by 20 per cent. In turn, no economic instruments such as an energy tax were considered. The political feasibility was no problem, because the political system was open and the techno-economic actors proactive. The efficiency increase, however, was feasible with incremental improvements. Concerning the impact of subsidies on innovation, Luiten (2001, 191) concludes that in most cases, the support led to additional research while its impact concerning an acceleration of the development is less clear.

In the middle of the 1990s, a very time critical stage of window preparation was reached, in which again subsidies played an important role. In 1997, the Dutch government announced the so-called CO_2 Reduction plan that involved substantial budgets. The integrated steel producer Hoogovens applied for government support of a demonstration facility. The latter awarded 30 million US $ which was about 25% of total expenditures. Hoogovens wanted to provide the same amount but failed to find another investor for the remaining 60 millions. Hoogovens, however, was not willing to invest more, given the rather high risk of the project. Thus in 1999, the firm formally announced a development stop (Luiten 2001, 196). That in fact the window preparation policies did not result in the commercialisation of the new technology did not lie in the hand of policy but seems to be a reasonable element of contingency, leaving market actors the last decision about the outcome of the competition.

There was no political window necessary, because the proposed policy, i.e. a subsidy scheme, was an established instrument and the Dutch political system is well known for its strategic capabilities (e.g. Nill et al. 2002, 23-31). And the expected effects were incremental because the change of technologies, even if radical in terms of processes, is not disruptive, but indeed competence enhancing for the main economic actor concerned. So there is not too much stickiness towards the old path and an adaptation to the new solution is feasible. Moreover, there were some, however not binding restrictions at the European level, i.e. the Coal and steel subsidy framework to avoid unfair competition. The intended subsidy had to be approved by the European Commission, which was done with the (questionable) argument that the demonstration project would be far from market commercialisation. In general, there is no example that an iron making demonstration plant failed due to lack of political support. Almost everywhere where a window preparation seemed promising, governments were ready to support the projects, even with substantial amounts of money.

In the case of low energy housing in Germany, regulation and subsidies are the dominant policy instruments. The innovative effects of regulatory policies are usually limited. This is particularly true for building regulation in Germany, where rather the opposite causal chain, i.e. from innovation with a large time lag to regulation, can be observed (Lehr 2000). The first commercial passive houses were sometimes supported at the Länder level. After the success of the first niche was visible, policy reacted by redirecting an existing premium loan programme for new private housings from low energy housing to passive housing, what can be called a window preparing policy. It supported more than 300 houses in 1999 and more than 500 houses in 2000 and thus supported stabilisation and expansion of the niche. In 2001 the performance standards have been changed from end energy to primary energy use, creating more favorable conditions for the integration of renewable energy heating systems. Since then, also the more incremental new option of three-litre housing is backed, albeit with less favorable interest rate conditions. It is worth mentioning that since 1999 in the framework of the so-called ecological tax reform also the tax on gas and heating oil has been risen to some extent. Expert interviews, however, accord more importance to the subsidies than the tax changes, what is in line with a recent survey of empirical studies (OECD 2003). In effects there were some elements of an unintended niche management present, mainly carried out by the administrative part of the political system which was open to the innovation dynamics.

Hence in both cases, subsidies were in fact the main instrument for political window preparation strategies - as far as such strategies have been in place at all. In the iron and steel case, only in the Netherlands there was a kind of gradual transition strategy; this is not yet the case in low energy housing in Germany, albeit some first political attempts are observable.

4.4. The empirical role of subsidies in transition strategies - window utilisation

In the case of new ironmaking technologies, in integrated steel mills in industrialised countries up to now no window utilisation occurred, the worsening economic dynamics working against reinvestment. However, one could argue that the Dutch climate protection programme contained already some element of de facto window utilisation, given the decisive role of a successful demonstration project. The use of subsidies as proper window utilisation instrument, however, is restricted by European state aid policies in the iron and steel sector. The planned European emission trading system is a chance to revive technological competition in this field - but only if it is appropriately designed and keeps an emission reduction incentive. In fact, by licensing initial emissions levels for free and not setting strict standards, it does not work as window preparing instrument in itself. Hence a so-called innovation reserve - a de facto subsidy which provides similar opportunities to newcomers - is indeed a necessary complement from a time strategic perspective.

In the case of low energy housing, in October 2002 the renewed red-green German government stated the ambition to utilise the emerging techno-economic window and to create an incentive programme for 30.000 passive houses. Originally it was intended as capital subsidy, reflecting the well established result that this constitutes a better incentive than a premium loan programme (OECD 2003). Due to budget constraints and administrative problems of creating a new scheme, it has been implemented only to a limited extent, by the way of changing the financial conditions of the premium loan scheme in May 2003. The incentive is now better than before, but with some Länder schemes being reduced at the same time and another capital subsidy being stopped, the effects remain to be seen.

What is observable is a clear effect of the subsidy offer also for less energy efficient houses, which were reintroduced following demands of construction industry. In 2002 the number of about 700 accomodation units of passive house standard or equivalent technology was doubled by more than 1500 approved houses of the less ambitious standard. There may be a ratio to do so for environmental reasons, i.e. to achieve an old/new substitution, as long as it leads to additional well performing houses. From a time strategic perspective, however, it is a questionable window-utilising policy, because it may also lead to a replacement of more ambitious new solutions, and hence their dynamic economies are supposed to be lower.

A credible transition strategy is still missing - with regard to the strength of the impulse as well as to time limitations of the instruments. Moreover, in the decentralised housing market, the critical phase of competition is diffusion beyond a niche, and for this subsidies are a quite expensive instrument, while framework instruments like energy taxes would influence the old and new path at the same time. However, for the latter no political window can be discerned.

5. Conclusion

Time strategies for transitions are a promising way to conceptualise policies which use techno-economic dynamics as leverage for a transition towards sustainability. They often combine a long term framework with specific impulses. Within such a framework, also traditional instruments such as subsidies play a transformed but important role. Put differently, a time strategic policy framework may well explain why subsidies are still used a lot more in real life policies than advised by conventional theoretical considerations.

A time strategic environmental innovation policy is demanding in terms of the abilities of political and administrative actors to manage dynamic processes. The set of abilities required include monitoring to identify possible techno-economic windows, evaluating technological potentials, balancing credible transition goals and a flexible time schedule, developing a proper design of instruments and a willingness to learn. Nevertheless, the empirical cases show at least that it seems to be possible not only for economic but also for political actors to discern techno-economic windows. Also political capabilities to react to these dynamics are observable, albeit considerable improvements are envisageable. And if the hypothesis holds that it is almost impossible to have environmental policy without effect on technology choice in a path dependent world, the solution cannot be to refrain from political interventions but to more closely examine how to improve political capabilities for an environmental innovation policy.

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Combining Long-Term and Short-Term Perspectives on Food Choice: The Case of Meat's Animal Origin

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Introduction

Although Europe, and particularly north-western Europe, has often been characterised as a meat eating continent (Braudel, 1987; Montanari, 1994), there are indications that meat is losing its position as a particular attractive source of proteins, only to be criticized by marginal groups of vegetarians. The indications do not only refer to the negative role of meat in several recent food safety crises but also to a number of socio-cultural changes that might gradually gain importance in the long-term. Some relevant examples are the increasing significance that consumers attribute to animal welfare (Issanchou, 1996) and the growing appreciation of vegetarian meals, not only by consumers (Beardsworth & Keil, 1997) but also by nutritionists (Sabaté, Duk, & Lee, 1999). Given the various manifestations of these changes, the question can be raised whether they will continue and get a substantial impact on the consumption of meat. This question is particularly important in view of the environmental pressure that is attributed to the current system of meat supply (Aiking & Vellinga, 2000; Tilman, Cassman, Matson et al., 2002). Gaining more insight into socio-cultural changes and their linkages with food choice criteria may contribute to the pursuit of a food system that is more sustainable.

From a methodological point of view, studying the links between food choice criteria and long-term socio-cultural development is a challenging task. Research into food choice criteria is often undertaken from a bottom-up perspective in which the behaviour of the consumer is seen as the result of a restricted number of causes (e.g. Connors, Bisogni, Sobal et al., 2001). The causes specify, for example, *how* consumers make a choice given their motives for a certain type of meal (e.g., a quick meal) and their beliefs about the foods that fit into such a meal (e.g., a hamburger). In contrast, studies of long-term socio-cultural changes are often undertaken from a top-down perspective to explain *why* people's activities in a certain period have developed in a particular direction (Goudsblom, 1996). This approach can reveal irreversible changes in systems of food provision and consumption, such as the development of fast food chains in relationship with Western modernization processes (Ritzer, 1996).

Although bottom-up and top-down approaches are often applied separately, they can be mutually enhancing. For example, a top-down approach of social change may lead to sweeping generalizations about dramatic transitions, if it neglects the experience of the people involved who may just have adapted their behaviour to changing circumstances (Levine, 2001). Similarly, a bottom-up approach may miss the direction of gradual changes in people's behaviour if this direction can only be observed from a long-term perspective.

Combining top-down and bottom-up approaches is particularly relevant for research into the ways food choices are changing. By examining how current food choice criteria are linked with long-term socio-cultural development, their potential impact on future food consumption can be assessed. Generally, distal processes (i.e. long-term causes) will determine how proximal factors (i.e. short-term causes) might work. More specifically, a long-term development will create opportunities for food choices that match its general direction, whereas it will put constraints on others. Accordingly, it might be expected that those food choice criteria that appear to be part of a long-term change will have more impact in the future than criteria that are only based on short-term trends.

A combined approach to long-term and short-term processes is not a simple task, however, because there is as yet no historical social psychology to draw the connections. Moreover, there are no databases and tools to support this type of research. As two of Europe's most renowned culinary historians, Jean-Louis Flandrin and Massimo Montanari (1999: 3), note, we are still ignorant about the reasons for certain fundamental changes in the routines of everyday life, such as changes in cooking techniques, choice of ingredients and seasoning. Nevertheless, it is possible to use insights from the relevant disciplines (i.e. psychology, sociology, anthropology, history) as elementary building blocks, and to test at least some implications by small-scale experiments.

The main strategy chosen here is the development of a framework that sorts insights on influences on behaviour into a logical order. Two general notions have been extremely useful for this approach. The first one is that it makes sense to consider, from a behavioural perspective, the time it takes to create or develop something. For example, a real problem cannot be solved in one second and a friendship cannot be built in an hour. The second notion is that any potentially causal factor can only cause an effect in a certain context. In other words, a virus can only cause an illness among those persons who are not immune to it. And this context, in turn, is dependent on other causal factors, such as the special vulnerability that is determined by heredity. The best approach to combine the two notions is one that builds a cascade-like framework of the relevant processes.

In the next section, the framework of influences on behaviour is explained. Then, the role of Western modernization processes is analysed as an example of long-term influences on food choice criteria. These results will be combined with a short description of the changes that have influenced food supply in the past decades. In the final part of the chapter, I shall draw conclusions and discuss the implications for the pursuit of Industrial Transformation.

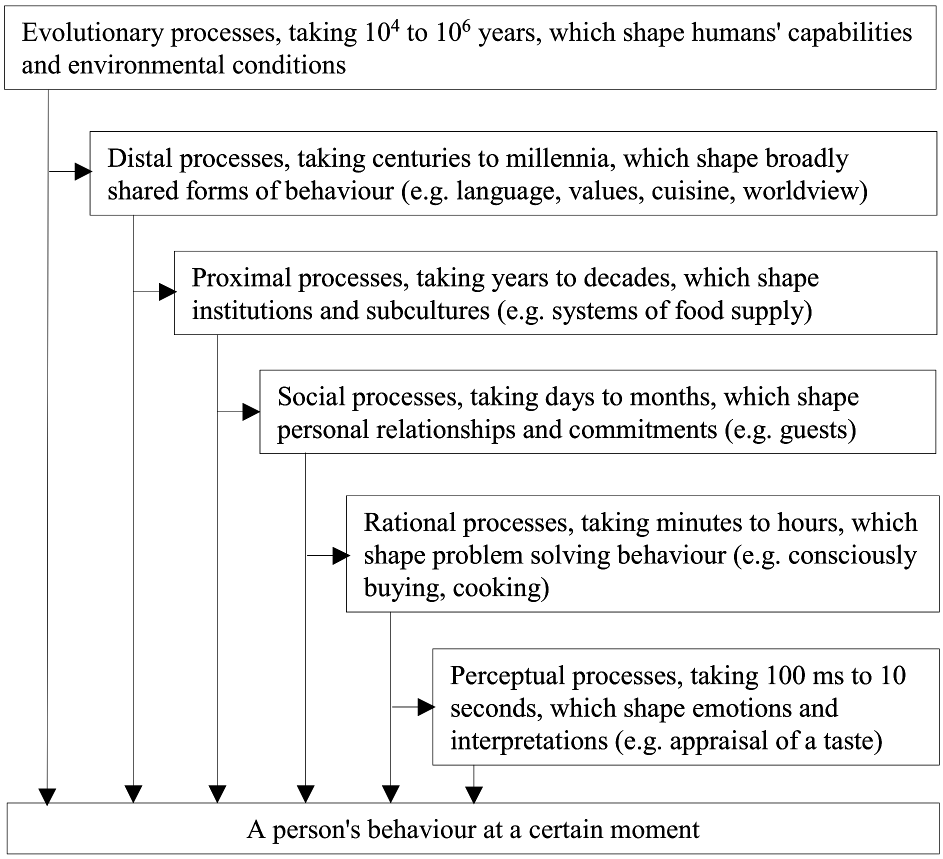
Framework of influences on behaviour

In considering the causes of a person's behaviour, it is important to take into account that any act is the result of multiple determinants. The most obvious determinants are the perceptual and rational processes that enable the person to adapt his or her behaviour to the situation at hand. This refers, for example, to the taste of a food and the person's ideas about its origin. If the person is in doubt about the food's purity, his or her behaviour might also be influenced by personal loyalties to the person who serves it. Also relevant are the business practices that are common in the supply chain. In short, the behaviour in question is not only a function of processes within the person, but also of social and organizational processes that can work as proximal causes of behaviour.

Moving from processes that are internal and proximal to more distal processes, we can see those determinants of behaviour that will not dramatically change during the lifetime of an individual. These relatively stable, distal processes can influence the food tasting person, for example, as far as his or her attention is drawn to beliefs about purity and danger that are part of broadly shared worldviews (e.g., philosophies of life, magical thinking). Unlike mediaeval men and women, modern people will not expect solutions from magical powers but they may still be sensitive to some of these beliefs under conditions of uncertainty. Notably, the process of cultural modernization has taken almost a millennium to develop (Levine, 2001). On an even longer time scale, there are evolutionary processes that have shaped human capabilities to cope with various kinds of environmental danger, for example, by enabling them to make a hasty distinction between sweet and bitter tasting foods.

The processes mentioned above can be arranged in a cascade-like framework that is shown in Figure 1. Its highest level refers to evolutionary processes. One of the results of the evolution is that humans are able to assess a difference between positive and negative stimuli in about 100 milliseconds (Smith, Cacioppo, Larsen et al., 2003). Another relevant feature with an evolutionary origin involves the response strength of brain systems. Brain systems responsible for evaluating negative stimuli respond more strongly than those responsible for evaluating positive stimuli (Smith et al., 2003). This so-called negativity bias means that negative stimuli (e.g. suspect odours) have a greater impact on information processing than positive stimuli do.

Figure 1: A cascade-like framework of influences on behaviour.



The next level of Figure 1 refers to distal processes that have shaped broadly shared forms of behaviour in periods of centuries or millennia. This includes the rise of practices, values and worldviews that are typical of the modern culture in the Western part of the world. To put it simply, the "modern" period started in 1900 and modern Western societies can be distinguished from their predecessors by their potential democratisation of both their wealth and their political process (Levine, 2001: 11). The overall concept of modernization covers a number of more specific processes, such as the growing importance of an "engineering culture" characterized by the systemic application of scientific knowledge to societal issues (Carroll-Burke, 2001). The "engineering culture" produced the steam engine and many other things that account for the present welfare.

By their very nature, distal processes like modernization have offered opportunities and constraints for the development of institutions and other coordinated practices that create incentives and disincentives for the behaviour of the people involved. These belong to the proximal processes of Figure 1, which include the development of educational systems and systems of food supply. The current functional integration of nationally and internationally dispersed activities involved in the primary production, processing, manufacturing, transport, marketing and selling of foods has been heavily influenced by all kinds of economic activity around food during the past decades (Fine, Heasman, & Wright, 1996).

The social processes in Figure 1 are more personal than the professional activities mentioned above and take much less time to develop. For example, a person's loyalty to a new housemate may grow in a few days or months. According to Newell (1990: 494) it is characteristic of social situations that there are at least three types of goals. (1) Each person cares about the shared activities the group is performing. (2) The person also cares about maintaining the social atmosphere of the group. (3) And each person cares about his or her own position in the group and the personal satisfactions of group membership. Regarding each of these goals, the person has an impact on the outcomes but he or she is also dependent on the other group members.

The processes mentioned above are external to the person, except for the social processes, which are a mixture of external and internal elements. The lowest levels of Figure 1 refer to processes that are internal to the person or that have been internalised. The rational processes, often taking minutes to hours, include conceptual learning, problem solving and decision-making. Notably, Figure 1 shows that the person's behaviour is not fully determined by rational processes. For example, even if the person aims to take a decision in a purely rational way, he or she will soon find out that on the one hand social commitments and on the other hand perceptual biases can interfere with such an approach as soon as the decision's consequences become serious.

Perceptual processes shape a person's rapid interpretations of a situation and the emotions that he or she experiences. An important distinction at this level is that between mindless and mindful processing. Psychological research has shown that people who are certainly capable of acting mindfully can perform seemingly complex tasks with little if any active mental involvement (Langer, 1989). This means, among other things, that they rely on routines developed in the past and that they do not make new distinctions to accommodate any changes of the task environment. In contrast, mindfulness is essentially awareness of contexts. Without this awareness, a person cannot improve his or her performance, self-esteem or health (Langer, 1989).

The framework of Figure 1 is the result of an attempt to sort a wide range of behavioural phenomena into a logical order. Only purely biological processes at the level of organs and cells (e.g. taking microseconds) have been left aside. The framework is relatively new, although similar ideas have been put forward by others (Diamond, 1999; Newell, 1990; Oyserman, Kemmelmeier, & Coon, 2002). A review of research and theory relating to these phenomena is obviously beyond the scope of this chapter. Without going into details, however, it is possible to highlight some relevant implications.

An important practical message of Figure 1 is that it is not necessary (if feasible) to change a given culture in order to change a particular behaviour. However, a governing body that wants to induce a behavioural change should be very familiar with the distal factors involved. The reason is that these factors provide the context in which the more proximal or internal factors can have their effect. For example, the taste of a new food may only be pleasurable for those persons who have already learned to appreciate the corresponding cuisine. Similarly, the introduction of a "free-range" label will only have a moral effect on people who value animal welfare. Both industries and governments know that the achievement of specific policy objectives (e.g., selling fat-laden foods or promoting health) can be aided by well-chosen appeals to a few broader values of the same culture (e.g., appeals to the value of "hedonism" or "security" respectively).

Figure 1 can help to generate information on the chances that a particular diet shift will be promoted or inhibited. Generally, the effectiveness of interventions will increase if all the influences on a particular behaviour point in the same direction. If a particular behaviour, such as smoking, is difficult to change, it is essential to combine as many supporting influences as possible. Moreover, it should be kept in mind that the impacts of positive and negative events are not symmetrical. This is evident from the following:

- The pleasure of eating might easily be spoiled by unpleasant ideas about the origin of the food.
- However, the unpleasant taste of a food will not easily be improved by pleasant ideas about its origin.

In sum, the framework can help to get insight into the congruency of the various influences on behaviour. The framework also helps to consider the role of time for diagnoses and interventions. The fact that the various influences on behaviour have their own pace has consequences for the diagnosis of present influences and for the design of an intervention. The pace of change will depend on the type of process to be changed. For example, it may take less time to increase the practical knowledge of consumers than to improve the social status of novel products.

The role of Western modernization processes

Many of the links between current food choices and long-term socio-cultural development can be explained in terms of Western modernization processes. To put it simply, modern society can be distinguished from its predecessor by its potential democratisation of both its wealth and its political process (Levine, 2001: 11). In terms of important periods in world history, it can be said that the "late premodern" period began in 1350 when Europe had to cope with the social, economic and political effects of the Black Death and that the "modern" period started in 1900 (Goldstone, 2002). The overall process of modernization covers a number of more specific socio-cultural processes, three of which should be mentioned here. They are:

- the increasing self-control considered typical of Western civilized man, such as the self-control of animal-like behaviour (since about 1500, see Elias, 1978),
- the rise of consumerism (or the belief that it is good to buy and use a lot of goods) among the middle classes (since about 1700, see Stearns, 2001),
- and the growing importance of an "engineering culture" characterized by the systemic application of scientific knowledge to societal issues (since about 1800, see Carroll-Burke, 2001).

Table 1: Main characteristics of three socio-cultural processes that mediate Western modernization.

Decoupling	Direction of mainstream	Direction of counter-movement
Increasing self-control to weaken the link between impulses and behaviour (since about 1500).	Development of more predictable and civilized behaviour, suppressing every characteristic felt to be "animal," such as spitting or gobbling or the tendency to sniff at food.	Discovery by the upper and middle classes of "pacified nature" as an escape from civilizing rules, a source of pleasure and knowledge (reason for protests against the cruel treatment of animals).
Break with the rule that people should consume according to their rank in society (since about 1700).	Development of social arrangements (e.g., shops) and personal lifestyles (e.g., those of shoppers) in pursuit of the belief that it is good to buy and use a lot of goods.	From its early beginning in Britain, France, the Low Countries and parts of Germany and Italy, consumerism has provoked opposition, inspired by various moral, esthetical and political themes.
Break with the link between what is morally right and scientifically true (since about 1800).	Development of "engineering cultures," which use the powers of engine science in the laboratory for other cultural forms such as agriculture and medicine.	Rise of various subcultures concerned, among other things, with natural foods and holistic medicines, trusting the self-healing capacity of the human body.

Each of these socio-cultural processes implied some kind of decoupling between phenomena that once were closely related, such as impulses and behaviour. For example, people of the Middle Ages could burst out into emotional behaviour, including violence, but this became gradually less acceptable. Other changes would make people's consumption less dependent on their social status, and the conclusions of science less dependent on their moral meaning. The changes were to a certain degree supported by the mainstream of society, but criticized by one or more counter-movements. For example, the "democratisation of meat " among European working-class families in the nineteenth century, influenced by the agricultural and industrial revolutions (Knapp, 1997), was accompanied by moral objections to the subjugation of animals and the foundation of the first vegetarian societies (Thomas, 1983). Table 1 summarizes the characteristics of the three processes in terms of decoupling, direction of the mainstream and direction of the counter-movement.

The process of modernization brought many changes in dietary choice and culinary technique. Due to the prevailing prominent position of the court society in France, most of the changes were at first part of a French-style modernization before they became accepted more generally. As far as meat is concerned, many changes are particularly related to its animal origin. An interesting example is the practice of bringing the whole dead animal, or large parts of it, to the table, where the meat was to be carved by the master of the house or by distinguished guests. Research by Flandrin (1999) indicates that the number of animal species served on the tables of the French aristocrats decreased between 1500 and 1650. This refers, for example, to a decreasing consumption of various large birds (e.g., swan). By contrast, the status of beef rose and much attention was paid to the particular cut of meat.

Focussing on meat-related practices, Table 2 summarizes a number of differences between on the one hand the sixteenth/seventeenth century and on the other hand the beginning of the twenty-first century, based on reports on the history of food (e.g., Flandrin, 1999). The differences refer to the sections of the population who could afford to eat meat, the types of animal that were eaten, the manner in which they were served, and the scientific (or pseudoscientific) ideas about proper food. Flandrin notes, for example, that as late as the beginning of the seventeenth century, members of the elite left "gross" meats such as beef and pork as well as most vegetables to the common people, whose stomachs were supposedly more robust. The elite ate only "delicate" fowl, relatively "light" fish and soft wheat bread. Notably, the wisdom of these differences was supported by the scientists of those days.

The list of observations mentioned in Table 2 suggests a significant diet shift and it confirms that people's preferences are far from fixed. However, it should be emphasised that it is difficult to assess whether the list is complete. Moreover, each of

Table 2: Some meat-related practices that have changed in the period between the sixteenth/seventeenth century (see Flandrin, 1999) and the beginning of the twenty-first century.

Sixteenth and seventeenth century	Beginning of the twenty-first century
There were very large differences between high and low members of society.	A large part of the population of Western countries can afford to eat meat.
Rich people ate many types of animals, including various birds such as swans.	Consumers mainly choose a few types of animal.
Their cooks served large parts of the animal, which were carved at table.	Consumers seldom serve whole animals; instead they serve cuts of meat.
It was a matter of good manners that upper class men should be able to cut meat from a pheasant still decorated with its feathers.	The cuts are bought at stores in which the carcasses have been hidden from the customer's eye. The practice of slaughtering has been removed behind the scenes of social life.
Scientists agreed that the rich needed to eat birds to keep their intelligence and sensibility more alert.	The nutritional literature has begun to appreciate the value of low-meat diets and vegetarian diets.
The working classes were considered best off eating large amounts of vegetables.	Nutritionists see vegetables as an essential part of each diet.
Local authorities tried to ensure an adequate supply of "good and honest" food.	Ensuring the provision of "good and honest" food is a task for supra-national authorities.

the differences must have one or more proximal causes that explain how changes were created, but the literature only offers some suggestions of what these might have been. For example, that members of the elite ate many types of animal may indicate that 17th-century diet was still largely determined by fluctuating natural circumstances (Flandrin, 1999). In that period in history, beef was considered "crude" and dismissed as indigestible by chefs in the aristocratic kitchens. In later years, progress in the arts of butchery and cooking made it possible that the status of beef rose and that more attention was paid to the particular cut of meat. Accordingly, the serving of large parts of the animal to be carved at table slowly went out of use. This decreasing practice is also connected with the gradual reduction in the size of the household and the transference of household activities to specialists (Elias, 1978).

Although the direct causes and the precise timing of the changes mentioned in Table 2 may not always be clear, their consequences got their meaning in the long-term process of Western modernization. For example, due to the circumstances mentioned above, people got fewer reminders that the meat dish has something to do with the killing of an animal. According to Elias (1978: 120) this shift means that the mediaeval standard of feeling by which the sight and carving of a dead animal on the table were actually pleasurable, or at least not at all unpleasant, has been replaced by another standard by which reminders that the meat dish has something to do with the killing of an animal are avoided. Notably, this development is not uniform everywhere. There are differences between the urban society of France and the more rural society of, for example, England, where older forms are more prominently preserved. However, the general direction of the changes seems to be the same. As Elias (1978: 120) notes, in many of our meat dishes the animal form is so concealed and changed by the art of its preparation and carving that while eating one is scarcely reminded of its origin.

Current development

The long-term processes mentioned in the previous section can be complemented by a number of processes that have happened during the past decades. Some of these processes refer to shifts in the way people manage to organize their household, taking due account of differences in economy of scale. For example, if the costs of preparing a meal are compared per unit time of the eaters, a decreasing number of persons per household will make convenience food more attractive (Beardsworth et al., 1997; Warde, 1997). Other important processes refer to the way producers manage to supply foods and the way the authorities manage to control the public dimensions of food (Atkins & Bowler, 2001; Nestle, 2002). The main characteristics of these processes are presented in Table 3.

One of the almost unnoticed consequences that the shifts of Table 3 have in common is their match with the long-term process of paying less attention to the meat-producing animal as a whole. As mentioned in Table 2, modern consumers seldom serve whole animals, but they serve cuts of meat that they have bought at stores in which the carcasses have been hidden from the customer's eye. Partly as a result of concerns about risk factors, such as fatty acid profiles, there has been a shift in consumption toward poultry and fish and away from beef and pork. As opposed to whole roasters, many consumers use further processed products, such as fillets.

The psychological and socio-cultural implications of this development have not yet been fully explored. Some results of a recent small-scale experiment among consumers in the Netherlands give an interesting clue. It appears that many people are no longer aware of the animal origin of meat and that this awareness strongly decreases among the younger generations (see Figure 2). Another result is that the "three components" meal (meat, potatoes, vegetables) that was dominant in the Netherlands during the second part of the 20th century has become less popular (see Figure 3). This may indicate that meat is less used as a central part of the meal. It should be emphasized that these people had not become full vegetarians and that they at least sometimes bought meat. Their attitude towards meat was not completely negative and they showed positive responses to either meat from well-treated animals or some meat alternatives.

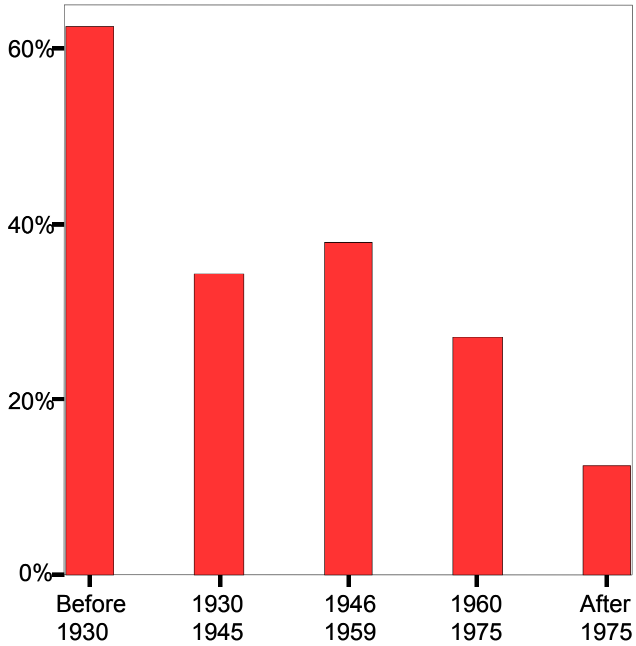


Figure 2 Percentage "always" giving thought to the animal origin of meat according to year of birth.
Source: Sample of 313 supermarket customers in Rotterdam who at least sometimes bought meat (Hoogland, De Boer, Boersema, in preparation).

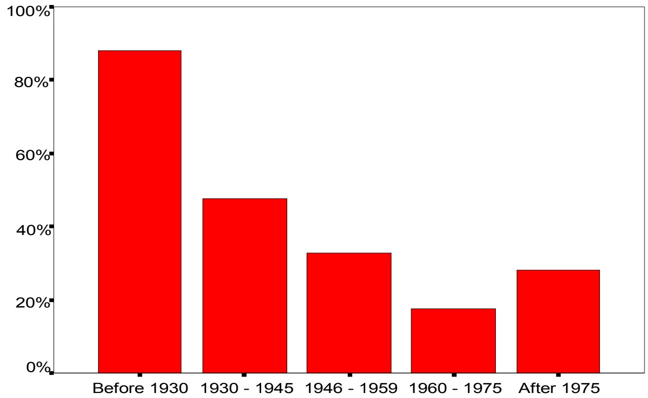


Figure 3 Percentage that prefers a conventional (i.e. three components) meal according to year of birth.
Source: Sample of 313 supermarket customers in Rotterdam who at least sometimes bought meat (Hoogland, De Boer, Boersema, in preparation).

Final remarks

Industrial transformation is not primarily a psychological process. Technical experts might change a technological system in a way that does not have to be noticed by the people that are using it. For example, the fact that meat is less used as a central part of the meal makes it feasible to design ready-made meals that contain less animal and more plant proteins. Such an approach might create a substantial shift from animal to plant protein foods without any involvement of consumers. However, there are at least three reasons why such an approach is not recommendable. Firstly, there are cases in which a behavioural change can contribute to the objectives of an industrial transformation, such as doing more with less. Secondly, it is expected that values will come into conflict in many technology-related areas, such as genetically modified food. This makes it important that all the people involved are mindful of those conflicts. And thirdly, by reinforcing mindless acceptance of technological changes people might become a kind of ecological dummy.

The main message from psychologists to non-psychologists is that there are more opportunities to induce a behavioural change than commonly is expected. Whether these opportunities will result in the desired end-states depends heavily on the degree in which the various determinants of behaviour can be made congruent with each other. The fact that many people are no longer aware of the animal origin of meat may be interpreted in terms of indifference toward the origins of proteins. This opens possibilities for novel protein foods, based on plants. However, if people are no longer aware of meat's animal origin, they will also be less inclined to pay attention to animal welfare. This might have negative consequences for attempts to stimulate sustainable agriculture by promoting high quality meat from well-treated animals. The solution will be that governing bodies should pay more attention to the segmentation of protein products in terms of bulk products and specialties.

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Users as Pioneers: Transformation in the Electricity System, MicroCHP and the Role of the Users

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1. Introduction: MicroCHP and the Transformation of the Electricity System

The electricity system in Germany and Europe is currently undergoing a process of transformation. Market liberalisation led to fusions and mergers among electricity suppliers, but also made companies seek out new business areas. Environmental regulation, like the Kyoto process, is putting external pressure onto the sector. New technologies are emerging, be it renewable energy technologies, combined heat and power (CHP) or "clean coal" technologies. In Germany, the nuclear phase-out and the decommissioning of outdated coal plants will lead to a need for replacement of at least 40.000 MW_{el} generation capacity until 2020 (Umweltbundesamt 2003). The need for replacement is an extremely important driver for transformation, making old and new technologies compete for a role in the future energy supply. The recent experiences with blackouts in the USA, Scandinavia and Italy have disturbed the public and security of supply is on the agenda again.

One possible development path is decentralisation. Distributed power generation in small, decentralised, interconnected units could help to save grid capacity, immunise the system against failures and provide opportunities for renewable energies. It may be one building block for a more sustainable energy future. A broad implementation of distributed generation, however, would mean a thorough structural change and require a surge of innovation. Grid access needs to be regulated and adequate system charges be defined to take into account avoided generation and distribution cost as well as additional costs for regulating energy to balance the feed-in of small intermittent power generators. If the decentralised units are to operate in industry buildings or private homes, new forms of co-operation between energy companies and private operators, new models of operating these systems, and new forms of ownership must be devised. Load regulation may require users to change habits, for example to use energy-intensive applications at another time of the day, or to allow the energy supplier to switch certain applications or generation devices on or off in exchange for price incentives. In short, a complex bundle of innovations is needed. Technical and social changes must interlock to make decentralisation possible.

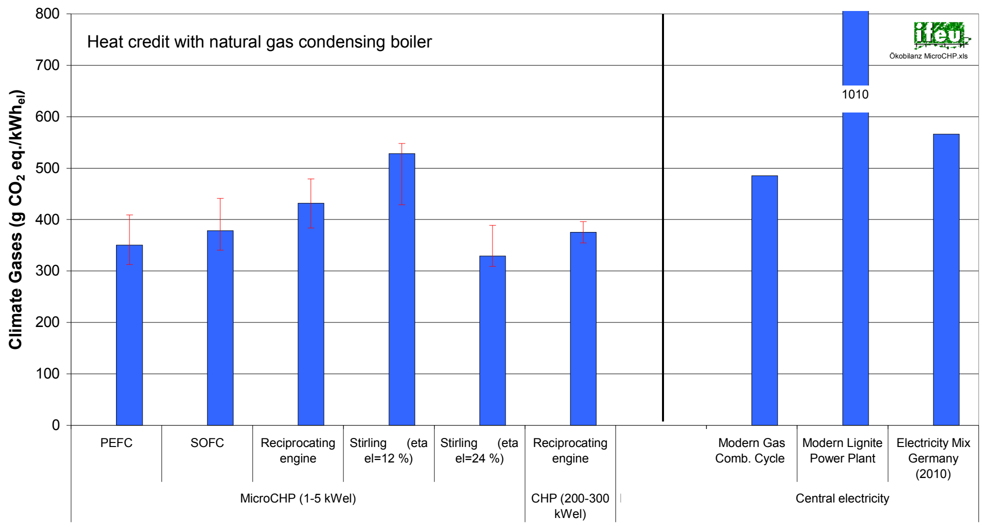
In a current project, the interdisciplinary research group TIPS (Transformation and Innovation in Power Systems, www.tips-project.de) investigates a section of this potential innovation cluster: small combined heat and power plants (MicroCHP) and the conditions for their establishment. Industrial transformation is thus studied in a "micro" perspective: one innovation that could be a contribution to a possible transformation path is investigated intensively. The goal is to identify possible levers and steering mechanisms to shape a process of innovation – and thereby, transformation – in a more sustainable direction.

MicroCHP, as defined in this study, are small cogeneration systems under 15 $kW_{el.}$ They are designed for use in family homes, multi family houses, schools or kindergartens, small commercial enterprises such as hotels, or the like. Various generation technologies are applied: conventional reciprocating engines, Stirling motors, fuel cells or even microturbines. Whereas reciprocating engines are commercially available by a number of manufacturers, Stirling and fuel cell based MicroCHP are still in the development phase.

A large potential is seen for MicroCHP Europe-wide. The British Energy Saving Trust expects 250.000 systems to be installed in Britain until 2010 (Harrison & Redford 2001). The MicroMap study (MicroMap 2002) forecasts between 5 and 12 million MicroCHP systems in 2020.

Life Cycle analyses done in the context of the TIPS project show that MicroCHP promises substantial environmental benefits. Fig. 1 shows the reduction in greenhouse gas emissions that MicroCHP may provide in comparison to other modes of electricity production. Heat output has been credited with a modern natural gas boiler (data and figure courtesy to Dr. Martin Pehnt, Insitut für Energie und Umwelt, Heidelberg).

Fig.1: Greenhouse gas reduction by MicroCHP. Source: Dr. Martin Pehnt, IFEU Heidelberg



The TIPS study investigates the interlocking technical, cultural, institutional, economical and political factors that shape the development of the innovation "MicroCHP". One part of the project is to investigate the role of the end user in shaping and distributing the innovation. Results from this partial study will be presented here.

2. Investigating the Role of the End User

2.1. Why Do End Users Matter?

Technology does not develop autonomously, nor is its course determined by the quest for technological and economical optimisation alone. Rather, technology development is shaped by actions and interactions of various societal actors. These actions and interactions are, in turn, directed by institutional arrangements, by the power structure, and by the actors' goals, values, interests, perceptions and worldviews.

Technology users are an important constituent of this tightly woven network of actors. They influence not only the course of technology and the fate of innovations, they also influence whether the application of some technology leads to more sustainability or not. The exact degree and type of their influence depends, among other things, on the specific technology at stake and on its development phase. As I have argued elsewhere, there are four general dimensions of user influence: technology acceptance, technology handling, technology-induced behavioural change (e.g., the rebound effect), and technology-independent user behaviour – that is, activities that are seemingly unrelated to the specific technology, but may interfere with its functioning, make it obsolete or substitute it (Fischer 2004, forthcoming). In our case, as we are talking about a technology that has not yet been introduced, the main topic of interest is technology acceptance. An end user may decide whether or not to buy and use a new technology. Technology acceptance therefore determines the chances of a new technology to be introduced and to find widespread diffusion. This is true especially when the technology is marketed directly to the end user. When it is sold to an intermediary, for example when a housing company buys heating systems, end user acceptance is less important.

MicroCHP systems are being designed for multi-family houses as well as for individual homes. In the individual home sector it is the end users who will have to decide on whether to apply the new technology. But will they be interested? Which features of the new technology will appeal to them? Which aspects do they consider important? Which economic conditions, institutional frameworks and political instruments are perceived as facilitating or inhibiting the introduction of the new technology?

These questions cannot be answered for all consumers alike. Rogers (1995) has identified different groups of actors in the diffusion process of innovation. Villiger et al. (2002) have adapted this general framework for consumers and for the market diffusion of green products. They distinguish between different consumer groups who take up the product at different times: In the "introduction" phase, it is taken up by a small group of "innovators". This phase is followed by the "early growth" phase where the product is purchased by "early adopters". However, the process only gains momentum when a mass market is reached in the "take-off" phase where uptake increases steeply and the "(early) majority" is ready for the project. In the "maturity" phase, market saturation is reached and the process slows down.

MicroCHP is still in the introduction phase, meaning that our target group are "innovators". However, I prefer the term "pioneers", because "innovators" evokes the association of the entrepreneur and in fact denotes rather the inventor of some novelty than its first user. "Pioneers" seems more suitable to denote users. These pioneers have very specific characteristics. Rogers (1995) describes them as "venturesome", interested in new ideas, as controlling substantial funds which allow them to compensate for potential losses of an investment, and as well educated which enables them to understand the innovation. Due to their originality, though, they may be outsiders. This chapter will try and describe these pioneers in more detail by answering some of the above questions. The following section will describe the methods applied for this purpose.

2.2. Methodology

As MicroCHP is an emerging technology, there is yet no chance to conduct comprehensive market research. Therefore, we built our study on two pillars: first, we tried to infer some conclusions from a literature study on analogous cases, and secondly, we are currently conducting a combined survey and qualitative study on persons who had opted for taking part in a field test of fuel cell based MicroCHP.

The study on analogous cases. As „analogous cases“, we defined technologies for home production of electricity and / or heat which are, in comparison with the established ones[1], innovative and advanced regarding efficiency and environmental effects. The technologies we investigated were, on the heat side, small biomass plants and solarthermal panels. On the electricity side, we focussed on photovoltaics. A literature research, heavily relying on the internet, was done to identify studies that discussed consumer aspects of the introduction of these technologies. The geographical focus was on Germany and Austria. The studies were analysed with regard to the following aspects: socio-demographic characteristics of the technology adopters; attitudes (comprising motives and goals, technology evaluation; and perception of facilitating and inhibiting factors), and, finally, behavioural changes induced by the technology. Hypotheses and questions regarding the transferability of the results to the MicroCHP case were developed. In this chapter, I will focus on the description of the technology adopters in terms of socio-demographic characteristics and attitudes. Induced behavioral changes will not be discussed because there is so far no empirical information on MicroCHP users that could be utilised to compare them to other technology users, test the hypotheses or answer the questions.

The study on field test applicants. The basis of the study is formed by a sample of persons who had opted to take part in a field test of fuel cell based MicroCHP. The number of applicants by far exceeded the number of systems to be tested: of almost 1000 applicants, only 25 could be chosen to take part in the test. The study will comprise interviews with the participants, a survey of half of the 1000 applicants, and focus group discussions with selected applicants.

The survey and the interviews with participants took place in early 2004. There results will be presented by end of July 2004. This chapter focuses on the results of three focus group discussions with applicants which have been completed by the end of 2003. All of the applicants within a certain geographic region were invited to the focus group discussion. The aim was to keep travel distance to the discussion location below 50 km. There were 99 applicants in the region which were contacted by mail. Of these, 94 addresses were still valid. 35 applicants volunteered to take part in a discussion. 28 were finally chosen on the basis of availability at the scheduled time, of which 26 actually showed up. The groups comprised 6-12 participants each and discussed for 2,5 – 3 hours. On the basis of an interview guide, group members were asked about the reasons for their application, about hopes and fears regarding fuel cell MicroCHP, about preferred ownership models, and about the advantages and disadvantages of fuel cell MicroCHP as compared to other electricity or heat technologies. The groups were facilitated by an interviewer who applied various facilitation and activation techniques. During the group session, there was a short “guided tour” to a fuel cell system in action. At the end of the session, interviewees were asked to fill in a short questionnaire with sociodemographic data. Preliminary results will be presented here and compared to the results of the literature study.

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1 Conventional German heating systems are gas or oil-based central heating, gas-based apartment heating, district heating, and, in a few East German cases, individual coal stoves. Electricity is usually taken from the grid.

3. Consumer Needs and Acceptance: Results from the Literature Study

3.1. Overview of the Literature

In general, it was not easy to find scientific studies dealing with consumer aspects of the introduction of the respective technologies. Studies usually focused on technological performance and economic feasibility. All in all, twelve studies dating from 1992 to 2003 could be used. Table 1 gives an overview of the studies considered (sorted by technology). It becomes clear that besides end users, also multipliers, interested persons and non-users have been studied. In this chapter, I will concentrate on information about end users.

Table 1: Literature basis of the study of analogous cases

Study	Technology	Goal	Topics	Sample
Greenpeace 1996	Photovoltaics	Evaluation of the CYRUS campaign (which offered a low cost PV system)	Success of campaign (number of PV systems installed), motivation, user evaluation of state support schemes	1662 persons interested in the campaign
Genennig 1996	Photovoltaics	Evaluation of the national „1000 roofs“ support programme	Motivation, satisfaction, user evaluation of the support programme, electricity consumption behaviour	1.445 PV owners in survey, 48 in interviews.
Katzbeck 1997	Photovoltaics	Analysis of electricity consumption behaviour of PV owners	Possession of other energy technologies; attitudes towards electricity consumption, consumption data	32 PV owners
Karsten 1998	Photovoltaics	Survey of motives and experiences of PV owners; development recommendations for support programmes	Motivation, experience, suggestions	123 PV owners: 106 households, 17 firms, associations and public sector departments
Haas et al. 1999	Photovoltaics	Evaluation of the Austrian support programme „Breitenwirkung“	Characteristics of the users: are they „early adopters“ as characterized by Rogers (1995)?	60 PV owners, 17 PV merchants, 660 „informed persons“
Reif 2000	Photovoltaics	Project report	Output and consumption data, ratio of output / consumption, degree of self-reliance	23 PV users: 22 households, 1 kindergarten
Hübner & Felser 2001	Solarthermal panels and photovoltaics	Identification of psychological factors conducive to the use of solar energy; advice on how to conduct campaigns and convince people	Motives, barriers, desired characteristics of the technology	Secondary study, no own sample
Polzer 2003	Solar thermal panels and photovoltaics	Assessment of the status of PV and solarthermal systems in a small town	Number and size of systems in the town, motivation, satisfaction, suggestions	147 owners of solar thermal panels, 22 PV owners
Hackstock et al. 1992	Solarthermal panels	Evaluation of the Do-It-Yourself Solarthermal Movement in Austria	Information, motives, user evaluation of the Do-It-Yourself programme	238 panel owners
DENA 2003	Solarthermal panels	Market research	Motivation, attitudes, image of the technology, barriers, user evaluation of support programmes	Users of solar thermal panels no older than two years; sample size is not communicated
Haas et al. 2001	Solarthermal panels, photovoltaics, heat pumps, biomass heaters	Analysis of energy consumption behaviour and energy consumption data in households which use renewable energies	Investment behaviour, consumption behaviour, influence of structural aspects, information, attitudes and motives on energy consumption	101 households owning renewable energy technology, 177 regular households
Rohracher et al. 1997	Biomass heaters	Scientific support for the market penetration of small biomass heaters	Economic, technological and social conditions, motivation, trigger, sources of information, user evaluation of state support schemes	25 biomass heater owners, 116 owners of regular heating systems, 28 multipliers

3.2. Socio-Demographic Characteristics

There is no information about the socio-demographic characteristics of the users in Hübner and Felser (2001) and in Polzer (2003). In the other studies, remarkable convergence of the results can be found. All the respondents were technology *users* and not just owners. That is, the studies do not cover cases where a landlord or a housing company installed innovative energy technology in a house that was not for their personal use. On the other hand, users of innovative energy technology were usually also the owners, with one exception that will be discussed below. They are very often families, live in family homes which they own, and come predominantly from rural areas and small towns. There is an over-representation of the South of Germany, namely Bavaria and Baden-Württemberg. Though there are too little cases to draw a definit conclusion, user groups seem to differ slightly depending on the technology studied. On the one hand, there are the users of solar thermal panels (Hackstock et al. 1992; dena 2003) and biomass (Rohracher et al. 1997). These are predominantly non-academic, with a large share of farmers and skilled manual workers. On the other hand, users of photovoltaics (Genennig 1996; Karsten 1998, Haas et al. 1999; Haas et al. 2001)[2] tend to be high-income academics with a special interest in sociopolitical issues in general and energy issues in particular. An exception to this rule is Reif (2000) where the photovoltaic users are low-income families. This is due to the special design of the project: the 23 houses in question have been built and equipped with PV by a non-profit cooperative who made them available for hire purchase to the families. The families therefore acquired the houses complete with PV systems, which were run by a contractor. In the other cases, in contrast, house owners had to make a particular investment to equip their house with PV.

Which of these results may be transferred to the case of MicroCHP? To answer this question, we need first to understand the results. If we know *why* it was a certain social group that "jumped on the train", we may draw conclusions on whether the same reasons apply to MicroCHP.

A plausible hypothesis is that the possession of a family home is decisive. In contrast to tenants and to flat owners in multi-family houses, family home owners have direct personal control over the house technology that is being installed. In contrast to landlords and housing companies, on the other hand, they have a direct financial interest. Lower energy costs will have an immediate effect on them whereas in a rented house, under German law, they will first of all benefit the tenants and not the landlord. Furthermore, even if the technology should not pay off financially, this does not matter as much in a family home than in real estate purchased for investment purposes. A family home is something else, and something more, than an investment that needs to pay off. It is a culturally defined space for expressing the owner's ideas, values and aesthetic preferences, for fulfilling his or her needs, for being shaped according to the personal lifestyle. Innovative energy technology may be installed if the owner considers it important for some reason, even if it is not profitable.

Home ownership is therefore the core variable that explains the prevalence of families and rural areas: the purchase of a home is usually related to having a family, and home ownership is more prevalent in rural areas. An additional hypothesis is that in villages and small towns, the network of interaction between inhabitants is more tightly woven, so that the word about experiences with new technologies will more easily spread and neighbours and friends will be motivated to try the same. This hypotheses is supported by the fact that a great deal of the study subjects report to have received essential information from neighbours, friends or relatives.

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[2] There is no information about education in Greenpeace 1996.

The prevalence of the German South may be explained by the fact that people believe – counterfactually – that only in the South irradiation is sufficient to run a solar system (Hübner & Felser 2001, p.78 ff).

What is interesting is the difference in professional and educational status between the users of different technologies. In the biomass case, most users run the plants with wood from their own land which explains the prevalence of farmers. For the difference between solar thermal applications and photovoltaics, my hypothesis is that solar thermal panels (as well as biomass) are better known, more thoroughly understood and perceived as rather low-tech applications, therefore inviting "Do-It-Yourself". In the study of Hackstock et al. (1992) this aspect is explicit because they evaluated a programme distributing "Do-It-Yourself" kits for solar panels. „Do it yourself" has the double effect of saving investment costs and offering a challenge for people interested in crafting and manual work. Therefore, these technologies may attract users with technical and manual skills to whom the mounting and maintenance of the system has aspects of a hobby. Although there are also "Do-It-Yourself" possibilities for photovoltaics, the latter is less well understood, has a high-tech image, is expensive and, without state support, not economical. It is therefore easily perceived not as a technology for broad application but as a hobbyhorse of technology nerds and environmentalists. Having photovoltaics therefore implies a genuine socio-political statement, means „outing" oneself as environmentalist and pioneer. This may appeal rather to people with „green" political orientation, postmaterialist values, specialised technical interests and / or to individualists willing to take risks. These groups can traditionally be found in the academic high-income strata. Of course, this hypothesis needs careful testing which will be done in the survey to come by assessing the political and value orientation of different technology owners as well as the image of various technologies.

What can we learn for MicroCHP, then? With respect to electrical power, they are designed to fit single or small multi-family houses. For analogous reasons than with the other technologies, we expect that especially family home owners will be interested, and that therefore families and rural areas or small towns will prevail. The prevalence of the South will probably not be replicated because the sunshine argument does not apply. We also expect that professional and educational status of potential MicroCHP users will vary, depending on which technology is applied: reciprocating engine (or motor) CHP, stirling CHP, or fuel cell. MotorCHP is an established technology that seems feasible and economically sound. It will therefore appeal to broader target groups, maybe especially to skilled manual workers and farmers who are experienced in maintenance work and see possibilities for "Do-It-Yourself". Fuel cell MicroCHP, on the other hand, has a high tech image similar to photovoltaics. Self-maintenance is not possible and its workability and reliability is yet unclear. It may therefore appeal rather to people with specialised technical interests or postmaterialist values who would like to make an explicit environmentalist statement – that is, to the academic high-income groups. It is difficult to determine the target group for stirling MicroCHP. On the one hand, it is a rather old technology. On the other, it has been little applied and is not too well-known. It remains an open question which groups of users will be interested in it.

3.3. Attitudes

Three aspects of the users' attitudes have been investigated in the literature: first, the motives, goals and interests that made them decide to apply the technology, secondly, their experience and satisfaction with it, and finally, their perception of support and barriers, especially with respect to state support schemes.

Motives, goals and interests. In all studies, innovative technology users reported mixtures of different motives. Among the most prominent motives were: autonomy, interest in the new technology and a desire to promote it, the wish to help the environment, and economic motives. In some studies, convenience and user friendliness were also mentioned. But because the energy technologies studied do not normally provide more user-friendliness or convenience than conventional ones, these seem rather conditions any technology must fulfill to be accepted than genuine motives to choose innovative ones.

Autonomy was usually not specified by the study authors. It may mean (partial) independence from the grid and transport subjective notions of security of supply, independence from great companies, and the possibility of self-control. Environmentalism encompasses various aspects, most prominently, emission reduction and restraining nuclear energy. Especially interesting is the aspect of promoting a new technology. Subjects see themselves as „pioneers", they want to give a positive example for others and sensitise the public. However, from the wording of most studies it does not become clear what exactly is perceived as the positive or pioneering aspect that deserves promotion. Do subjects admire engineering skills and technical achievement in the new technology? Is it its novelty? Its efficiency gains? Or rather the expected positive ecological effect? Economic motives usually mean the hope to reduce energy cost. Less often, the technology is perceived as capital investment.

As much as the general set of motives is constant, as much does their relative importance differ among the various studies. Sometimes environmental motives are most prominent, sometimes autonomy, sometimes technical interest. (However, economical motives are never primary). The differences are probably to a great deal due to methodological reasons. The studies word questions differently, present different sets of answers to choose from, pose them in different order and elaborate topics in different detail. For example, there is just one general question on the „environment" in Rohracher et al. (1997) whereas Haas et al. (1997) mention the environment in several items and highlight specific aspects like "providing alternatives to the nuclear".

What does this mean for MicroCHP? Most of the motives mentioned above may also be valid for MicroCHP. It is a rather new technology, it promises environmental benefits, and there may be an economic incentive once the systems are mature and go into mass production. In contrast to these three motives, I expect that the autonomy motive is not as valid as long as the machines run on gas, gasoline, or other fuels that need to be purchased.

Because of its novelty, MicroCHP involves both high risk and high profile, probably attracting people who define themselves as „pioneers" (or "innovators", in the terms of Rogers (1995)). There may be a problem with the „pioneering" motive, however. A MicroCHP plant is not visible from outside the house, like a solar panel or solar cell is. Even when shown, its appearance tells nothing about its functioning – it is nothing but a „grey box". Therefore, its owners cannot as easily demonstrate their pioneering efforts to the world. Promoting the technology and setting an example therefore requires discussions and explanations. Thus making promotion more difficult, MicroCHP may not be the technology of choice for people who would like to make a visible statement.

For our study, it is also interesting how the various motives are weighted and what they mean in detail: What exactly is attractive about a new technology? What are the expected environmental benefits? What amount of economic benefit do people expect? How do they want to promote it?

Experience and satisfaction. Virtually all participants in all studies are highly satisfied with their systems. Satisfaction is even higher when participants monitor their system themselves, receiving detailed feedback on its performance. Occasional dissatisfaction relates almost exclusively to economic aspects: investment costs were too high or savings were not as substantive as expected. Some PV users had initial problems with the reliability of their systems which diminished over time, though (Karsten 1998).

A prerequisite for satisfaction, of course, is the functioning of the system. Given this, and given the fact that an innovative energy system is something that does not come automatically but is actively sought ought by the users, I assume that satisfaction stems from having successfully realised one's goals and aspirations, and observing the positive effects of this. Therefore, I assume that MicroCHP users will also be satisfied, provided the system works. Satisfaction may be even increased when detailed data about system performance is available.

Support and barriers. An important supportive factor is reliable information. Technology users get information from many different sources: mass media, specialised media, panel or plant producers, energy suppliers, conferences and fairs, environmental groups or plumber firms, the internet, and personal contacts. Many of them are interested in technical or energy topics and have been following the discussion for a while. The variety of possible information sources may, however, also pose problems. It is not always easy to identify relevant information, and to deal with contradictory statements.

Among photovoltaic users, we can observe that many of them made other energy-related investments before. Among them are heat insulation, energy saving appliances and, specifically, solar thermal applications. It seems therefore that other technologies allow participants to gain experience and pave the way for the application of more complex technologies. We can call this the phenomenon of „trigger technologies".

By technology users, barriers were perceived mainly in the administration of support schemes. Programmes were handled too bureaucratically, application procedures too prolonged, sometimes the combination between investment subsidies and feed-in bonuses was not optimised. Although a substantial number of the users would have installed their system even without any support programmes, public support schemes play a significant symbolic role in recognising the new technology as good investment.

To identify barriers, it is helpful to also look at non-users, which was done by Greenpeace (1996), Rohracher et al. (1997), Hübner & Felser (2001), Haas et al. (2001) and dena (2003). It turns out that a substantive barrier is doubt and uncertainty. Doubt refers to the reliability and maturity of the systems, but also to the cost and profitability. With solar systems, there is doubt on whether there will be sufficient sunshine outside Bavaria or Baden-Württemberg. Subjects perceive a high North-South divide in sunshine, though in fact irradiation does not differ much between North and South Germany (Hübner & Felser 2001, p.78 ff). Doubt and insecurity prevail especially when the technology is uncommon so there is no chance to personally make sure it is performing well. This interpretation is backed by the fact that „clusters" of solar energy applications form in certain villages or small towns (Hübner & Felser 2001, p.23): once some systems are installed, they provide a possibility for first-hand information and experience that can reduce doubt.

Other important barriers are of a physical and infrastructural nature. Some potential users just do not have the right roof gradient or direction for solar applications, or lack space for storing wood. And finally, there are aesthetic objections to solar applications.

I assume that for MicroCHP, reliable information will be even more important because the technology is even less known. Trigger technologies will therefore play an important role. Also, infrastructural barriers are important, because the systems take up considerable space and, in case of fuel cell CHP, are dependent on gas supply. Aesthetic considerations will of course not be relevant, which may make the MicroCHP's „invisibility" a good thing, in contrast to the considerations presented above.

3.4. Hypotheses

On the basis of this discussion, I can now formulate some hypotheses concerning the potential target group for MicroCHP.

1. The main target group are families living in their own house in rural areas or small towns. While fuel cell-based MicroCHP may appeal mainly to academic high-income groups, there is potential for MotorCHP among skilled manual workers and small workshop owners.
2. Persons interested in MicroCHP will perceive themselves as „pioneers" with a mission to promote a new technology. The motives behind this are either a keen technical interest, a positive evaluation of innovation in general, or environmental reasons. The technical interest may have a hobby component. Economic motives may also play a part, but are not decisive. The autonomy motive is less prevalent.
3. Being „pioneers", users will have an interest in distributing their ideas, sharing experience and demonstrating the new technology and its workability. These intentions may be counteracted by the fact that MicroCHP is little visible. Users will therefore welcome opportunities to share ideas, thoughts and experience.
4. Provided that the system works satisfactorily, MicroCHP users will be satisfied with their decision and possibly act as multipliers for the idea. Feedback on system performance and possibilities to monitor performance oneself may increase satisfaction.
5. In order to promote MicroCHP, reliable information is crucial to reduce doubt. Potential users will therefore be people who have been dealing with related topics for some time, and probably have gained some experience with „trigger technologies".
6. Infrastructural restrictions play an important role as long as space requirements are not reduced.
7. MicroCHP can be promoted by suitable design of support schemes. A combination between investment subsidies and feed-in tariffs will be welcomed by most users. It is important that programmes are administered flexibly, swiftly and unbureaucratically.

4. Focus Groups: Preliminary Results

Focus group results, especially with respect to sociodemographic data, must be interpreted with caution. On the one hand, the high response rate of 37% indicates that focus group participants are not too untypical for the whole sample of field test applicants. But still, they are probably not entirely representative, but do represent an especially interested and committed subgroup. Given the fact that even the applicants are a positive selection of all potential users and may be characterised as "pioneers", we can assume that focus group participants exhibit these "pioneer" qualities to an even higher degree. Therefore, they do not give us information about the average user, but allow us to describe a special group that paves a new technology the way into the market and is therefore crucially important.

4.1. Socio-Demographic Characteristics

The most striking feature is that all focus group participants were men. In this, they are representative for the sample that was addressed: of the 99 addressees, 91 were men, 4 couples and 4 women. In one group, group members realised and discussed this fact. The discussion brought up possible explanations that will be explored in more detail in part 4.2.

Regarding age group, both mode and median were in the age group of 41-50 years, but there were more participants older than 50 than younger than 40. As expected, all but one were home owners. All lived with a wife, and 20 in families with underage children. Of the 6 participants with no children in their house, 5 were pensioneers. The families were also relatively big: the average number of children per family (excluding the couples without children) was 2,1. Fig. 2 and 3 give an overview of age groups and family sizes.

Fig. 2: Age of participants

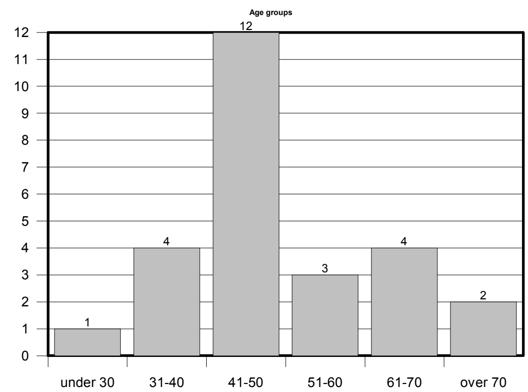
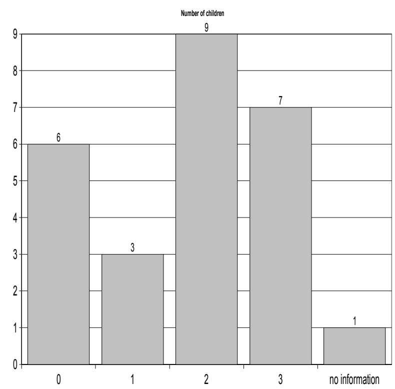


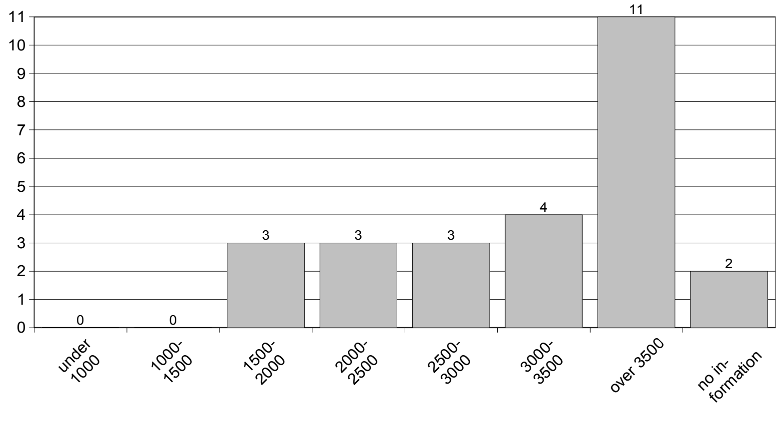
Fig.3: Number of children under 18



We also find that focus group members were highly educated. 81% have a grammar school degree as compared to 20% in the general population. 69% have a university or comparable degree, 20% a technical degree that allows them to train apprentices (*Meister*). With the income, the picture is more mixed. On the one hand, focus group members have high household incomes (see Fig.4), indicating a qualified, high-status career. The results therefore fit into the picture of academic elites. On the other hand, high income does not necessarily mean high disposable funds. Focus gro

Fup members have comparatively big families (sometimes including grown-up children or other relatives) which lowers per capita income. Unfortunately, no exact calculation of per capita income can be given because income was measured in ranges. The result therefore indicates that the most important aspect of income is not the availability of funds for investment, but rather, income functions as an indicator for social status and education.

Fig.4: Monthly household income in EUR of the group members



What is highly interesting is the professions of the group participants. First, there is high technical competence and interest. Of 26 participants, 13 are engineers or technicians. Three more are teachers, all with a science or technology subject. Secondly, the professions mirror an interest in energy and / or the environment. Four of the applicants work in the energy sector, one deals with hydrogen applications, three work in the environmental sector. All in all, there are 19 persons who work either on a technical, energy or environmental topic.

The socio-demographic characteristics of focus group members fit well with Hypothesis 1. We are dealing with a high status, elite group with good education and accordingly good income, living in their own homes with their families. Three quarters of the group members demonstrate an interest in technology, energy and / or the environment already by their choice of education and career. However, the profession only partly indicates a person's interests and competences, therefore I will discuss this subject in more depth in part 4.2. What is striking is the almost exclusive prevalence of men. When I discuss attitudes, I will come back to this fact and consider possible explanations.

4.2. Attitudes

I discuss three aspects of attitudes: first, the motives, goals and interests that made group members apply for the field test, secondly, perceived supporting factors and barriers, thirdly, satisfaction. Because group members were not able to test the fuel cell systems in their homes, satisfaction is mostly based on what they learnt about the systems during the group sessions and the guided tour.

4.2.1. Motives, Goals, and Interests

Motives, goals and interests were surveyed by different techniques. Every group member was asked to explain the motivation for their application. Furthermore, group members performed a guided brainstorming on hopes and fears relating to fuel cell MicroCHP. Every group member was asked to note their ideas on slips of paper, then the ideas were arranged thematically, presented, and discussed in the group. Finally, group members were asked to reach consensus on a hierarchy among different technologies for heat and power generation and give reasons for the order chosen.

When asked about their motives, it first turned out that most participants became interested on some specific occasion. In twelve cases, the heating system was outdated and needed replacement, in three more, the interviewees had purchased or inherited a house and were considering necessary updates. However, there were also interviewees who explicitly stated that there was no special occasion, and that their heating system would continue to work for some time, but they were more generally interested in fuel cell technology.

As expected, we find a very strong interest in technical innovation. 18 interviewees discuss this topic in detail when asked about their motives. Many have been following the development of energy technologies in general, or of fuel cells or hydrogen technology in particular, for a number of years. Among them are not only interviewees with a professional background in engineering or technology, but also "hobby technicians". Technical interest is inseparably interwoven with the interest in the "new" and forward-looking (*zukunftsweisend, Zukunftstechnologie*). Interviewees state to be "open for everything that's new", they want to "jump on the bandwagon of cutting-edge technologies". For this purpose, they are willing to invest some money and incur certain risks. Fuel cell systems are interesting because they are perceived as especially modern in comparison with other generation techniques. Visions articulated in this context dealt with a hydrogen economy, import of solar hydrogen from desert areas, and self-sufficient home systems based on a combination of fuel cells, photovoltaics, and hydrogen storage.

Subjects were not very specific on what exactly makes a technology "forward-looking", though. The notion of the forward-looking in German may have a connotation of the ecologically sustainable, but not necessarily so. Because some interviewees make this link explicit, but others don't, we cannot be sure whether ecological aspects are always implied in the "forward-looking".

Ecological aspects are important, however. Sixteen people spontaneously mention an interest in ecology or "alternative energy", when asked about their motives. Environmental benefits form the biggest share of all hopes articulated in all three groups. Some members state rather broadly that they are looking for something "innovative and ecological" or "ecologically sound". But there are also a number of more specific statements that demonstrate that group members are well informed: they hope to lower CO_2 and pollutant emissions, protect the climate, and give an answer to resource depletion.

Interviewees are no full-fledged environmentalists, though. They don't favour alternative lifestyles and distance themselves from "Greens". Ecological considerations are usually tightly interwoven with the interest in technological innovation – the wording "innovative and ecological" is characteristic. Interest in ecology and innovation melt in the much-used concept of the "forward-looking". Interviewees have an optimistic outlook, assuming that technology will solve the environmental problems. At the same time, new technologies are expected to be more "efficient" and "economical", thus linking environmental and economic benefits. Only in a few cases do people report a more philosophically or politically motivated environmentalism: two are religiously motivated, one is "a determined nuclear opponent", a third one is "grown up with agriculture and feel[s] close to nature".

Group members do not only pay lip service to innovation and the environment. They have already made considerable investments in it. Six have installed solar thermal panels (mostly for hot water) and / or photovoltaics, three more have such systems under construction. A few invested in heat pumps, a wood heater or have equipped their house with heat insulation. As one participant puts it:

It is my aim to rearrange the building in terms of optimum [energy] use. Better heat supply and heat insulation – a combination of solar thermal water heating and a fuel cell would be ideal. Later, this could be combined with photovoltaics, and I'd achieve some form of self-sufficiency.

Self-sufficiency – or autonomy – turns out to be an important idea. Participants stress their desire to be independent from the grid and thus safe from grid failure or blackouts. Autarchy is a dream for many. Autonomy is spontaneously associated with fuel cells even if, at the moment, they run on gas from the grid. When participants become aware of this problem, it is discussed with great interest and balanced against the dependence on fuel oil and the electricity grid that is implied by conventional solutions. The desire for autonomy goes together with a remarkable degree of distrust in anything that cannot be controlled oneself. This becomes very noticeable when participants (in the context of constructing a hierarchy of power supply options) discuss „green power". Green power is unanimously rejected because "I don't know what kind of green power it is", "anyone who believes it is dim-witted", "I fail to see why I should pay more when I don't know where the electricity comes from".

Distrust, however, can be overcome. Participants voice satisfaction that the field test is done by a company that is trustworthy because it is big, well-known and rooted in the region. These qualities make it an acceptable partner.

The desire for personal control becomes also visible when participants argue against contracting, because they want to possess their heating system and "tinker with it". They perceive it as a space for self-actualisation:

„House technology is space for creativity, something you can shape, you can unfold your talents, find solutions. It's not only „It's working, and that's all I'm interested in". No, I want to be ahead, find better solutions than others."

Thus taking pride in the new technology and their competence in handling it, group members are also willing to act as multipliers and inform others. When asked whether they would like to show their fuell cell to others, if they had one, they eagerly agree.

„I look at my solar thermal panel every day. It would be the same with that [fuel cell] system. I'd tell everybody: Hey, come on, look, I show you something."

The teachers among the participants want to pass the information on to their students, and everybody says at the end of the interview that they enjoyed very much exchanging information within the group.

This kind of enthusiasm seems to be specific for the male viewpoint. Group members state that it had been difficult to convince their wives of taking part in the field test. The wives, they argued, had not shared their fascination with the technology or their idealism for the environment, but demonstrated a more pragmatic outlook: How reliable was the new technology? How often would it have to be repaired? Was there a danger to sit in the cold? What tangible benefits would come from it?

The discussion points to the importance of the gender aspect in marketing technology. The women's resistance may stem from two sources: a different interest profile due to a different socialisation, and the responsibility for reproduction work. The socialisation of most women in the generation of the group members did not include raising their interest in technical issues. It is therefore hard for them to share their husbands' enthusiasm. What is more, the wives' reproduction tasks imply that they feel responsible for the family's comfort, and they would be hit more than men by the daily hassles that would come from faults and repairs of the heating system. To market a new technology successfully, it is therefore important to adapt it to the demands of reproduction work.

Finally, there are economic considerations. None of the participants hopes to benefit financially from the field test – they volunteered out of enthusiasm and stress that they want to give the new technology a boost, even if this needs some financial investment. In one group, it is discussed controversially whether economic aspects should be a criterion at all. It is argued that economic cost and benefit is not (and should not be) the central criterion in buying goods. Other aspects like comfort, security, or symbolic reasons were just as important. However, there is general agreement that new solutions need to become economically feasible in the long term. An insatisfactory price-performance relation is tolerated in the development phase, but not for long. Furthermore, economic aspects are thought important for the "ordinary" citizen who does not share the enthusiasm of the group members. Interviewees do not demand high financial returns. Feasibility is enough for them – it must "pay off" after some time. Economic considerations are therefore present, but do not feature too prominently and are thought to be important especially in later phases of technology development when a mass market is tackled.

The motives, goals and interests of focus group members fit hypotheses 2 and 3 with some adjustments. Group members are "pioneers" with a mission to promote the new technology and its environmental benefits. They own "trigger technologies" and are now looking for more. Environmental aspects are important and there is optimism that environmental problems can be technically solved. Economic feasibility is necessary in the long run, but economic motives do not feature prominently. The "pioneers" are eager to spread the word and exchange information and views with each other. Outward visibility is not important for this purpose.

Contrary to hypothesis 2, autonomy is an important motive and fuel cell MicroCHP is measured against it. One possible explanation is that the "self production" of electricity in the fuel cell is very tangible while dependency from the gas grid only becomes clear at second sight. An additional finding is that "windows of opportunity" like heating replacement, can be used to sensitise potential users for new technologies.

4.2.2. Support and Barriers

The first and foremost barrier, specifically in the current state of technological development, is of an infrastructural nature. Most of the applicants, including most of the focus group members, were sorted out because cellars were just too small or low, or doors to narrow to mount the fuel cell system. Correspondingly, focus group members insisted that the systems become smaller.

The question about fears with respect to fuel cell MicroCHP reveals other barriers. First, the immaturity and possible „teething troubles" of the systems are a commonly articulated concern. People fear frequent faults and needs for repair. They are willing to incur a certain degree of risks, but do not want to function as „guninea pigs". Secondly, the uncertainty of costs seems deterring. People cannot assess neither investment costs nor operation and maintenance costs and therefore find it difficult to make a sound calculation and check whether the installation may be economically feasible. A third, albeit not so prominent concern is safety.

It is striking that all the barriers are related to the current, immature state of the technology. This does not mean that there will be no more barriers once fuel cell MicroCHP is ready for mass production. But it is difficult to assess possible future barriers today because they are eclipsed by the current problems.

What are supporting factors that can be weighted against the barriers and help to overcome them? It is crucially important to protect users from risks, may they be of a financial or technical nature. A contracting arrangement may be helpful for this. The contractor runs the plant, bears the financial risk and guarantees heat and power supply for a price fixed by contract. Group members welcome such a contracting system for the development and testing phase. They feel it would protect them well from risks. However, with few exceptions they hesitate to accept contracting in the long run. Once the system is mature, most interviewees prefer to own it themselves. Ownership is an important dimension of the autonomy that is sought.

Information plays a more ambigous role. On the one hand, the fact that interviewees are relatively well informed and have often been dealing with energy topics for a longer time seems to indicate that information supports interest. Interviewees were grateful for the opportunity of exchange with others that was provided by the group discussion, and for the information they received at the tour. They suggested that they be kept informed on a more regular basis and that information about recent developments and successes be published in company newsletters. On the other hand, it was disillusioning to participants when they received detailed information on the actual state and performance of fuel cell MicroCHP, as will be discussed below.

The results back, in general, hypotheses 5 and 6. Suitable infrastructure is necessary, its lack a decisive barrier. Information supports interest – provided, however, that the system is mature enough that the information is not disappointing. Little is there to be said about support schemes, because costs are yet incalculable so it is unclear what type of support programme would be needed. A new aspect is that contracting arrangements can help to overcome insecurity during the development phase.

4.2.3. Satisfaction

During the group discussion, interviewees had the opportunity to see a fuel cell-based MicroCHP in action and get recent information on its state of development. This information resulted in disillusionment among most participants. They had previously assumed that the product would be ready for the market much earlier, and had underestimated technical problems and costs. Some had hoped to be able to buy a fuel cell-based MicroCHP in one or two years. Now they learned that they would not go into mass production before 2008. The information did not result in dissatisfaction with the technology in general, but in disappointment about not being able to purchase it soon.

To avoid this disappointment, it seems important not to raise false expectations. If pioneers for a field test are needed, communication should be addressed only to a small group of possible pioneers and the status of the technology and aims of the field test must be clearly communicated. It is advisable to only address a wider public once the "teething troubles" are overcome.

It is therefore not yet possible to comment on hypothesis 4, because its provision, the trouble-free functioning of the technology, is not yet given.

5. Governing technological change: Some conclusions

Technological change does to a relevant degree depend on pioneer users. So does industrial transformation, insofar as it is driven by technological change. What pioneer users do for the diffusion of an innovative technology is much more than accept or reject it. They are ready to actively promote a technology and raise others' interest - but they are anything but uncritical mouthpieces. Pioneers critically follow the development process, demand to keep informed, make recommendations and communicate successes as well as failures to others. They can be a source of valuable advice to developers. When attempting to govern transformation, it is therefore helpful to know the pioneers and to design suitable programmes to support their pioneering action.

Knowing the pioneers. In the case of MicroCHP, first impressions show that the potential target group for MicroCHP in its early stage is a dedicated group with good education, high social status, enthusiasm for the topic and therefore the willingness to incur a certain degree of risk. They are males with predominantly technical professions or education, and have comparatively large families. They are not the outsider innovators portrayed by Rogers (1995). Rather, they have important characteristics of the "early adopters" that are described by Rogers as arising in the second innovation phase. "Early adopters" are socially well integrated, serve as a role model for others and communicate the new ideas.

Some of the fuel cell pioneers' fascination is specific to the fuel cell (especially the visions of a hydrogen economy), but there are more general motives, like environmental concern, autonomy and fascination with cutting-edge technologies, that make this group a target group also for other technologies. This is illustrated well by the fact that many of them already possess others or have been thinking of purchasing them. The fuel cell pioneers are therefore also possible target groups for other MicroCHP types.

Targeting the pioneers. Governing technological change implies designing political programmes that attract pioneer users and support them in their pioneering activities. First results of this study show that one of the pioneers' core concerns is reliable, trustworthy information. Information should tackle the areas of concern like safety, economic performance, and reliability. Regularity of information and the possibility for feeedback and dialogue are greatly valued. In order to avoid disappointment, information on the state of microCHP development should be veracious and avoid to raise false expectations. Information on sociodemographic data, motives and values of the pioneers, as presented above, may be used to design media, style and content of an information campaign suitable to the target group.

On the other hand, if the goal is broad diffusion of a technology, it is as important to find out who is *not* among the pioneers. That applies especially to the striking gender imbalance. Even if the pioneers users are predominantly male, they live in families and it can be assumed that investment decisions are discussed within the family so that women have an important say in the final decision. If a technology does not appeal to half of the population, its diffusion chances are limited. It is necessary to identify the "blind spots" in the technology and / or its diffusion strategy in order to find out what could make it attractive for women. Possible apects to explore are reliability and convenience.

Another conclusion is that it is important to value the pioneers' contribution, which may be done financially or ideationally. As stated in the studies on "analogous" cases, public support schemes also have an element of ideational recognition. At the very least, recognition means protecting users from risks so that they need not feel as "guinea pigs" of technological development. For such protection, it is helpful to design appropriate contracting or service schemes that remove from users the burden of maintenance.

A broad diffusion of MicroCHP depends strongly on the costs and technological barriers of installation and grid connection and on the financial rewards for feeding electricity into the grid, topics that have not been touched here but will receive more detailed consideration in an upcoming TIPS volume on MicroCHP scheduled for 2005.

As with governance of technological change in general, targeting pioneer users is an enterprise that needs cooperation of various players, including microCHP manufacturers, electricity companies, installers and their organisations, the state, and possibly NGOs. While the improvement of the technology lies in the hands of the manufacturers, electricity companies can aid in its marketing and simplify grid connection. The state and NGOs may provide independent information, the state can give financial incentives and set the political framework for grid connection, grid use and feed-in conditions and tariffs. Installers need special training to be able to install and maintain microCHP and give competent advice to users.

Future research issues. Future research within the TIPS project will describe the pioneer group more representatively and also try to collect information about the "blind spots" by means of a survey of about half of the 1000 applicants. A further step will be to study the interaction between technology and the user in a broader way. To achieve a sustainable energy future, it is not only important in which way a user supports, promotes or rejects potentially sustainable technologies. It also matters in which way he interacts with these technologies, and whether this interaction forms part of a sustainable lifestyle. We have to think not only about technology acceptance, but also technology handling, technology-induced behavioural changes or seemingly unrelated lifestyle issues that may nevertheless make an efficient technology obsolete. To put it boldly, MicroCHP will not help us if users do not accept cuts into their autonomy for load management reasons, if MicroCHP is used to heat ever bigger badly insulated houses, or if it blocks other sustainable technologies (like solar energy). One part of the TIPS project will therefore be to study how people use the technology, and which, if any, attitudinal and behavioural changes are triggered by it.

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Industrial Transformation and Agriculture: Agrobiodiversity Loss as Sustainability Problem

Franziska Wolff

1. Introduction

Despite leading a shadowy existence in the public biodiversity debate, the issue of the loss of agrobiodiversity is hotly debated in expert circles. A broad understanding of agrobiodiversity can be described as that part of biodiversity that contributes in the context of agriculture to nutrition, livelihoods and the maintenance of habitats. Its scope covers agricultural crops, productive livestock, raw materials, medical plants and animals used for transport. Agrobiodiversity is "man-made" biodiversity resulting from plant and animal breeding efforts. It highly threatened mostly by the spread of modern agriculture and the globalisation of food markets.

This article recognizes today's agrobiodiversity loss as a socio-ecological conflict and a second order problem (Jahn/Wehling 1998), as it significantly stems from earlier attempts to solve social problems (namely food insecurity in the early 20th century). By way of an extended policy-analysis it will be shown that beyond economic processes and technological developments, interest-formed policies and multi-level governance structures - especially intellectual property rights, sovereignty regimes as well as on seed trade and livestock breeding regulations - impact negatively on agrobiodiversity. Reflexive strategies will be necessary to overcome this sustainability problem characterised by structural uncertainty.

2. Industrial Transformation and agriculture

Industrial Transformation can be described as the changes in production and consumption patterns necessary on the path to sustainable development against the backdrop of complex society-environment interactions (Vellinga/Herb 1999). Despite the inclusion of the term "industrial", the concept certainly is not confined to the secondary, i.e. industrial sector: it has it's relevance for the primary sector of resource extraction and agriculture, too. This is valid particularly since the two sectors are interrelated to an ever increasing extent: Not only have soil and nature as prime production factors become increasingly substituted, but agricultural production has become intensely industrialized and integrated into the industrial production chain.

While the agricultural sector in the 19th century still disposed of a high autonomy via-a-vis the other economic sectors, today, most inputs such machines, fertilizers, seed, feedstuff and agricultural outputs are being manufactured industrially outside the actual agricultural sector (Bechmann 1990: 30, see also Ditt et al. 2001, Münkel 2000, Schulz 1996, Franz 1962). Production chains have become longer: food industry (which processes raw foodstuff industrially and demands standardised agricultural products to be easily treated by machines) and a highly concentrated trade sector hold a dominating position. With the politically promoted mechanisation of agriculture irreversible investment („sunk costs“) have escalated, and pressure has increased to compensate these costs by means of a higher productivity: i.e. through intensive land use systems, the use of machines, fertilisers and pesticides, monocultural cultivation - and the breeding of high yielding crops and high performing livestock. These processes have caused massive social and ecological effects, encompassing not only in a dramatically altered job profile of the farmer and a sinking job rate in agriculture but also unsustainable production and consumption patterns with impact among others on agrobiodiversity. For the breeding sector, the interrelatedness of policy, technological and environmental change as well as the need of Industrial Transformation will be described.

3. The concept of agrobiodiversity

The term agrobiodiversity has evolved only in recent years in the wake of the general biodiversity discourse, which really began in the 1980s. Analogous to the term biodiversity, agrobiodiversity encompasses different levels. It relates to the diversity of agro-ecosystems as well as that of species of crops and farm animals, and to the genetic variance within populations, varieties and races. In its broadest sense, agrobiodiversity also comprises soil organisms in cultivated areas, insects and fungi that promote good production, wild species from off-farm natural habitats as well as cultural and local knowledge of diversity and management forms as the basis of the exploitation of diversity (Thrupp 2001). This article focuses on species and genetic diversity.

Though the term agrobiodiversity emerged late, a wide intersection of the topic was already analysed under the term “genetic resources” in the 1960s when the FAO started to discuss the genetic foundations of plant breeding. Genetic resources for food and agriculture (GRFA), generally speaking, encompass the genetic material contained in (traditional and modern) plant varieties and farm animal species as well as well as in primitive and wild relatives that are used, or may be used, for the production of food and agriculture (FAO 1996a, 1999). The term of agrogenetic resources therefore not only embraces diversity in actual use, but also that of potential use and value (“latent diversity”, cf. Gollin/Smale 1999). They are the raw material from which new crop varieties and breeds are being developed.

During the last three decades the understanding of agrobiodiversity has developed from the recognition of the importance of genetic diversity, particularly for crops and an emphasis on the *ex situ* conservation of genetic resources in the 1970s, to the adoption of an *in situ*/on farm approach where plants and animals are kept in natural surroundings or used within agricultural production systems in the 1990s. Finally, agrobiodiversity thinking has become embedded in an integrated, holistic agro-ecosystem approach (Aarnink et al. 1998).

4. From riches to risk

While in animal breeding genetic erosion is conceded by most relevant actors, with respect to plants the diagnosis of agrobiodiversity loss is not undisputed. The plant breeding industry e.g. stresses that “although the visible diversity in farmers’ fields may have been reduced, the diversity of valuable genes has been increased by introgression of new materials” (ASSINSEL 1996). Not only does the analysis vary according to the level of diversity analysed (genetic, species, ecosystem), but also according to the measures of diversity and the methods of analysis employed. However, the following data and assessments can be considered reliable. In the report on the “State of the World’s Plant Genetic Resources for Food and Agriculture (PGRFA)”, the FAO (1996) describes as “substantial” the loss in diversity of plant genetic resources for food and agriculture (PGRFA) including the disappearance of species, plant varieties and gene complexes (“genetic erosion”). World nutrition today is mainly based on a mere ten crops. For Germany it is estimated that, compared to the first half of the twentieth century, 75 percent of cultivated plants in agriculture and horticulture have disappeared (UBA 2002: 403); in some areas “genetic erosion” is even supposed to have reached over 90 percent (TAB 1998). Similar processes have been taking place globally from the mid nineteenth century onwards (GTZ 2000). Concerning livestock, half of the breeds that existed in Europe at the turn of the century have become extinct; a third of the remaining 770 breeds are severely endangered. In Germany only 5 out of at least 35 indigenous breeds of cattle remain. The FAO predicts that worldwide 28 percent of livestock breeds are currently at risk of extinction (FAO 1993).

5. Agrobiodiversity loss as sustainability problem

Sustainability problems can be defined as conflicts with a social, ecological and an economic dimension both in terms of causes and impacts. However, they can also be defined structurally via their reflexive nature and the underlying interaction between social, ecological and technological change. All three approaches will be applied here.

5.1. The impacts

Why is agrobiodiversity loss problematic at all? This question will be answered with respect to the social, ecological and economic impacts that characterise agrobiodiversity loss as a sustainability problem.

In terms of its ecological dimension, the loss of robust cops and livestock adapted to their surrounding eco-systems (soil, climate) and the subsequent use of genetically homogenous high yield varieties and high performance animals (kept in high-tech sheds) makes necessary numerous unecological inputs: These varieties and races are not only more vulnerable, often prone to diseases caused by breeding (“burn out syndrome”), but they dependent on high and stable inputs of (fossil) energy, fertilizers and pesticides in the case of plants, and food, energy, and pharmaceuticals in the case of animals. The loss of locally adapted traditional varieties and races also impacts on the surrounding eco-system and wild biodiversity. On the other hand, the protection of landraces and indigenous livestock breeds is worthwhile despite their lower yields since they often possess valuable traits such as disease and pest resistance and are better adapted to harsh conditions and poor quality feed, which are qualities desirable for low-input, sustainable agriculture.

In terms of social impacts, the loss of genetic resources poses a threat to food security. Genetic resources, along with soil and water, constitute the foundation upon which agriculture and world food security are based (FAO 1996: 6). The destruction of the diversity of these resources not only increases vulnerability in terms of animal diseases, pests and harvest failures, but it also undermines the foundations of future breeding and development paths. Beyond the immediate uses of agrobiodiversity as described above (relevance to nutrition, livelihoods, habitats), agrobiodiversity is important to preserve possible future development paths: Genetic diversity found in domestic animal breeds and plant varieties allows farmers and breeders to select stocks or develop new breeds and varieties in response to changes in the environment, threats of disease, new knowledge of human nutrition requirements, changing market conditions and societal needs, all of which are largely unpredictable. A second social dimension of agrobiodiversity loss is the equity issue. It becomes relevant in relation to property rights regulating the balance between farmers and agribusiness, and in relation to the distribution of benefits between agrobiodiversity rich countries in the South and industrial countries in the North appropriating the returns when utilizing these resources.

Finally, agrobiodiversity loss also has economic impacts: the genetic, species and agro-ecosystems variety protects against vulnerability to e.g. climate stress, insect pests and diseases that can devastate a uniform crop, especially on large plantations. There are famous examples of economic disasters springing from 'genetic monoculture' such as the 19th century Irish potato famine and the US pest "Corn Leaf Blight" in 1969. With farm animals, too, lacking genetic diversity impedes adaptation to diseases, parasites, or variations in the availability and quality of food. Thus, agrobiodiversity loss increases the economic risks for individual farmers and can undermine the stability both of agriculture and the food business (Thrupp 1997).

5.2. The causes

The causes of agrobiodiversity loss are manifold and interrelated. The economic development, above all the spread of modern, commercial agriculture and intensive, high-input production systems features as prime driver of diversity decrease, putting native varieties and breeds at risk (FAO 1996a: 13, FAO 2003). Native varieties and breeds are substituted with high-yielding crops and breeds that no longer need to be adapted to natural (climate, soil etc.) conditions, since machinery, irrigation, fertilizers and pharmaceuticals homogenize habitats (in a both costly and environmentally harmful way). In developing countries, this process has been reinforced by a donor policy that has promoted the import of exotic breeds and crossbreeding and that threatens the survival of local breeds (Geerlings et al. 2002: 6). Both the markets for agricultural inputs and for agricultural outputs have been increasing in size, thus feeding into a globalising food market that demands goods in huge consignments. In order to process them industrially, those agricultural goods need to be homogenous. Therefore, apart from the yields it is the requirements of industrial cultivation, husbandry and processing (and to some extent consumer demand) that determine the breeding objectives rather then nutritional value, taste, improved stress resistance or adaptation to natural conditions.

A second driver of agrobiodiversity loss is seen in the technological realm. Modern, highly selective breeding methods contribute to the problem by making possible dangerous degrees of homogenisation. In livestock breeding e.g. artificial insemination, multiple ovulation and embryo transfer are applied to reproduce only a few top performers; a huge number of other individuals are thus excluded from breeding and the genetic distance within populations is correspondingly reduced. Hybrid breeding, with both animals (e.g. poultry, pigs) and plants (e.g. corn, rice), and in the future cloning are methods used to reproduce genetically homogenous and high performing livestock and plant varieties. In the case of animals, impacts on the genetic pool are expected when traditional pure breeding gets replaced by the modern methods (Wetterich 2001: pp. 45). Also, since hybrid breeding produces infertile breeds and seed farmers cannot use the material to continue breeding/growing according to their own selection preferences, they have to instead content themselves with commercially bred/grown livestock and seeds, which they even have to buy again every year. In plant breeding, 'Genetic Use Restriction Technologies' (GURTs) have the same effect.

In the social and political realm, policies and legal regimes contribute to agrobiodiversity loss, such as breeding law and intellectual property regimes. In chapter 5, a selection of these factors is discussed in detail. Interrelated with these policy factors, conflicting societal interests and interpretations characterise the arena and hamper a conflict resolution. In plant breeding, the mere problem perception is contentious, as was mentioned above.

5.3. The structure

Structurally, agrobiodiversity constitutes a genuine socio-ecological constellation: As opposed to wild biodiversity, agrobiodiversity (for the most part) is characterised by the proximate interaction between natural 'material' and human action. The diversity of productive livestock and crops is the result of a century of human breeding efforts based on locally differentiated resources. It reflects the diversity of various agricultural production systems and their cultural and social dependency. Also, the development (as well as the destruction) of agrobiodiversity is closely related to the human knowledge of cultivation and husbandry as well as the emergence of different breeding techniques and technologies. Maintenance of agrobiodiversity, too, is inseparably linked to the use and utilisation of crops and livestock by humans - unlike with wild biodiversity, protection in the sense of 'leaving it alone' does not suffice.

Besides the socio-ecological structure, agrobiodiversity loss like many other sustainability problems is characterised by a reflexive nature: A substantial part of the problem can be described as being caused by the unintended feedback of a previous problem solving strategy. Specifically, it was the post-war policy of food security that aimed at alleviating food scarcity but as a side effect destroyed agrobiodiversity. It massively promoted the industrialization of agriculture, first in the developed nations (e.g. through the EC Common Agricultural Policy) and later in developing countries. The "Green Revolution" - the political push for the introduction of high yield crops, irrigation, fertilizers, pesticides and mechanization from the 1960s on - aimed at closing the so-called 'development-gap' between the South and North. The model of food security not only led to major increases in production output, but also contributed - among other factors - to the global homogenising of production structures and market conditions. Agrobiodiversity loss thus can be considered a "second-order problem" (Jahn/Wehling 1998), to the extent that it is at least partly caused by efforts to solve (other) problems. The efforts have led, as a result, to the reduction of the fundamentals of agricultural production: agrobiodiversity. The development, therefore, is paradoxical: the result of breeding for a high yield and homogeneity for "food security" destroys the race, species and genetic diversity and, therefore, the resources on which the breeding itself is established.

6. The role of policy regimes and governance structures

The economic and technological developments detrimental to agrobiodiversity (described in chapter 5.2) were partly supported by policies and governance structures such as intellectual property rights and sovereignty regimes that regulate access to and control over genetic resources as well as seed and livestock breeding law. Those have intentionally, or as side effects, supported the orientation towards high output and homogenisation, thus also affecting the choice of plants and livestock in agricultural use.

6.1. The regulation of access and control

Access to and control of plant and farm animal genetic resources is regulated by Intellectual Property Rights (IPRs) in the realm of private law and, in the context of public (international) law by sovereign rights of states (Kameri-Mbote/ Cullet 1999).

6.1.1. Intellectual property regimes

Breeding, particularly of plants, heavily relies on Intellectual Property Rights. The background of this can be found in the specialised nature of agricultural production and the fact that breeding involves a high amount of work as well as intellectual and financial efforts. Especially for new plant varieties (not so much for animals), breeders' returns are endangered by the biological possibility that farmers would reproduce the seeds. Without breeders' efforts, on the other hand, it is argued that the supply of agricultural production with high quality seeds would suffer (Wuesthoff et al. 1999: 96). Against this backdrop, in the early twentieth century intellectual property rights that originally applied to industrial inventions were merely extended to living matter to compensate breeders' efforts.

Two major IPR regimes can be distinguished that impact on agrobiodiversity in varying degrees: plant variety protection (PVP), applying only to plants, and patents.

Plant Variety Protection (PVP)

PVP systems have emerged in Europe from the late 1920s onwards. At the core of PVP are the so-called Plant Breeders' Rights (PBR), a specific form of Intellectual Property Right, which provides an exclusive right over the variety a breeder has developed. The main difference from patent protection lies in the restriction of PBRs to the concrete variety as a marketable product, while patents provide generic protection. In the 1960s an international harmonisation of national plant protection laws took place and the International Union for the Protection of New Varieties of Plants (UPOV) was founded. Today, with 53 member states (increasingly from the developing world, too) the UPOV Convention has become the international reference system for PVP.

Plant Breeders Rights require that anybody who (re-) produces, conditions, offers for sale, markets or imports/exports propagating material of the protected variety needs the authorization of the breeder, which the breeder may subject to conditions (usually royalties) and limitations. (Art. 14 UPOV Convention) The breeders rights are restricted by the so-called breeders' exemption and the farmers' privilege (Art. 15.1, 15.2), both of which were cut back in 1991. The breeder's exemption constitutes the right to use protected varieties for the breeding of other varieties and for experimental purposes, while the farmer's privilege refers to the farmer's right to save and re-use (formerly also to sell) harvested material. Depending on national implementation, the plant variety protection may cover all plant varieties and needs to last a minimum of twenty years (Art. 3, 19 UPOV Convention).

In two senses the plant variety protection system of UPOV can be seen as harmful to agrobiodiversity. Firstly, the criteria for variety protection - the so called "DUS requirements" on Distinctness, Uniformity/Homogeneity and Stability of new plant varieties - impact on plant variability. Secondly, it is argued that Plant Breeders Rights, like other IPRs have indirect effects on agrobiodiversity by restricting access to genetic resources.

Within the DUS requirements it is particularly the uniformity criterion (Art. 5 (1) iii, Art. 8 UPOV Convention) that meets with criticism. It aims at restricting genetic diversity within a plant variety, because in order to apply a Plant Breeder's Right it is necessary to unequivocally distinguish the variety from other varieties. This presupposes physical distinctiveness and uniformity, which disappear at the expense of significant genetic variability (Crucible Group 1994). In the field, uniform varieties are less able to buffer stress (diseases, lack of growth factors) without suffering major qualitative and quantitative losses (Léon 2002: 33). At the same time, the uniformity criterion precludes the protection of old landraces, which are frequently rich in genetic diversity within a variety (Dutfield 2000). From a broader perspective, the uniformity criterion is identified as a factor that makes PVP biased towards plant breeding for industrial agriculture (GRAIN 1999): Compliance with this criterion inclines breeders to develop varieties that have low adaptability and are highly adjusted to monocultural production systems for large markets. Contrary to this rationale, it is also argued that PBRs enhance genetic diversity because the introduction of PVP regimes has boosted the growing number and registration of new varieties (UPOV 2002). However, linking the number of licensed varieties and the degree of genetic diversity neglects the issue of genetic distance or the degree of relationship between varieties. Phenotypical diversity does not give evidence of the genetic diversity of a plant variety (Neumeier 1990: 231; Butler/Marion 1983: 72, Prall 1998).

The indirect impacts of PVP on agrobiodiversity result from the restricted access they determine. The breeders' authorisation to (re-) produce, condition or market propagating material means that the material is not freely (i.e. free of charge) accessible. For the breeder, the right, in the first place, increases the incentive for commercial plant breeding. Secondly, it promotes the development of varieties with the largest market potential. This leads to the predominance of major crops that are widely adapted across large areas and that feature characteristics that best meet the needs of commercial farmers and the marketing or processing industries (Crucible Group 1994). This impedes diversity. Therefore, the strengthening of PBRs in the 1991 UPOV revision is to be seen critically. PBRs have been strengthened with respect to the object of protection (extension to *all* plant genera and species), to the scope of protection (extension to 'essentially derived' varieties and to harvested material) as well as to the possibility for member states to grant patents on top of breeders' rights ('double protection'). At the same time, the Breeder's exemption was restricted. These revisions mostly go back to pressures resulting from the growing importance of biotechnology (Bragdon/Downes 1998: 20). A further indirect effect of PVP is that it probably reduces the flow of scientific information and germplasm from the private to the public sector (Butler 1996). This is due both to the private sector's interest in not having public competitors who develop varieties for public welfare as well as to the forced market orientation within public research institutes in times of scarce public funding.

Patents

Originally, patent law was not designed to apply to living matter, i.e. to material capable of self-reproduction or of being reproduced in a biological system. However, in the United States plant patents have been granted since the 1930s. Internationally, patent law is becoming more and more important with the growing relevance of biotechnological methods, in particular genetic engineering. The patenting of biological material is regulated in international patent law such as the WTO Agreement on Trade Related Intellectual Property Rights (TRIPs), the European Patent Convention (EPC) and the EC Biotechnology Patent Directive. The interpretation of these, however, led to a number of highly contentious questions. The TRIPs constitutes the international minimum standard for all WTO members. It codifies that member states need to provide patents "for any inventions, whether products or processes, *in all fields of technology*" (Art. 27 (1) TRIPs, italics added). At the same time, "plants and animals other than micro-organisms, and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes" may be excluded from patentability in national legislation. However, states are bound to provide for the protection of plant varieties either by patents or by effective *sui gen-*

eris systems (e.g. plant variety protection, cf. Leskien/Flitner 1997) or a combination of the two regimes (Art. 27.3 (b) TRIPs). In the industrialized world, there is usually a lot less leeway in terms of legal coverage. In the EPC, patents in the field of biological matter are excluded merely for "plants or animal *varieties* or *essentially biological processes* for the production of plants or animals" (Art. 53 (b) EPC, italics added). This implies that plant and animal components such as genes, gene sequences or cells, individual plants/animals as well as certain (non-microbiological) processes actually are patentable. The patent exemption on plant and animal varieties as well is being watered down by the European Patent Office judicature. In the EC Biotechnology Patent Directive, plant and animal varies *prima facie* are also excluded from patentability (Art. 4.1 (a)) However, this provision is qualified by the clause that "Inventions which concern plants and animals shall be patentable if the technical feasibility is not confined to a particular plant or animal variety" (Art. 4.2). US patent law is even more expansive.

What is the background of this discussion? Generally, in order to receive a patent, an innovation in the first place needs to qualify as an invention. The term "invention", though, is defined in none of the international agreements on patent law. Nonetheless, there is a general agreement that innovations need to be practical and technical. In a second step, in order to be eligible for patent protection, the invention needs to be new, involve an inventive step (i.e. are 'non-obvious') and be capable of industrial application ('usefulness'). Finally, the granting of patent protection requires the disclosure of the invention. As for patents on biological matter ('biopatents'), a major dispute surrounds whether or not plant or animal genetic material may at all constitute the subject of an invention (WTO 2002, 1995; Marin 2002; Watal 2001). This raises doubts with respect to both practicality and technicality. In terms of practicality, it is still controversial whether products of biotechnology that are, or are based on, genes or cells taken from nature or isolated from pre-existing living matter constitute a product of nature and as such a unpatentable discovery, or whether they are patentable inventions. In the court practice of most industrialized countries, however, there is a clear, though not uniform, trend towards recognizing naturally occurring substances as patentable subject matter if they were isolated or purified and if their existence was previously unknown (Leskien/Flitner 1997: 9). The patentability as such of living matter is no longer disputed by most courts. In terms of technicality, over the last years in many countries (as well as implicitly in the TRIPs Agreement) living beings have been ascribed a 'technical nature' that is a prerequisite for patenting. Reproducibility, as an additional requirement to prove technicality, leads to the necessity of disclosing inventions relating to or relying on biological material that is not publicly available and cannot be described in writing alone; this conundrum is partly resolved by the possibility of depositing biological material for the purpose of sufficiently describing a product patent. On top of the decision of whether plant and animal genetic innovations fulfil the legal criteria of an invention at all (practicality, technicality), the specific patent requirements of novelty, non-obviousness/inventive step, usefulness/ industrial applicability as well as sufficient disclosure need to be satisfied (cf. Marin 2002; Dutfield 2000; Correa 2000, 1992; Leskien/Flitner 1997). Then again, these requirements are insufficiently specified in international agreements (e.g. TRIPS) and interpreted in different ways in national legal systems. However, they have proved not to be insurmountable for the granting of biopatents.

Patents impede the development of agrobiodiversity by restricting access to genetic resources used in breeding and research (CIMMYT 2000: 26). Similar to Plant Breeder's Rights in conventional plant breeding, the utilisation of germplasm, seeds of animals with a patented element (product patent), presupposes the right-holder's authorization. However, patents are more exclusive since licences to competitors can be refused. Only research without market-orientation is exempted. Also, licence fees are more costly than PBR royalties and may develop even prohibitive effects. When processes for the genetic modification of plants and animals are patented (process patents) third parties depend on the patent holder's authorisation not only for the immediate application of the patented process, but also for the use, selling or import of products immediately derived from the process. Not only due to this generic protection, but also due to the usual lack of a breeder's exemption and a farmer's privilege, the exclusive right provided by a patent has stronger exclusive effects than Plant Breeder's Rights. It is unclear whether a system of compulsory cross-licensing between patents and plant breeders' rights will suffice to secure access to genetic material for breeding purposes.

Experience with patents on plant biotechnological innovations corroborates the feared restrictions on access and utilisation of the protected products and processes. Patent licences, if granted by the patent holder, reduce the incentives for third parties to engage in research and breeding within the scope of protection of the patent. This indicates that broad patents, which extend to second-generation uses, have stifling effects on the breeding efforts of competitors of the first patentee. An example was the US patent on all transgenic cotton plants. With its extremely wide-ranging exclusive rights it had caused a standstill in cotton research so that in the end, the US Agriculture Department attained the patent's annulment (Seiler 2000: 16). The problem is aggravated by the cumulative application of IPRs. Developing a transgenic plant variety may lead to multiple rights, such as Breeder's Rights (on the variety) and patents (on selectable marker genes, traits, as well as transformation and gene expression technologies) (cf. Seghal/van Rompaey 1992). There are already over 9000 patents on staple crops (Action Aid et al. 2001: 8); in the case of animals, in Europe alone more than 50 animals have been patented with some 600 animal patents awaiting approval (Greenpeace 2001: 8). The multitude of IPRs and their accumulation will step up the costs of the breeding process as well as that of the end product. In the case of plants, this will increase the pressure to develop 'universal varieties' with a big market share that can be cultivated under very different natural conditions and feature only a minimum of uniform characteristics. It will also shift any added value from farmers to agribusiness and within agribusiness from small breeders to major companies that are equipped with the appropriate technology and with patents. Today, four multinationals hold 44 per cent of all patents on staple crops (Action Aid et al. 2001: 8). Concentration processes are likely (Ect Group 2003), leading to the fusion of corporate genebanks and breeding populations, thus not only reducing diversity of breeding strategies but also increasing the risk of genetic erosion.

Against this backdrop, the current tendencies of strengthening international IPR regimes are questionable. While TRIPS is still being severely criticized (especially from a developing country perspective), a new trend has emerged especially with the US, but also in the EU, to conclude bilateral "TRIPS Plus" treaties with developing countries that go beyond TRIPs. For example, they define the UPOV 1991 provisions as an effective sui generis system and demand "the highest international standards" in intellectual property rights protection, including patent protection of plant and animal varieties and of biotechnological inventions (GRAIN 2003). At the same time, the development of the Substantive Patent Law Treaty (SPLT) under the auspices of WIPO is being pushed (cf. WIPO 2002). The draft treaty not only strives for minimum standards (like TRIPS) but it defines both the top and the bottom line of IPR standards. The draft strongly expands the conditions of patentability (no concept of invention, no technicality), will probably restrict exclusions from patentability and aims at prohibiting member states from making any further demands on patent applicants than those found in the treaty (GRAIN 2002). Some potential for a movement away from mere tightening of patent regimes might be provided by internal processes in the WTO. Firstly, in 1999 a review of TRIPs Art. 27.3 (b) was started. It was initiated largely because the United States, under pressure from private industry, wanted to negotiate stronger life patenting requirements without exclusions for plants and animals

(Bragdon/Downes 1998: 11, cf. CIEL 1998). However, other members have perceived the review as an instrument to drive back bio-patenting. As the process has reached a deadlock, it is at present unforeseeable whether the US position will prevail. Secondly, the Doha Mandate in § 19 sets on the negotiation agenda the relationship between the TRIPS Agreement and the Convention on Biological Diversity (CBD). This raised the question whether TRIPS should be amended to incorporate certain requirements of the CBD (WTO 2002: pp. 3). Particularly, patent applicants might be required to disclose the origin of any genetic material or traditional knowledge used in inventions and to demonstrate that they have obtained prior informed consent from the competent authority in the country of origin and entered into appropriate benefit-sharing arrangements. Though it is unclear whether the development of an IPR regime for traditional knowledge (cf. WIPO 2003, IISD 2003, Dutfield 2002) might not lead to a further tightening up of the IPR system, which can be considered detrimental to agrobiodiversity, disclosure of origin and prior informed consent address "bio piracy" of biological resources and traditional knowledge, thus adding to a more equitable system (Correa 2003: 1). However, determining the "origin" of genetic resources for food and agriculture will prove difficult, since international exchange in breeding has led to a strong interdependency among countries. A last strand of discussion to mention is the debate on the design of "effective sui generis systems" under Art. 17.3 (b) TRIPs. This provision is only relevant for developing countries, which have yet to dispose of a regime for plant variety protection. A number of suggestions have been made. They range from the adoption of a UPOV 1991 or UPOV 1978 to developing alternative PVP systems with different criteria as well as to an opening of the protection system for benefit sharing agreements, Farmers' Rights or the protection of communities' intellectual rights (Biothai/Grain 1998, Leskien/Flitner 1997).

Farmers' Rights

Farmers' Rights are a very open concept that was meant to countervail 'classical' Intellectual Property Rights in the field of plant genetic resources for food and agriculture, especially with relevance to developing countries. They were created as a reaction to the asymmetric benefits derived by the Southern donors of plant agrogenetic resources (i.e. seed that was developed by local farmers and communities but that was unprotected by any IPR) and the Northern users of this germplasm. In the context of the (non-binding) International Undertaking on Plant Genetic Resources for Food and Agriculture (IU), the FAO Conference in 1989 defined Farmers' Rights as "rights arising from the past, present and future contributions of farmers in conserving, improving, and making available plant genetic resources, particularly those in the centres of origin/diversity" (Res. 5/89). As pledge to the recognition to Breeders' Rights the FAO member states recognised Framer's Rights. However, a substantive definition of those rights was not made. It was envisaged that the realization of Farmers' Rights should ensure a flow of benefits from the use of plant genetic resources, to farmers and their communities. FAO Resolution 3/91 therefore laid down that "Farmers' Rights will be implemented through international funding on plant genetic resources, which will support plant genetic conservation and utilization programmes, particularly, but not exclusively, in the developing countries". More radical proposals strived for developing Farmers' Rights into some form of property rights equivalent to Plant Breeders' Rights: "Farmers developing a new, distinct, variety would own it, just as plant breeders own varieties they have developed. Access to the variety would be under farmers' control" (Wood 1998: 24).

The International Seed Treaty signed in 2001 takes up the concept of Farmers' Rights which here includes the protection of traditional knowledge relevant to plant genetic resources for food and agriculture (PGRFA), the right to equitably participate in sharing benefits arising from the utilization of PGRFA, and the right to participate in making decisions, at the national level, on matters related to their conservation and sustainable use (Art. 9.2). The responsibility for implementing Farmers' Rights, however, is entrusted to the nation states.

While the effects of Farmer's Rights on North-South equity are obvious, it is unclear how exactly they will impact on agrobiodiversity. A plausible argumentation, however, is that local participation will help keeping local varieties in the developing countries. This might especially be relevant against the backdrop of weak performance of high yielding or GMO varieties under the conditions of the South and the experience of unfavourable side-effects like additional costs for the necessary agrochemicals.

6.1.2. Sovereignty

At the international level the questions of access relates to the public vs. national sovereignty over resources. As with private right restrictions (IPRs), access to, and exchange of genetic resources can be hampered by way of sovereignty regimes.

In 1992 when the Convention on Biological Diversity (CBD) was passed, a major shift in the property regime concerning genetic resources took place: Up to then, biological resources were considered a "common heritage" or public good, and access to them was unrestricted. Compared with this, the new regime was one of national sovereignty over genetic resources, including those for food and agriculture. Thus, biodiversity was attributed the same status as other natural resources like oil and ores. The background for this change was that during the 1980s the utility value of biodiversity (for pharmaceutical and industrial purposes) became more apparent, especially combined with the emergence of new methods of biotechnological use and bioprospecting. The utilisation perspective began to dominate the international debate on biodiversity loss that led to the CBD negotiations (Elliott 1998: 74). As it is the South where the major part of global biodiversity is concentrated, developing countries played an important role in raising equity concerns about the open access system. They argued that if Northern companies were to continue to exploit the species and genetic resources of the South, while the South had to pay when making use of the breeding results, an equitable sharing of benefits was necessary to compensate for the unequal exchange. The concept of common heritage favoured by the industrialised countries and nature protectionists was successfully rejected (Henne 1997: 190). The CBD instead recognizes the sovereignty of nations over their genetic resources, thus defining property rights. It also requires the establishment of conditions of access to genetic resources and the fair and equitable sharing of the benefits arising out of their utilization (Art. 15 CBD). The core of the access regime is a bilateral system that is subject to mutually agreed terms and prior informed consent. On a case by case basis, nation states and companies that want to use genetic resources from the country sign public-private contracts on the exchange of genetic resources as well as monetary and non-monetary benefits such as technologies and knowledge. A number of such biopartnerships have been agreed with varying degrees of success (Marin 2002: pp. 120, Bialy 1998). The crucial point is the negotiation of fair and clear contractual terms in a situation that might be asymmetric in terms of information and power shares.

As the exchange of genetic material in the field of agriculture is much more common, breeding having long since been an internationalised activity, it was obvious that the CBD bilateral system would not be optimal for agro-genetic resources, for the transaction costs of negotiating bilateral agreements would simply be too high. Also, it was feared that developing countries would stop to contributing genetic material into international gene banks since access to ex situ collections was not addressed by the Convention - a loophole threatening to undermine the CBD. Therefore, in order not to thwart the CBD adoption, it was agreed to regulate this issue under the auspices of the FAO, traditionally responsible for agriculture. This change of forum lead to the revision of the International Undertaking on Plant Genetic Resources for Food and Agriculture (IU), a non-binding instrument that had to date governed access to plant genetic resources for food and agriculture (PGRFA). Still based on the concept of "heritage of mankind", the IU needed to be brought into harmony with the CBD. After eight years of tough negotiating, an internationally binding Seed Treaty (International Treaty on Plant Genetic Resources for Food and Agriculture/ITPGR) was signed in 2001, which regulates facilitated access to PGRFA.

The crucial difference in the access regimes of CBD and Seed Treaty is that the latter is based on a Multilateral System (Art. 10 ITPGR). This Multilateral System consists of a list of 35 food and feed crops for which the member states will provide facilitated access. The respective genetic material belonging to public institutions will be kept in the public domain. "Facilitated access" means that an exchange free of charge or at minimum fees may exclusively take place for breeding, research and - expressly not for industrial purposes (Art. 12.3 (a) (b)). Unlike in the CBD there is no need to apply prior informed consent procedures on a case-by-case basis. Although a number of countries (among others the EU) aimed at maintaining open access to PGRFA, a restriction in the form of a list was inevitable; especially the Group of Megadiverse Countries under the leadership of Brazil had fought hard for it and wanted to keep it as short as possible. A standardised Material Transfer Agreement (MTA) will specify the details of access and will also be the basis for private contracts between the providers (mostly gene banks) and the demanders of PGRFA. Many questions are still open and will need to be clarified once the Treaty comes into force. One of those questions is the status of intellectual property rights, since the interpretation of the Treaty's wording on the protection of material received via the multilateral system is still very contentious. Some discern it as a loophole since the holder of an IPR, specifically of a patent, could restrict use of the protected sequence or compound by others, and even access if the patent covered the method of isolation, so that the Seed Treaty's intention of facilitating access would be undermined (Dutfield 2002: 17, CIPR 2002: 69). Despite some weak spots the ITPGR is certainly an essential instrument for ensuring the sustainable use of PGRFA. It might serve as a blueprint for dealing with farm animal genetic resources that have not yet been the object of much specific consideration within international politics.

6.2. Seed and breeding regulations

Seed and breeding law is national law, although some aspects in EC countries underlie European harmonisation. As an example, aspects of German seed law and animal breeding law will be described in order to outline what other legal factors apart from IPRs and international access regulation may turn out to restrict the development of agrobiodiversity. They are problematic in terms of agrobiodiversity to the extent that they promote the streamlining of selection criteria. Also, by implicitly furthering high performance varieties and races they contribute not only the displacement of traditional varieties/races but also to the spread of high input agriculture.

In plant breeding, independent of private law on variety protection, EU member states, most transition countries and some developing countries feature a compulsory variety registration under public law (Gisselquist 1999: 413). This means that in order to market seeds commercially, the variety needs to fulfil specific criteria. The basic principle of the German Seed Law (SaatG) concerning agricultural varieties goes: Seeds and seedlings can only be marketed when they are approved of; they will only be approved of when they belong to a variety that is registered (Rutz 2002: 8). For variety registration, Germany, like many other countries, has established a double set of requirements. Firstly, the "DUS" criteria, that are also crucial for variety protection, demand that plants grown from a specific lot of seeds are *d*istinct and *u*niform, and that their characteristics are *s*table over a minimum of 2 years. For the reasons outlined above (chapter 6.1.1), it is the uniformity criterion (§§ 30.1, 32 SaatG) that some experts are very sceptical about. In addition to the DUS, set seed registration in Germany presupposes that the variety demonstrates *v*alue in *c*ultivation and *u*se (VCU) (§ 30 (1), § 34 SaatG). A government agency, the Bundessortenamt (Federal Agency for Varieties), conducts the DUS and VCU tests, which are paid for by the breeding companies, who also pay an annual fee for the listing of registered cultivars. The VCU, or performance criteria, are a bundle of value designating qualities such as qualities of cultivation, resistance, yield and quality. The VCU is, under German Seed Law, the toughest standard that a breeder has to comply with in order to get a new crop registered; some 90% of applications fail, mostly due to lacking VCU (Steinberger 1999: 34). Varieties are considered to have value in cultivation and use when the entirety of their 'value designating qualities' represents a distinct improvement vis-à-vis existing varieties (at least within a regional area) in terms of the exploitation of either the harvested material or any products thereof. Individual, unfavourable characteristics may be compensated for by other favourable qualities (cf. § 34 SaatG). The specification of VCU, which is crop-specific, is being defined by the Bundessortenamt, i.e. by the executive powers. Although there have been some change in the weighting of the qualities (Steinberger 1999), high yield for many crops still constitutes the predominant orientation. In terms of agrobiodiversity, this legal provision adds to economic incentives for a relatively mono-structured alignment of plant breeding. Per se, a standardisation of selection criteria is promoted. Thus, variety registration as a means that was, and is, intended for consumer (i.e. farmer) protection as a side effect streamlines plant breeding according to state-defined preferences. And those preferences are not shared by every farmer; organic farmers, for example, require varieties with different qualities since chemical inputs in cultivation are prohibited in organic farming (FiBL/Öko-Institut 2003: pp. 55). Another bottleneck of diversity is that seed sale of old cultivars - traditional varieties as well as out-of-date commercial cultivars - is illegal. This issue, however, is being tackled by way of an EU initiative on conservation varieties. Registration of land races and varieties endangered by genetic erosion shall do without the DUS criteria and with liberalised VCU requirements. At the moment, the implementation provisions are still being drawn up by the European Commission.

Beyond seed and beering law, marketing standards and grades of goods play an important role in terms of agrobiodiversity. Based on UN/ECE norms, the EC (and for some additional crops German legislation) have specified standards for a vast number of fruit and vegetables, potatoes etc. that are relevant in trade. The standards regulate quality grades, sizes (diameter, weight), tolerances vis-à-vis sorting errors, packaging and labelling for agricultural products that are sold freshly (aid 2001). While the standards aim at protecting processors, traders and consumers against cheating and aim at furthering simplification and differentiated sales, they also impact on the variety of marketed crops. Those varieties of apples, tomatoes and potatoes that are bigger or smaller than required, that are not as regular as required cannot be offered for sale to the end user except in direct marketing on farms. This has led to a comprehensive drop out of cultivation and sale of many crop varieties and to the dominance of 'standard cops'.

The regulatory regime on livestock breeding reflects to a large extent the economic conditions. Over a long period of time, animal breeding and husbandry law have supported one-sided selection strategies focused on economic performance. They have thus contributed to the depletion of farm animal diversity. Although in the meantime the objective of "genetic diversity" is codified in the German Livestock Breeding Act (§ 1.2 (4), § 4.1 TierZG), the longstanding specification of selection criteria through state agencies, which used to build the basis of performance tests and of obligatory assessments of breeding quality, has fostered a narrowing of animal genetic diversity.

This trend has been resumed by including into the Breeding Act the promotion of "breeding progress" as an undefined legal term (§ 5 TierZG). As a consequence of this orientation, the administrative bodies give permission for the insemination of cattle, pigs, sheep, goats and horses only if the breeding value of the sperm donating animal is higher than the average breeding value of comparable animals (§ 10.2 (1) TierZG). For chickens, there is no legal control of breeding. Nor is there access to the breeding process for chicken farmers since the existing breeding lines of laying hens and broiler are private property of a small number of trans-national breeding companies; farmers only raise hybrid chickens and they, themselves, cannot breed, correspondingly influencing genetic diversity.

7. Conclusions

This article has shown that access restriction in the form of IPRs and sovereign rights as well as high performance oriented regulation of crop and livestock breeding might impact negatively on agrobiodiversity. The respective regimes have only developed in the last 80 years, gaining rigidity parallel to the increasing relevance of biotechnology (Raustiala/Victor 2004). From the 1920s onwards, these various regimes started to replace an open access regime and a largely unregulated seed and livestock sector. It needs to be stressed that the former regimes actually contained a number of deficiencies. The introduction of variety protection (plants) and performance testing (livestock) certainly increased productivity in times when food security in Europe was still endangered. Also, before the introduction of seed testing there was the danger of cheating farmers by not procuring information on the quality of the seed. The solution of restricting and privatising access and of prescribing selection objectives, however, might turn out to have caused new problems: the loss of agrobiodiversity.

Having described agrobiodiversity loss as unintended feedback of previous problem solving strategies, the imminent challenge now is not only about reducing given obstacles and introducing new instruments. It is also about using *reflexive* strategies to avoid causing new problems in the future. Elements of a reflexive strategy could be integrated knowledge production, the anticipation of systemic consequences, adaptivity of problem-solving, as well as participatory evaluation and goal formulation (Voss/Kemp 2003). Some of these elements have already become reality, such as participatory breeding approaches as promoted by the FAO; others need to be developed.

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Driving Forces for Environmentally Sounder Innovations: The Case of Finnish Pulp and Paper Industry

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1. Introduction

Moving towards sustainability requires that new environmentally sounder technologies are developed and widely adopted. Policy instruments that advance technological development are necessary, while at the same time it is clear that public policy is far from the only factor affecting the emergence and diffusion of environmentally sounder technological innovations. Other factors influencing the innovation process arrive from company external influences such as market forces or within the company due to desires e.g. for cost cuts.

Even though there is wide spread agreement on the importance of technological innovations, there is still comparably little consensus on the relationship between different types of policies and technological development. Several contradicting claims have been expressed regarding the policy-innovation relationship, yet empirical thoroughly examined evidence is rare.

Some argue that environmental regulation is likely to stimulate innovation and technology adoption that will facilitate environmental compliance (e.g. Porter and van der Linde 1995, Jaffe et al. 2003), while others have found that emissions standards are often based on available technology with little incentive for innovation (e.g. Kemp 2000). Common to these studies has been the view that stringent regulations are more likely to produce innovations than lax regulations (Porter and van der Linde 1995, Kemp 2000). Another commonly held view is that economic instruments are more likely to prompt innovations than regulations (Milliman and Prince 1989, Jung et al. 1996, Hemmelskamp 1997). It has, however, also been found that, according to empirical studies, the dynamic effects of environmental policy instruments in practice differ from the ideal instruments in theoretical studies and that the relationship of policies and innovations may not be as simple as often stated (e.g. Hemmelskamp 1997). Regarding technology policy, it has been stated that public R&D may play an important role for environment-related science and technology (Jaffe et al. 2003), but that subsidies have had a limited impact on decisions regarding investments in environmentally beneficial technology (Kemp 2000).

Innovation has been defined by Freeman (1987) as "the introduction of a new product, process, method or system into the economy". If a broader view including also social innovations is taken, innovations can mean all new elements, practices and applications used in a social system. The term environmental innovation has had many different meanings. Some use it for all innovations with beneficial environmental effects (e.g. Kemp 1997), while others have used the term for those innovations intended to have positive environmental effects (e.g. Hemmelskamp 1997). In this article we focus solely on technological innovation and use the term environmentally sounder innovations to describe any new and innovative technology with less harmful environmental effects than the available alternatives. The term environmental innovations is, in turn, used only for those technologies that have specifically aimed at reduced environmental impacts.

Based on a previous examination of selected claims in the light of the pulp and paper and the marine engine sectors, we have chosen a number of specific innovations in the Finnish pulp and paper sector to further examine the driving forces for innovations and their diffusion. The sector provides an interesting focus because it has long been a target of traditional pollution control measures, while restructuring and globalisation have reformed the industry during the last decades. Three innovation cases, namely the development of black liquor recovery technology, a paper machine pump system, and an effluent concentrate combustion system, were selected to present innovations with reduced environmental impact but different innovation settings.

This article presents a study of how environmental policy and R&D support have affected the emergence and diffusion of these environmentally sounder innovations. It begins by providing a background for the study and introducing the Finnish pulp and paper industry. The impacts of environmental policy and R&D support measures on innovation are analysed empirically, followed by a discussion on their combined impact. The wider innovation setting is accounted for by discussing internationalisation and its influence on innovations. The article ends with a summary of the key conclusions.

2. The starting point and scope of the study

Previously we have examined selected claims on the effects of policy instruments on innovation and diffusion based on empirical experiences from the Finnish pulp and paper sector and a company producing marine engines (Mickwitz *et al.* 2003). The results for the pulp and paper sector are summarised in Table 1. Although the marine engine case is not discussed, it should be noted that the results differ for some of the claims.

Table 1: Summarising the experiences on the policy-innovation claims* (Mickwitz *et al* . 2003)

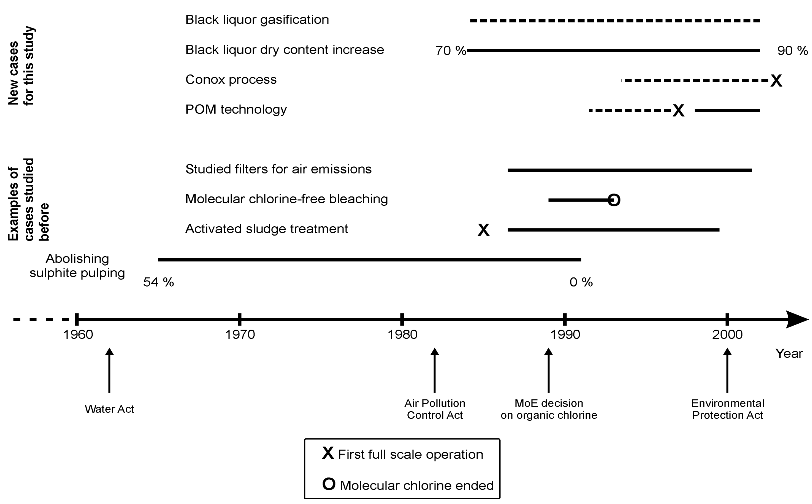
Claim	Supporting experiences	Contradicting experiences
• Environmental regulations (permits, standards, etc.) are often based on existing technology and provide no incentive to innovate but may stimulate diffusion.	• Activated sludge treatment - diffusion was stimulated • Chlorine-free bleaching of pulp • Filters for air emissions	• Activated sludge treatment - innovative application to this sector and these climatic conditions
• Non-binding permit conditions or standards do not provide any incentive to innovate.		• Waste water permits, especially for BOD and phosphorus
• Permit conditions or standards only confirm the development that has taken place otherwise.	• Reduced discharges of chlorine compounds from pulp bleaching • Change from sulphite to sulphate pulp production	• Activated sludge treatment was applied in novel conditions due to strict standards
• Environmental regulations can easily hamper innovations, by directly specifying the technology to use or indirectly making try-outs impossible.		• The flexibility of the Finnish water permits to support try-outs
• Environmental taxes are superior to other policy instruments with respect to innovations.		• The Finnish energy taxation had no effect on innovation in pulp and paper production
• R&D subsidies have limited impacts.	• The share of R&D subsidies is low in the total R&D expenditure of the forest cluster	• The existence of subsidies is important
• Innovations can be promoted by encouraging/forcing co-operation between organizations that would not otherwise work together.		• When networks are traditionally strong, as in the forest cluster, no change may be imposed.

**Some claims are widely supported and others are held by a few. They have all been challenged.*

Our analyses have shown clear effects of policies on the diffusion of environmentally sounder technologies but less on the very emergence of innovations. Furthermore, we have found that the effects of policy instruments on innovations are context specific, e.g. influenced by the cost-benefit distribution of the policy (Mickwitz *et al.* 2003). Various factors such as market demand for new technologies affect also the formation of different innovation settings.

Earlier studies by our research group (Hildén *et al.* 2002, Similä 2002, Mickwitz 2003 and Mickwitz *et al.* 2003) have examined the issues largely from the perspectives of the pulp and paper companies and public authorities. The innovations that were examined in detail were those technologies that have attributed to the drop in traditional water and air emissions, and our focus was largely on the period between the early 1970s to the mid 1990s (Figure 1). Since then the concentration and increased globalisation of the industry have affected for example the investment behaviour of the companies (e.g. Siitonen 2003).

Figure 1: Temporal distribution of some earlier cases and the new cases for this study



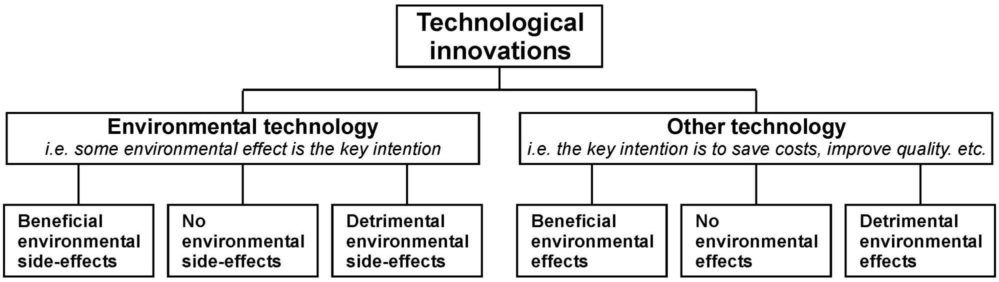
Three new cases were selected to expand our earlier picture of the innovation processes and to bring forth the perspectives of technology developers and researchers within the Finnish forest cluster (Box 1). Two of the cases were chosen to represent very recent innovations, whereas the third case covers innovations development on a wider scale and during a longer time period from the 1980s to the present. Also, the company format differs between the cases covering two small companies, POM Technology and Conox Ltd, and two major machinery developers, Tampella Power and Ahlström.

Box 1: Three additional cases

Technology	Description	Empirical sources
POM technology - air removing pump system for paper machine	**POM** is a compact wet end system for the paper making process, developed by *POM Technology,* and its main component is air-removing centrifugal pump. POM achieves faster and shorter water recirculations in the paper mill and reduces grade change times, resulting in improved energy efficiency and reduced water consumption, effluent discharge and waste compared to the conventional process. This has been regarded by some as one of the most important pulp and paper innovations of the 1990s (Oinonen 2000, HS 2004). The idea was generated in the early 1990s and the first full scale operation started in 1997.	www.pom.fi Interviews: *P. Meinander*, POM Technology Sept. 2003. E-mail quest. to 3 customers Newspaper & trade journal articles
Conox process - effluent concentrate combustion system	The **Conox** process, developed by *Conox Ltd,* is based on pressurised thermal oxidation of process water effluent concentrate. It was originally designed to eliminate organic compounds creating chemical oxygen demand (COD) present in bleaching plant effluents (Myréen *et al.* 2001). Later the concept was applied to black liquor from non-wood pulping. In addition to reduced water discharges, it's a development towards closed water cycles and it somewhat improves energy-efficiency. The idea was generated in the early 1990s and the first full scale operation for non-wood pulping started in 2003.	www.conox.com Interviews: *B. Myréen* & *L. Prepula*, Conox Ltd Nov. 2003. *M. Hupa*, Åbo Akademi University Nov. 2003. *B. Myréen* 2002. Trade journal articles & other documentation
Black liquor recovery technologies - increased dry solids content, gasification	The third case explores the development of various **black liquor recovery technologies** aimed towards increased dry solids content and gasification of black liquor. Efficient black liquor recovery reduces air emissions and increases the plant's energy supply. To a large extent, the significant sulphur emission reduction of the forest industry in the 1980s can be attributed to the increase of the black liquor dry solids content to over 70% (Interview II). These technologies have been developed by *Tampella Power* (now Aker Kvaerner) and *Ahlström* (now Andritz)	Interviews: *E. Vakkilainen*, Jaakko Pöyry Ltd Oct. 2003. *M. Hupa*, Åbo Akademi University Nov. 2003. Trade journal articles & other literature

Common to the selected cases has been reduced environmental impact, but in comparison, the innovations are of different types. Viewed from a purpose perspective, technological innovations can be divided into two categories: *environmental technologies,* where a specific environmental effect has been a key intention of the innovation, and *other technologies*, where the key intentions have not included environmental concerns but e.g. cost reduction (Figure 2). The paper machine pump system POM is a process innovation with beneficial environmental side-effects, whereas the effluent concentrate combustion system Conox was created as an environmental technology to reduce the organic pollutant load to water. Black liquor recovery technology positions itself somewhere between the two, being originally developed for improving the process and saving costs, but further innovative development has also had environmental intentions.

Figure 2: A typology of technological innovations viewed from the environmental perspective



3. The Finnish pulp and paper industry

The pulp and paper industry has had a highly significant role in the Finnish economy since the 19th century. Finland's first paper mill was established in 1873. The significant expansion of the industry began in the 1950s and by 1970s the production of paper had experienced a six-fold increase (VTT 1999, 39). In 2002 the annual pulp and paper production were nearly 12 million tonnes and 13 million tonnes respectively (FFIF 2003). The forest cluster, comprising forestry and the production of pulp, paper and wood products, contributes to about 20% of the industrial value added gross production (Statistics Finland 2002). The forest industry's share of total export value was 26% in 2001 and the largest share, 19% of total export value, can be attributed to the pulp and paper sector (Metla 2002, 284). Although exports have been growing, their share of the total export value has been shrinking with e.g. high-tech electronic companies gaining increased export volumes (Ali-Yrkkö and Hermans 2002).

Concentration of the Finnish pulp and paper industry has resulted in only six companies operating in the sector (Näsi 2001, 13) compared to over 20 independent companies in the beginning of the 1980s (Hagström-Näsi 1999, 88) and around 30 companies in the mid 20th century. The three largest corporations, Stora Enso, UPM-Kymmene Corporation and the Metsäliitto Group, constitute circa 98% of Finland's paper and pulp production capacity (FFIF 2000) as well as being internationally significant actors in the sector.

Also technology companies Metso Paper and Ahlström have developed globally significant market positions as manufacturers of paper and pulp machinery. Much of the technological development occurs in cooperation with pulp and paper producers, technology companies and consultancies, such as Jaakko Pöyry and some smaller actors. In addition universities, e.g. Helsinki University of Technology and Åbo Akademi University, have had important roles in basic and applied research.

The environmental impacts of the sector have been significant due to extensive use of energy and timber as well as emissions to air and water. Technological innovation and development have lead to increased production capacity simultaneously reducing the pollutant load significantly. A change from sulphite pulping to sulphate pulping is an example of a significant process change. In 1965, nineteen of total 35 pulp mills were sulphite mills but by 1985 only three sulphite mills were left and, since 1991, only the sulphate process has been used (Ministry of the Environment 1997, 39). This shift that has taken place mainly for economic reasons has contributed significantly to the decline in water discharges (Hildén *et al.* 2002). Several important developments in environmental technology can be identified in the past three decades, e.g.

chlorine-free bleaching and tertiary waste water treatment. Significant advances have been made to improve the resource efficiency and water consumption of the production processes, the latter developing towards closed water systems within the plant. For example, the per unit water consumption of pulp production has been reduced from 600 m^3 per ton, in the 1950s, to close to 10 m^3 per ton in the early 21st century (Kettunen 2002, 36).

4. The impact of environmental policies on innovations

4.1. Regulatory environmental policy instruments

In Finland permits, designed on a case-by-case basis, have been the main way of controlling point source pollution (Hildén *et al.* 2002, 37-44). Emissions to air and water were controlled separately through different kinds of procedures prior to the implementation of the EU Directive on Integrated Pollution Prevention and Control (IPPC) in 2000. For air emissions the limit values in individual permits were complemented with general norms and guidelines, e.g. regarding air quality, depositions or emissions. Contrarily, for water discharges the permit system has functioned without general standards to explicitly guide individual decisions. Our earlier empirical examinations have indicated that permit decisions have mostly been based on existing technology and have provided no incentive for innovation, and have affected diffusion mainly in relation to activated sludge technology for water treatment and filters for air emissions (Hildén *et al.* 2002, Mickwitz *et al.* 2003). The three cases examined here also reveal diffusion effects of the regulatory instruments.

The origin of innovations increasing the dry solids content of black liquor lies in basic scientific research and in attempts to achieve more economic thermo-technical solutions for black liquor combustion. For example, Ahlström's evaporation technology increasing the dry solids content of black liquor, achieved in the early 1980s, originated from the basic research of lignin not related to energy efficiency or emissions (Kettunen 2002, 88). As a result, it was noticed that sulphur emissions after the process were practically non-existent (Interviews II, III). During the 1980s and 1990s, the process was further developed through large national research programmes and development work by major technology companies. The air emissions received increased focus in the later development phases partly through tightening environmental regulation *"which probably brought forward these issues to the pulp and paper producers, who then knew both to require improvements from the technology developers and to enthuse about the developers' solutions"* (Interview III). Specific permit conditions have in some cases affected the diffusion of the technology, while in others adoption has preceded actual permit regulation. For example, one pulp mill postponed new investments for nearly ten years, and permit conditions effective from the beginning of 1999 finally forced investment in new technology including 80% dry solids content evaporation and recovery boiler with a new system to collect and combust odorous gases (Illi 1999).

For POM technology, environmental policy had no role in the innovation process (Interview I). Also, the diffusion of this technology to various countries, e.g. Germany and Japan, has occurred due to cost and competitiveness factors alone. As an exception out of 20 installations, environmental regulation was one of the reasons for acquiring this technology for a paper mill in Spain. POM enabled them to meet the short-term maximum limits in the water permit and reduce the emissions below the legal requirements set up by the Municipality (Clariana 2003). This together with increased flexibility was considered as an important characteristic when deciding on the investment. By 2003, POM had been installed in only one Finnish paper mill, for process improvement reasons not related to environmental issues.

In 2003, Conox had not reached the demonstration stage in Finland and the progress had halted for various reasons. Some view that the environmental regulations concerning e.g. discharges of heavy metals are not strict enough to awake the interest of pulp and paper producers for this technology, while others argue that competing solutions are more appealing (Interviews III, IV). However, during 2003, the Conox application to non-wood pulping was installed to small mills in Spain and China. These mills faced tight regulations, and non-complying would have closed the mills, resulting in serious conditions for the rural communities dependent on those mills (Interview IV).

4.2. Anticipation of new or tightening regulations

The impact of environmental policies on the innovation process is, in effect, not straightforward and the dynamic nature of both innovations development and environmental policy must be accounted for. The duration of an innovation process in the pulp and paper industry is often more than a decade, and therefore anticipation of future markets is essential. Anticipation of future environmental policies may, consequently, have a decisive role in the innovation process.

The development of the Conox system addressed the issue of water pollution caused by plant effluents. The original idea was spurred by anticipation of increased regulatory measures for closing the bleaching processes. The anticipation rose from the issue being high on the agenda for the Central European paper buyers and NGOs, such as Greenpeace, during the early 1990s (Interviews IV,V). Unexpectedly, in the late 1990s, the NGO and government interest in the chlorine issue diminished in Western and Northern Europe due to reduced organic loads, and the anticipated regulatory action did not happen. Simultaneously water discharges of non-wood pulping, e.g. in China, were discovered to be a significant environmental problem (e.g. WBCSD 1996) and the further development of Conox was redirected to those markets.

The anticipation of future regulation has also played a role in the development of black liquor innovations. Much of the R&D for increasing the black liquor dry solids content had already been carried out prior to the 1987 Council of State Decisions that for the first time set national guidelines for sulphur emissions. Yet the need to reduce forest industry's emissions was already discussed in the 1970s and e.g. Finland's signature for the Convention on Long-Range Transboundary Air Pollution in 1979 was an indication of possible future regulation regarding air emissions. Later, the need to reduce sulphur emissions affected the participation of pulp mills in the try-outs of emerging technologies. For example, this motivated the Äänekoski pulp mill to purchase Ahlström's LHT-system (Interview II), one of the first to achieve over 80% dry content and zero sulphur emissions, in 1990 (Pearson 1993).

In many instances technological R&D and environmental policy have progressed simultaneously, and it is difficult to identify when policy affects technological development and vice versa. For example, in the black liquor case, national air pollution regulations were implemented in permit decisions from 1987 onwards and national technology programmes, including black liquor research, were carried out from 1988.

5. The impact of public R&D support on innovations

5.1. R&D support

During the last decade the trend in Finland has moved from financing individual projects towards focused technology programmes. Also, the public expenditure on

R&D has increased both in monetary terms and as share of the GDP (Prihti *et al.* 2000). At the same time the financial contribution of external R&D support has reduced in the pulp and paper sector. In the 1970s, a large corporation may have received over 25% of its R&D finance from outside (Kettunen 2002, 102) whereas, in 2001, only 3,3% of R&D funding in the sector was received from external sources, less than received by industrial companies in general (4,7%) (Statistics Finland 2003). For example public finance received by KCL, a research company owned by the four largest pulp and paper companies in Finland, has reduced by half from 9,4% of turnover to only 4,6% between 1998 and 2002 (KCL 2002, 24). Although, the share of public finance seems rather low, a former head of research at Metsäliitto Group has stated that the National Technology Agency of Finland (Tekes), after its founding in 1983, has provided funding to every major research project of new technology that the company has undertaken (Kettunen 2002, 104).

Public funding is mainly given out in the form of grants and low-interest loans from Tekes and the Ministry of Trade and Industry (MTI). These constitute to 60% and 36% of external R&D funding respectively (Statistics Finland 2003). Tekes also supports pilot projects and commercialisation. Other sources of public funding include the Finnish National Fund for Research and Development (Sitra), the Start Fund of Kera, and the regional TE Employment and Economic Development Centres. Besides R&D funding for independent projects, there have been six major technology research programmes supporting the development of environmentally sounder technologies relevant to the pulp and paper sector.

With respect to black liquor innovations, it has been argued that technological change would have progressed more slowly without public subsidies that have lowered the barriers and risks to investors (Interview II). Black liquor related R&D has received financial aid motivated by several political goals, including environmental protection, enhancing the competitiveness of domestic industry and supporting the use of domestic fuels. The aid has been especially significant through the two LIEKKI research programmes (1988-1992, 1993-1998), financing projects related to combustion and gasification technology. These created a favourable climate resulting in "two waves": firstly, over 80% dry solids content evaporators focusing on other than sulphur emissions and, second, chemical research and information systems aiding e.g. gasification research (Interview II). The Jalo (1988-1992) and Code (1999-2002) programmes have also covered black liquor research. Code developed numerical modelling of combustion processes dramatically reducing the need for pilot experiments (Interview III). The technology programmes have been crucially important in creating and increasing the necessary knowledge base for black liquor research before specific innovations could be generated (Interviews II, III).

The Conox developer views that public R&D funding is important in the early stages for generating inventions, but for innovations to appear also risk capital and markets are required (Interview V). The general view appears to be that public funding is fairly well available for basic and applied research and technology development, but finding finance for prototypes is more difficult. Black liquor dry content technologies have reached the commercialisation phase because they have been fairly risk-free incremental innovations on the existing system, whereas black liquor gasification is a technology requiring more significant system changes. No demonstration system has yet been created in Finland due, likely, to the high risks and costs involved (Interview III).

POM Technology received public R&D funding in the technology development and the installation phase. Tekes provided product development support in the beginning and, with the help of development support from Tekes and risk capital from the Start Fund of Kera, the first four POM systems were installed in Germany and USA in the late 1990s (Lindén 2000, 1996; Oinonen 2000). Significant funding from

Tekes and other public sources reduced the risk for other investors and made reaching the commercialisation stage possible.

5.2. R&D networks

Co-operation of pulp and paper companies with technology developers, consultancies and research organizations has been characteristic to the industry throughout its history (Hildén *et al.* 2002). Information on end-of-pipe solutions has been quite freely exchanged between mills and often R&D has been undertaken jointly. For example Conox Ltd was jointly established by a consultancy, a chemical producer and an environmental technology company, and the technology was developed in cooperation with two large pulp and paper companies. The development of POM technology involved cooperation with a university and some paper mills, whereas the black liquor R&D has been jointly carried out by several public and private actors. The co-operation of the technology companies with public research institutes has been crucial to advance black liquor related R&D.

> "The Finnish situation, where two major technology developers have co-operated in the same projects and research programmes has been unique from the global perspective, and this has created a positive competition on the level of basic know-how… the know-how of both has clearly increased and they were clearly distinguished from their American or Japanese competitors." (Interview III)

Some public funding schemes require companies to have a university or public research institute as a partner in R&D projects. The critique suggests that the measures used to encourage or even force co-operation and networking between organizations can also have negative effects and that establishing a technology programme is not necessarily the best form of public R&D funding from the perspective of the established players in the field (Mickwitz *et al.* 2003). However, at least Ahlström saw the experiences from the LIEKKI programme positively:

> "The LIEKKI program has improved the availability of information resulting from public research, and it has enhanced the adjustment of the research needs of public organisations and those of industry for better mutual agreement. At the same time it has improved the cooperation between public projects…and the industrial projects aimed at product development" (Hupa 1994, 71).

Also, Tampella stated that the programme enabled international cooperation in black liquor related modelling, but viewed the programme benefiting cooperation only when entering new research areas (Hupa 1994, 73). This view is supported by the fact that POM Technology did not gain any new cooperation for joining the CACTUS programme (1996-1999) three years after patenting its first invention. In the POM case, there has not been a difference between participating in a technology programme and receiving outside-programme public funding since the CACTUS programme only resulted in one way information flow from the project to other participants:

> "…certain large companies invested in their own development projects and, regarding information access and participation, we did not gain participation to those seminars that covered these results and did not become sharers of others' results, but did present our own results." (Interview I)

In many occasions, the additional benefits of a technology programme in comparison to funding for independent projects seem insignificant from the technology developers' viewpoint. However, according to a consultant and former representative of a technology company, technology programmes are necessary to generate and share basic research knowledge, without which even private commercial projects would be difficult to carry out (Interview II). This point is further illustrated in the Conox case, where the developer received technical answers for many uncertainties from the 'combustion technology cluster' created by the LIEKKI-programmes (Interview III).

The impact of public R&D support on innovation may differ between smaller and larger companies. On one hand, smaller companies with fewer resources tend to be more dependent on outside financial support, but large companies benefit from wide access to various research programmes. For example, the role of Ahlström and Tampella has been significant in combustion technology programmes. Their projects, although not all black liquor related research, accounted for 29% of the total expenditure of the LIEKKI programme and received 17% of the total MTI funding (Hupa 1994).

6. Combined impact of environmental policies and R&D support

Although many policy issues of today are so broad and complex that they involve several traditional policy branches and institutions, there is still often a lack of co-ordination. This can result in at least two kinds of problems: aspects of an issue not being covered by any sector and aspects covered by several sectors but potentially in conflicting ways or inefficiently. It has been argued that these types of problems are present in the Finnish central administration (Bouckaert *et al.* 2000). Examining the combined impacts of environmental policies and R&D support can thus be seen as being relevant also in this wider context.

Environmental and technology policy measures are usually directed at very different aims, yet they both influence the emergence and diffusion of innovations affecting the environment. Table 2 lists the environmental policies and R&D support measures having affected the studied innovations. It appears that R&D support has affected all these innovations and environmental policy has acted as a driving force for all but one, namely the development of POM technology. However, the connection between policies and innovations is complex. For example, the CACTUS technology programme financing POM included environmental aims, such as reducing the use of water and the environmental impacts in water, in air and on land (Komppa and Neimo 2000). In turn, the development of the Conox system was partly influenced by the know-how created in the LIEKKI programme.

Table 2: The impact of environmental policies and R&D support on the studied cases

Environmental Policy	Innovation	R&D Support
▪ Generally no impact ▪ Water permit limits affected the adoption in a Spanish mill.	POM	▪ Start Fund of Kera capital & TE loan for company establishment ▪ Independent Tekes finance 1994-95,2000-02 ▪ CACTUS programme 1996-99 ▪ EU funding for first commercial installation
▪ Anticipation of regulatory measures for closing bleaching processes in W. Europe - did not happen ▪ Water discharge limits for non-wood pulping in Spain & China	Conox	▪ Research project partly funded by Tekes 1995-98 ▪ Independent Tekes finance 1999-2002 ▪ EU LIFE funding for a planned prototype in a Finnish mill - not realised ▪ Finnfund a shared owner of Conox Holdings Ltd to finance installations in China
▪ Anticipation of emission limits for sulphur & nitrogen in 1980s - Council of state decisions issued 1987 onwards ▪ Emission limits & technology specifying permit conditions affecting diffusion	Black liquor dry content increase	▪ LIEKKI programme 1988-92 ▪ LIEKKI 2 programme 1993-98 ▪ CODE programme 1999-02
▪ Anticipation of emission limits for sulphur & nitrogen in 1980s ▪ Discussion on the need to prevent the fifth nuclear power plant in the late 1980s and early 1990s by providing more electricity from gasification and biomass combustion. (Interview II)	Black liquor gasification	▪ JALO programme 1988-92 ▪ LIEKKI 2 programme 1993-98

The combined effects of environmental policies and R&D support can be studied more specifically by using the typology of technological innovations introduced in Section 2 (Figure 2). Potential goal-conflicts occur in areas where R&D support is directed at technologies with detrimental environmental effects (Table 3). These environmental effects may be anticipated or unanticipated. In occasions, there can be lack of knowledge transfer between the policy sectors. If an invention is dependent on a chemical that will be prohibited or the use of which will be circumscribed through environmental regulation, it might never be realised and the work done by the innovator and the allocated R&D support could be wasted.

Table 3: Policy intentions vis-à-vis different types of innovations

	Technological innovations					
	Environmental technology			Other technology		
	Beneficial environmental side-effects	No environmental side-effects	Detrimental environmental side-effects	Beneficial environmental effects	No environmental effects	Detrimental environmental effects
Environmental policy	Encourage	Encourage	Encourage / Obstruct	Encourage	Neutral	Obstruct
R&D support	Encourage	Encourage	Encourage	Encourage	Encourage	Encourage
Combination	Potential synergies	Potential synergies	Potential goal-conflict	Potential synergies	No interaction	Potential goal-conflict

While Table 3 only lists the overall intentions of the policies, actual policy practices might differ from these intentions. It is well known that good intentions do not guarantee good results. The adoption of environmentally sounder technologies may in fact be obstructed by environmental policies in force, even though there might be a joint interest to promote the diffusion of such technologies. Policies focusing solely on environmental technologies may delay environmental improvement, because often the non-environmental technologies bring many environmental benefits. This is in line with the results of several other studies, which have shown that a range of technological changes with major environmental performance impacts are not shaped by environmental factors (Berkhout 2003, Hildén *et al.* 2002). In Finland, due to the flexibility of the permitting system, conditions have often been temporarily relaxed during demonstration periods or pilot phases of new end-of-pipe technologies (Hildén *et al.* 2002). Innovations have, therefore, not been hindered in a way that for example emission limit values, in theory, could do.

The studied innovations are all examples of cases where there are potential synergies between the policies, i.e. they have resulted in beneficial environmental effects. For example, the further development of black liquor recovery was simultaneously supported by national emission limits and various research programmes. However, in some instances, the encouraging effect of environmental policies may not be strong enough to support the commercialisation or diffusion of environmentally sounder innovations, especially if the users cannot see the other benefits of the technology. The Conox process was not adopted in Finland because, despite a granted EU LIFE funding for a prototype in a Finnish mill, environmental regulations were not strict enough to keep up the interests of pulp producers to install this technology. In turn, the development and diffusion of some environmentally sounder technologies, such as POM, may occur without the direct impact of public environmental intervention. These are often so called 'win-win' solutions that are driven by other factors bringing also competitive advantage for the companies.

7. Internationalisation and its effects on innovations and policies

Market areas outside Finland have always been important for the Finnish forest industry. Until the 1970s the forest industry exports accounted for more than half of the total exports. Subsequently the forest industry's share of the total export value has decreased from 56% in 1970 to 27% in 2000, despite the real value of forest industry exports doubling during that period (Metla 2002, 295).

The pressures and opportunities caused by increased globalisation of the sector are an important factor behind the concentration of the industry, where a few major international companies control over 90% of the markers, in pulp and paper production as well as in technology development. The largest paper producer Stora Enso is a merger of two previously national companies, the Swedish Stora and the Finnish Enso-Gutzeit. A similar example from the technology side is Aker Kvaerner. There are about 20 companies in the forest cluster that are in foreign ownership, and especially the manufacturers of chemicals, suppliers of systems and equipment and industrial automation companies have attracted foreign capital during the 1990s (Lammi 1999).

One feature of the ongoing globalisation process is that it has become easier even for small and medium-sized companies to sell their products in other parts of the world than where they are designed or produced. This feature is especially important for firms in know-how intensive sectors where production does not require a lot of capital. For both POM and Conox technologies, the main markets have been abroad. Moreover, innovation spin-offs can emerge if the access to global information and markets is present, as the Conox case illustrates. This benefits both the domestic technology sector and the environment, through more rapid international transfer of new, environmentally sounder technologies. The Aracruz pulp mill is another example of the global deliveries of the machinery and plant manufacturing sector, installing equipment from several Finnish companies: Ahlström, Sunds and Rauma (Häggblom 1999, 300).

While globalisation has widened the market and created increased possibilities for companies, it is obvious that international markets mean an increased level of competition. It has also been argued (e.g. Foster *et al.* 2003) that, as a side-effect of globalisation, the company motivation for investing in new, innovative and unestablished technology has decreased. This is because new technology is simultaneously available for pulp and paper producers all over the world if proven successful, and the forerunner's benefit is thus reduced. However, even if technologies are usually available for purchase immediately after commercialisation, in practice technology transfer to other countries can be slower because, for example in Finland, the interaction between companies is more frequent and information transfer is faster than e.g. between Finnish and Brazilian companies (Interview II).

The internationalisation of companies can also have negative effects on the development of innovations. It sometimes becomes more difficult to receive public R&D support, because national organisations may not be willing to finance R&D by companies in foreign ownership (e.g. Interviews II, III). Conox Ltd has a contract for a cooperative project with a German research laboratory, but proceeding in it has been extremely slow perhaps partly due to local decision makers' reluctance to support foreign technology (Interview IV). However, it can also be argued that, generally, company ownership is not as an important criterion for public funding as the effects of the company operations for the country in question. Tampella still continued to be part of the LIEKKI research programmes after being sold to Kvaerner. Andritz and Foster Wheeler, that are not in Finnish ownership but continue to concentrate their research operations to Finland, have still been actively involved in Finnish research programmes after acquiring the Finnish companies (Interview III).

The internalisation of markets can also be observed in many other sectors, some of which may be linked to the pulp and paper industry. Several countries have deregulated the electricity market creating an opportunity for any company to participate, while previously selling electricity has been limited to a government-owned regulated monopoly. The next possible step to deregulation - common markets between countries - is gradually succeeding with plans for a common market for trading electricity within the EU borders and the already operating Nordic market covering four states.

The Finnish electricity market was deregulated in 1995 and Finland joined the Nordic electricity market system, Nordpool, at the start of 1998 (e.g. Pineau and Hämäläinen 2000). The new markets have increased the diffusion of new, more efficient black liquor recovery boilers by creating a incentive for the pulp and paper companies to produce electricity exceeding their own needs. Already three mills have been (re)designed for producing electricity for the markets: Metsä-Rauma in 1995, Joutseno Pulp during 1997-2001 and Wisaforest completed in 2004 (Interview II). For example, the Joutseno mill can annually export 15-30 MW of the electricity produced with the black liquor recovery boiler alone while, prior to the new recovery boiler, it had to purchase around 8 MW of electricity from outside producers (Illi 1999, Interview II). However, generally the short term effects of the electricity market liberalisation have been perceived as reducing the interest of companies for new investments (Interview III). In the future, electricity markets will guide the innovation development through the electricity price. If electricity prices increase, the development and diffusion of energy-efficient technologies will be promoted.

8. Conclusion

The cases studied have reinforced our position that it is equally important when analysing as well as promoting technological change to consider both technologies developed for environmental purposes and technologies with beneficial environmental effects primarily developed for some other reason.

Policy anticipation affects both the innovation and diffusion processes. When companies have reasons to believe that environmental requirements set by public policies will become tighter they often act in advance. By adopting environmentally sounder technologies before required to do so they gain leeway to respond to political and market situations. Our case studies have shown in practice that expectations about future environmental policies can have an important role for the innovation processes of environmentally sounder technologies. Developing innovations is a long-term task focused on future markets, where environmental policies are among the key shapers. However, uncertainties are always involved in future predictions and, in occasions, the anticipated conditions may not arise, as illustrated by the Conox case. If environmental policy does not develop as expected by the innovator, at the absence of alternative markets, the R&D efforts might have been wasted. Although the future will always be uncertain, this stresses the importance of transparent and predictable long term environmental policies.

For a successful environmental innovation to emerge and diffuse, often a combination of R&D support and environmental policy measures is required. While there are areas where the interests of the two policy fields are compatible, there are cases where these interests are conflicting, potentially resulting in both negative environmental impacts and wasted resources. When a technology, that is above all developed to increase competitiveness, has environmental benefits the challenge is to ensure that the intentions are also supported in practice. This stresses the significance of coordination in policymaking, but also emphasises the importance of accounting endogenous technological change when formulating environmental policies. Co-operative networks have been shown here to have a significant impact on innovation, and these could be expanded to include policymakers in order to facilitate information transfer. When environmental policies are well known by those providing R&D support there is a reduced risk of wasted R&D resources for technologies that will be impeded or even blocked by environmental policy measures. Also, when new technologies with negative environmental effects are emerging or when significant environmental improvements can be achieved with new technologies, it is important that the environmental authorities are aware of the development so that policies can be redirected accordingly.

The increased globalisation has at least two important effects on environmentally sounder innovations. Firstly, it increases the potential markets for these innovations. If the anticipation of one emerging market is wrong, there might be market potential for the new technology somewhere else as in the Conox case. Alternatively, if the conditions for the crucial first commercial application are not right in the domestic market it might be carried out elsewhere, as in the POM case. Secondly, when a Finnish innovation is developed because a potential market has been identified, it is likely that a foreign competitor has also seen the opportunity. Competition is thus clearly increased by globalisation.

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The Ecological Modernisation of the Automotive Industry

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Introduction

Few can doubt that the contemporary automotive industry is one of the most obvious manifestations of the difficulty of reconciling environmental, social and economic goals simultaneously. Nonetheless, there are indications that the internalisation of ecological responsibility, the implementation of anticipatory planning practices, and the switch to the use of cleaner technologies are happening in the context of the auto business. These practices characterise the phenomenon of *ecological modernisation* (Cohen 1997; Orsato 2001).

For those interested in sustainable industrial development, the question then is not about whether or not improvements have been made in the auto industry but rather whether the improvements are conducive to ecological sustainability. Indeed, the methodological rigour of scientific research leaves little room for studies attempting to guide decisions over *what might be* (i.e. as a prescriptive tool to guide innovative strategy) a transformed – or as we prefer to use, an ecologically modern – automotive industry.

Finally, the sheer size and complexity of the sector makes for a problematic and political policy arena, and indeed limit the chances we have to do full justice to the sector in this article. Nonetheless, we challenged ourselves to create one possible view of what a sustainable automobile industry could look like. By exploring the business concept of Micro Factory Retailing (MFR), we attempt to demonstrate that a new paradigm of production and consumption for the car industry is not only possible but has already been seeded by several empirical examples. Importantly, business models have been relatively neglected within the overall theme of industrial transformations, which as we argue in this chapter is a significant oversight from a policy perspective.

Traditional Manufacturing and Distribution: 'locked in' large scale

The current business model for vehicle manufacturing involves the construction of large car plants able to manufacture and assemble all-steel cars in large numbers. Manufacturing economies of scale are realised and per-unit ex-factory costs are low. In order to sell this many cars, geographically extensive markets are required – which in turn means long logistics chains and dense networks of retail outlets. To date, most vehicle manufacturers have not had to bear a great deal of the investment cost in the dealer network because these have been independent, franchised retail concerns. Neither have the vehicle manufacturers sought to capture a high proportion of the total lifetime revenue stream created by a car in use: revenues have been earned primarily through the sale of new cars and through associated finance packages for consumers. Between the manufacturing plant and the customer are stockpiles of cars throughout the system, build to order is only achieved by long customer lead times. The essence of lean production has been to seek compliance from the supply base and the vehicle distribution network to the demands of the vehicle manufacturing process thereby reducing stock levels in the system– not to optimise the system as a whole.

Despite many measures, the traditional manufacturing and distribution business model faces problems (Wells and Nieuwenhuis, 2000). The high capital costs with very 'lumpy' investment in plant and models inherent in all-steel body technology are high risk. There is a chronic tendency to over-supply, resulting in discounting and rapid erosion of residual values in cars already sold. This rapid depreciation in economic value results in reduced economic lifetimes for the car, and in turn reduced product longevity: hence rates of material usage and vehicle scrappage are much higher than optimum. At the same time, the introduction of a new model can often lead to long waiting times for customer-ordered cars.

The inflexibility of manufacturing is leading to an inability to adjust output to demand and difficulties in switching from one model to another – responding to increasingly violent market fluctuations is difficult with existing production technology. In essence, the prevailing business model is best suited to market conditions of continuous steady expansion, and profits achieved via reduction in per-unit manufacturing costs. As market conditions have changed, so the business model has come under greater pressure. The reliance on the continued expansion sales of cars as the main source of revenue is increasingly untenable in saturated developed markets, while costs rise as shorter model lifetimes lead to lower per model volumes.

Eco-modernisation in the Auto Industry

The automobile constitutes an industrial product that engenders both considerable economic wealth creation and serious burdens to the natural environment. Although governments worldwide regard the capacity of the auto industry to generate jobs as a political asset to be preserved, they have also pressured car manufacturers to improve environmental performance. The industry has responded to stricter governmental regulation, voluntary agreements, and collaborative R&D initiatives by seeking to adopt cleaner manufacturing technologies and investing in environment-related research. In addition, competitive pressures ensure that every major high-volume car manufacturer is working towards increased levels of resource productivity. They have targeted energy and material conservation for both financial and environmental reasons (Knibb *et al.* 1998; Rogers 1993). From the mid-1990s, most world carmakers have also started to release annual environmental reports containing detailed information about improvements in vehicle manufacturing, emissions reduction in vehicle use, developments in hybrid and fuel cell powertrains, and recycling strategies for end-of-life vehicles.

There are no doubts that improvements have indeed been made by car assemblers. The average environmental performance of most fleets has significantly improved in the last quarter of the 20th century (Graedel & Allenby 1998), at least in terms of toxic emissions. With respect to fuel economy and carbon dioxide emissions the industry has not performed as well, because the benefits of more efficient engines have been offset by increased vehicle weight, along with the favouring of performance characteristics such as acceleration and top speed (Wells, 2003a). Such improvements as have been made, however, have not alleviated the pressure faced by firms operating in the industry. Regulatory measures on air emissions from exhausts have continuously intensified. During the 1990s, although the industry in Europe lobbied against the imposition of direct regulations on end-of-life vehicles (ELVs), the European Parliament approved a new Directive on ELVs in September 2000 (CEC, 2000). In order to satisfy standards of environmental performance, the industry has also been obliged to invest in increasingly expensive research and development activities. Environmental issues have certainly become an important economic issue for the automotive industry.

Vehicle manufacturers have responded to the regulatory and market pressure but the technological paradigm orientating car design and manufacture substantially limits the alternatives available to them. Most actions have been designed to reduce costs by reaching greater economies of scale in all aspects of the vehicle production industry including R&D, purchasing, production, distribution, marketing and sales. Platform consolidation whereby many visibly different models are derived from substantially common underpinnings, supply chain management and modular assembly constitute the most widely adopted management initiatives pursued among vehicle manufacturers in this direction. Additionally, the industry has sought cost-savings through consolidation with mergers and acquisitions to create 'multi-brand constellations' or groups with a portfolio of brands that straddle the major markets of the world. Such rationalisation practices have the potential to generate substantial cost savings in systems of design, component supply, production, and distribution and marketing. As a result, industry consolidation has assumed such a pace that many expect that by 2020 only six global corporations, each one producing around 15 million cars per year, will be competing worldwide (Eggleston *et al.* 1999; Feast 2000).

The current approach adopted by industry players can be seen as indicative of an appreciation that the contemporary business model is under threat. What is less clear is whether these actions represent the last gasp of the technological regime that was framed by and for the automobile industry during the 20th century. Although no one can forecast who will be the key players in an ecologically modernised industry, most within and outside the industry would agree that the technology used in the vehicles of the near future will differ substantially from that currently used. The reason for such conviction is contained in the word 'efficiency'. After more than one hundred years of technical improvements, current automobiles are absurdly inefficient – if efficiency is measured in terms of the conversion of energy (fuel) to the functional purpose of the car (transporting people and items). It is unlikely that these changes in the technology that constitute the car will occur in an industry that is otherwise exactly the same as today. Rather, these technologies in the car will allow, enable and require a change in the terms of competition, and alter the balance of the industry.

Vehicle manufacturers are already aware of the poor efficiency of their cars, and in various ways are working towards major shifts in design and manufacturing technologies. The problem, for most of them, is that they lack the core competences required to produce radically more efficient vehicles, and are struggling to escape from their own embedded business models. Moreover, a shift away from the current all-steel, internal combustion engine car requires automakers fundamentally to reform their systems of production – something not so easy for those who have sunk investments in current car manufacturing technology. That is, there is a deeply entrenched sense of the need to change, but rather less clarity on how to change.

Barriers for the Transformation of the Automobile Industry

Isolating the variables influencing the transformation of the automotive industry has been tried from several scientific disciplines and perspectives. Studies based on evolutionary and quasi-evolutionary economics in constructivist sociology suggest that a 'lock in' situation have been created around the ICE technology (Kemp 1994; Schot *et al.* 1994). The socio-technical context of the modern automobile is embedded in a self-reinforcing system of rules and beliefs of design and engineering practices, characterising what Nelson and Winter (1977) called a *technological regime*.

Orsato (2001; 2004) analysed the socio-technical context of the automobile from a multi-disciplinary perspective and identified seven factors fostering or inhibiting the industry to develop environmentally sound strategies and practices. These are: (i) organisational commitments, competences and constraints, (ii) market demand and patterns of utilisation, (iii) environmental policies and programmes, (iv) competitive forces and collaboration (v) industrial ecology conditions, (vi) positioning of related businesses, and (vii) interest groups and organisations. These are the main influences in a process that can eventually result in changes in the automobile field. However, the factors should not be seen as independent entities. They are immersed in what Orsato and Clegg (1999) termed 'the circuits of political ecology' – the terrain political and strategic actions in which the environmental strategies and practices are embedded. From such perspective, transforming the automobile industry requires a redefinition of its *circuits of political ecology*.

At the organisational level, while not seeking to deride or belittle the very real progress made by global vehicle manufacturers, it is hard to escape the conclusion that these companies are to some extent trapped within their own paradigm (Niewenhuis & Wells, 1997; 2003). Our contention is that a vital missing ingredient is the *business model* that underpins 'normal' practice within the car industry. In our view, there is an intimate causal relationship between the characteristics of product design, the manufacturing processes used to create those products, and the consumption patterns that result. Surrounding and reinforcing these characteristics, the pervading business models in the automotive industry consist of a set of assumptions, practices and norms that define and constrain what is 'possible'. Thus far, most studies have concerned with process, and to a lesser extent with product design, in a multiple organisation context. However, in order to achieve industrial transformation at an aggregate level there is a need for it to be achieved at a business level, either by new entrants or by existing businesses.

The Micro Factory Retailing Approach for Industrial Transformation

The concept of Micro Factory Retailing (MFR) is in essence a business model for the automotive industry in a distributed economy: in this sense it is an attempt to define a business model that allows the transition to be made from the current condition to some (more sustainable) future.. The MFR concept is <u>not</u> an account of an existing business. It is an idealisation, a vision, a view of what might be rather than what is, a hypothesis that could be tested by the tools of IT or worked towards from a 'backcasting' perspective. MFR is an attempt to provide an individual understanding of how a specific industry could try to meet the many and varied demands of sustainability. As such, MFR represents a radical reshaping of the relationships between product technology, process technology, business organisation, and the purchase and use of cars.

If new patterns of production and consumption are to emerge, MFR might be one means of achieving these new patterns. Despite these comments, the MFR concept is grounded in contemporary reality, it is based upon the reality that parts of the MFR concept are in evidence in the industry today – albeit not in one single place. In this respect the MFR concept seeks to identify a business model that can transform the automotive industry today.

Thus far, eco-modernisation in the automotive industry has foundered on being unable to compete in economic terms with the existing vehicle manufacturers and their prevailing business models: there is therefore a need to redefine the terms of competition, to find a business model wherein eco-modernisation can flourish. This transformative business model needs to embrace several aspects. These may include a radical (and more sustainable) product technology that is less polluting, less energy intensive, longer product lifetimes and so forth. In turn there will be a radical manufacturing technology and strategy with reduced environmental burdens and no or reduced tendency to over-supply. New ways of reaching customers will be needed, alongside new ways for people to own and use vehicles to allow greater overall efficiency in vehicle use. The key is for the innovative business model to allow market entry, to overcome existing barriers erected by the contemporary industry and its surrounding technological regime.

Micro factory retailing refutes the logic of matching the high-volume, low unit cost approach of traditional manufacturing and distribution by placing small factories within the markets they serve and so eliminates the distinction between production and retailing (see Wells and Nieuwenhuis, 2000). For example, rather than having one large plant producing 250,000 cars per annum (an average break-even point in traditional car manufacturing) the MFR approach would involve 50 plants, each assembling 5,000 cars per annum (i.e. 250,000 in total) and distributed spatially to match concentrations in population. Importantly this approach makes feasible alternative materials and design concepts that are only viable at 'low volume', and which in many ways allow significant improvements in the industrial ecology of the automobile, but which in traditional business model thinking are not economically viable at 'high volume'. It does so through the mechanism of multiple low volumes generating economies of scale in different ways to the traditional centralised factory. There would be no separate distribution channels or sales outlets: the factory is also the sales, maintenance, service and repair location. Powertrain components and other generic items could be centrally produced in conveniently located highly automated facilities for distribution to the decentralised assembly plants, thus allowing small scale assemblers to benefit from externalised economies of scale.

The MFR concept is not just normal car manufacturing on a small scale, it necessarily involves a radically different product technology and body production process, as the case of TH!NK, in the next section, will make it clear. This was a vehicle built on a folded steel platform onto which is fixed an aluminium body frame, which holds thermoplastic outer panels. Virtually any type of non-steel unitary body technology is suitable for this type of low volume, modular, low investment devolved assembly. Despite this, the idea of factory retailing itself is not entirely new to the automotive industry and there are parallel lessons to be learned from other sectors (such as steel mini-mills, specialty chemicals and micro-breweries that have already experienced some aspects of MFR in action (see: Johanasson & Holapa, 2003). In other sectors, such as computers (see for example Dell Computers) consumers deal direct with the factory, a practice likely to become more prevalent with Internet shopping.

The combined fixed cost of traditional manufacturing and distribution, including the franchised dealer network, is indeed substantial and represents a formidable barrier to entry or to change. Compared with this, the fixed costs for MFR are probably an order of magnitude lower. Perhaps more important than the simple investment cost comparison are the many strategic possibilities which flow from MFR (Wells, 2001a) that collectively create the strategic space to redefine the business model and thereby obviate or negate the barriers to transformation.

Before we provide some empirical examples of MFR (next section), we emphasise that we make no claims here that our concept of Micro Factory Retailing (MFR) is 'the' answer i.e.: that it will make the automotive industry ecologically and economically sustainable. Indeed, the logical conclusion of our analysis that economic activity needs to be embedded in locality and context means that there can be no prescriptive, generic solution of the type purveyed by the business gurus to be found on the shelves of airport bookshops around the world. Diversity means just that, a multiplicity of solutions that might all co-exist in time and possibly space. Moreover, our understanding of the significance of organisational fields is such that there are huge impediments to any process of change that might lead from the automotive industry as currently constituted towards something like the vision we have for MFR. An interesting issue, though one that cannot be explored here, is whether the demise of the existing automotive industry is inevitable, that the alternative structures envisaged under the MFR concept will triumph purely because of economic (competitive) superiority over existing business. However, in order to give some illustration of the ways in which the automotive industry could be transformed through a re-design based on industrial ecology we here outline the basic concept of MFR – though other accounts could also be consulted (Wells and Nieuwenhuis, 2003)

Empirical Examples of MFR

Research into the MFR concept has identified several instances where the approach, or parts thereof, have been tried. The various examples illustrate one or more aspects of transformative business models that challenge the existing set of assumptions and norms. It is interesting to note that thus far the larger suppliers to the automotive industry, be they materials companies or component suppliers, have not attempted direct involvement – perhaps because of fear that they would not like to appear as competitors to their customers, the vehicle manufacturers. Rather, most of the examples listed briefly below come from those who are outside the industry or on its periphery in various ways. One example is presented in a little more detail, but are several ways of thinking about product technology, manufacturing process, industrial inter-linkages, scale, and business models that go beyond 'fire and forget' production.

TH!INK: radical innovations in manufacturing

One version or approach was the TH!NK[1]. This example illustrates new product and process technology, and new ways of reaching customers while foregoing the use of franchised dealerships. That is, the factory with a low break-even point, is also the point of sale. The basic design concept was a two-seat city battery electric vehicle with a thermoplastic body for urban commuters and utilities (Wells and Nieuwenhuis, 1999). The TH!NK employed a lower frame constructed from 90% high strength steel cut, folded and welded rather than pressed into shape – the design for which was developed in co-operation with British Steel Automotive Engineering Group. Normal steel pressings would have required large investments in tooling. Mounted onto the lower frame was an upper frame constructed from aluminium extrusions, seam welded at the joints - this time Norsk Hydro provided useful expertise. The thermoplastic body was moulded in one operation, with separate mouldings for the doors,

[1] For a detailed account of the evolution of the TH!NK enterprise, see Chapter 10 of Orsato (2001b).

roof and a few smaller parts, and was non-structural. The factory in Norway had a design capacity of 5,000 units per annum. The wider business plan included the use of internet sales and mobile service delivery to obviate the need for dealerships. Furthermore, the intention was to supply potential new markets such as California by locating a 'cloned' factory in the market.

Ridek: Sharing vehicle parts

This example illustrates the ways in which an innovative product design can also liberate an innovative approach to vehicle ownership and use. It does not illustrate innovative manufacturing techniques, but the original concept was designed around the need to use large and heavy battery packs for a zero emissions vehicle. The example highlighted here is that embodied in the Ridek concept (Wells, 2003b). The Ridek consists of two parts: a motorised deck (or 'Modek') that combines the chassis with the powertrain in one integral unit; and a self-contained body module (or 'Ridon') that is mounted onto the motorised deck via four fixing points. Under the proposed business model only the Ridon would be purchased and owned by the consumer. The Modek would be owned by the municipal authority, which would have to retain sufficient numbers to allow Modeks to be exchanged as required. Modeks would then be rented or leased out to consumers, but could be serviced, repaired, maintained or upgraded at a central urban facility.

MDI Air Car: a new business model for card design, production and distribution

This particular business idea provides a good illustration of an attempt to combine in one innovative package a new approach to vehicle design, vehicle production, and exploitation of the market with a rapid approach tomarket entry and expansion through franchising of production. Motor Development International (MDI) is the company formed to bring to market the ideas of the inventor of the compressed air engine, Guy Negre (Wells, 2002). The technical concept and the business plan have generated much controversy in the automotive industry, and doubts over both remain.

However, the case is reported here as indicative of a different means of combining product technology and business model. In this vehicle, compressed air is held in a suitable canister. As such, compressed air represents stored energy. The compressed air is then fed into a cylinder and allowed to expand, and in so doing the expansion provides the motive force to push a piston and hence turn the engine. There is no combustion, so there are no emissions at the point of use other than air- though of course overall emissions performance depends upon the energy source used to compress the air. A useful attribute of the technology is that any sort of dedicated infrastructure would not be technically difficult or expensive to install – air refilling points could easily be added to existing petrol stations for example. Simple air compressors could be run from domestic electricity and re-charge the cylinders overnight. The detailed design of The Air Car is more complex than the above suggests, for example it involves an innovative articulated connecting rod to allow the piston to be positioned at top dead centre for a longer duration in the cycle than is normally the case with an internal combustion engine. The engine develops maximum power at 3,500 rpm and maximum torque at just 800-1,300 rpm. The slow speed and low temperature of operation (air in the cylinder head reaches 400 C maximum) mean than vegetable oil is sufficient for lubrication, and the oil will last up to 50,000 km.

The car is positioned and performs rather like a battery electric vehicle without the weight and cost penalty of high performance batteries. Compared with contemporary petrol and diesel cars the range, top speed and acceleration are limited. An interesting by-product of the technology is that the exhaust air is at minus 15 Celcius, so air conditioning for the cabin is easy to obtain.

The engine concept has various non-automotive applications. However, MDI have designed a vehicle structure within which the engine and tanks can be placed. The vehicle is available in four basic body styles that reflect the urban / commercial vehicle focus of the product: family car; van; taxi; and pick-up.

However, of equal interest is the business plan developed by MDI. With many innovators, the core problem is usually lack of investment resources allied to the need to break the hold of the existing market leaders. MDI is no exception, but rather than seek to persuade an existing vehicle manufacturer to take up the technology, MDI have tried a quite different approach. The core of the MDI approach is to grant licences to third parties that in effect take on an MDI franchise for a defined territory in return for the investment needed to create the factory to serve that territory. MDI has designed a standardised or modular factory, and claims that 50 factories have already been allocated in various locations around the world. In addition, the standardised factory includes office space and a showroom, because in the MDI concept the point of manufacturing is also the point of retail and service / maintenance delivery. A prototype factory is claimed to exist in Nice. The factory therefore includes 4,200 m^2 of workshop space; 500 m^2 of offices; and 300 m^2 of showroom space. On a single shift, with 70 workers, the factory is expected to produce about 2,000 vehicles per annum. In terms of operations, the factory would manufacture and assemble engines, car parts, the chassis, and undertake final assembly. The large plastic body panels would be manufactured at the factory as well. Of course, in addition the factory would undertake promotion and sales, and distribution, sale of spare parts, repairs and service within the zone allocated to them.

The MFR Approach as a *Business Model* to achieve Industrial Transformation

It is worthwhile to consider how far this re-thinking of a major industry fundamentally changes the terms of comparison and performance, in business, social and environmental terms. These issues are treated in several themes below.

Customers, brands and market success

In order to be sustainable a business must be commercially viable, and the way to achieve this is to deliver superior customer satisfaction than rival approaches. A key problem for new market entrants, and one that is not entirely resolved by the MFR concept, is that of brand value. Particularly in large, complex and expensive products such as cars it is the case that consumers tend to be risk averse. Of course new brands have been introduced into the market over recent years by the existing vehicle manufacturers, but at great cost and over a long period of time. The MFR concept may allow some of this risk to be reduced because customers do not necessarily have to buy the product, they might well just buy the mobility service. However, the MFR business model offers a mechanism to deliver superior customer satisfaction in many different ways if sufficient credibility can be established. For example, the consumer will benefit from a reduction in depreciation of the vehicle (reflected as lower lease rates), because of reduced over-supply.. One interesting aspect is that customers can visit the plant, can meet the workers on the production floor who will make their car, and can thereby have an affinity with the product (a practice already used to sell prestige vehicles in Europe). The factory gains valuable market data direct from customers, with insights into customer life-styles, aspirations and mobility needs. In turn this might help shape new product development, because the factory has daily dealings with those buying, servicing and repairing their cars: even modifications to the production process can be instituted quickly and cheaply. The inherent production flexibility and geographic proximity of MFR is the practical basis upon which new levels of customer care can be built. MFR makes possible flexible response, shorter lead times, and late configuration that in turn yield shorter times to market, and quick responses to customer orders.

Sustainable growth strategies

Existing industry grows by producing more and selling more. This in itself is not sustainable, while the actual growth patterns are severely disruptive. Investments with a MFR framework in assembly capacity can be relatively small-scale and incremental, either by adding (subtracting) more units or by the expansion (contraction) of existing units - and thereby supply can expand or contract in line with the market. A chronic problem with industries that have sought ever-increasing economies of scale is large fluctuations in demand relative to supply. Each additional capacity increment or new plant is very large, a step-change in supply, so the industry comes to be characterised by poor capacity utilisation and low margins. Conversely, each MFR unit would have an investment cost well below that of a traditional manufacturing plant – although the cumulative investment cost for the same production capacity may be higher. The incremental expansion of capacity can also have a geographic component in that new plants can be added to develop new market territories. The environmental benefits or the economic benefits of this sort of 'smoothing' are by no means proven, but are at least suggestive and worthy of further detailed research.

The Social Value of MFR

One potential avenue for theoretical development is to bring in the concepts to be found in the debate on the decentralised economy and on the phenomena of 're-localisation'. In particular, the social value of production and work is of importance as an oft-neglected aspect of sustainability. The work on eco-industrial parks represents one (environmental) basis for understanding the character of localisation. Our first starting point for this analysis is that of Schumacher (1973), and that quite simply, 'small is beautiful'. By changing spatial scale it is possible to create wealth, useful products and 'rewarding' work to the community in which it is based – a goal that has value in its own right (Shuman, 1998).

With this combined product-service function and social applicability, the MFR factory becomes the location for repair, spare parts, in-use modification (e.g. external panel refresh, power-train upgrades, refitting of interior trim) that allows the manufacturer to benefit directly from profitable aftermarket activities. The factory becomes the centre for trade-ins, used vehicle sales, and End of Life Vehicle recycling and hence becomes the embodiment of product stewardship within the local community.

The MFR concept has potential to liberate communities and meet their social and political objectives by creating local employment and wealth creation in high-value manufacturing activities, countering the disenfranchising impacts of globalisation. Those purchasing the product or service would know that there would be direct local economic benefits and, equally, there would be fewer concerns over e.g. exploited labour in far-off locations. The MFR concept further embodies the growing desire to increase the use of skilled labour and reduce fixed investment in order to reduce cost, increase flexibility and increase social cohesion. Given that sustainability does not and can not mean the ossification of social or economic structures, it is incumbent upon those advocating a different future to consider the adaptability of the business solutions they propose: adaptability is a key facet of the MFR approach. In the longer term the business model assumes a transition from pure manufacture of new product into a greater reliance on service, support, re-manufacture, etc. and this offers a means to escape the 'production growth equals business growth' trap.

Transitions for Emerging Economies

One of the initial stimuli to the work undertaken in industrial ecology was the basic concern that it would be impossible for the planet to support a standard of material consumption attained by highly industrialized countries if the emerging economies attained the same level. In other words, emerging economies desperately need 'development', but the terms by which this is achieved must be different – this is the essential message of the Bruntland Report after all. In addition, emerging economies tend to suffer from chronic under-capitalisation, high levels of national debt, and surplus labour. While some materials may be abundent, these economies often lack local processing capabilities and export only the raw material: there is insufficient local added value. The MFR approach makes some contribution to these issues. For example, the approach is conducive to the creation of products that are appropriate to the locality. Of course it is debatable whether different places have different needs in terms of cars and mobility, but a cursory glance at the cities of the world would suggest that they do. Furthermore, the reduced capital requirements and high labour content implied is ideal for the structural conditions in many emerging economies, while simultaneously providing for a substitution of expensive imports.

The Environmental Footprint of MFR

In any industry or activity there is a choice to be made between concentrating or dispersing that activity, and which is 'better' for the environment. With fewer, larger plants there are various efficiencies (equivalent to economies of scale) in processes that will mean lower per-unit burdens in terms of e.g. energy consumption, water pollution, etc. However, a large facility can also mean that for the locality in which it is placed there are very real environmental consequences both with normal operations and with catastrophic events.

The environmental advantages of MFR are slightly different to this debate. For example, compared with traditional car manufacturing, the MFR approach makes viable low-volume production. This type of production often utilises technologies other than the all-steel body, pressed, welded and painted. Therefore the MFR approach enables the traditional paint-shop, one of the environmental 'hot-spots' in car manufacturing, to be abandoned. Other advantages might follow. The MFR plant does not require a large, flat dedicated site with extensive support services. A modern car plant occupies several square kilometres of land. Compared with this, MFR requires a classic 'light industrial' facility and could even be used in 'brownfield' sites needing industrial regeneration.

Another interesting aspect is that the factory can undergo a transition over time from an essentially new car production focus, to one more involved in service and repair. That is, the factory does not depend absolutely on the continued sale of new cars. This helps to mitigate the tendency to over-production with all manner of associated environmental and market benefits. The environmental cost of over-production is rarely addressed by environment-related studies, but we believe it to be crucial in the long term. Finally, the MFR can work as a point of collection of end-of-life vehicles, with the option to become a dismantling facility. This can certainly facilitate reuse and recycling of materials.

Concluding Remarks

In this article we not only analyse why the current system of production and distribution of automobiles is unsustainable but also presented an alternative for such paradigm. The MFR was introduced as an ideal typology. By doing so our 'ideal model' can be used as a basis for the evaluation of existing and future alternatives that combine environmental demands with those of business and society. Our experience in the industry taught us that the environmentally-sound processes and products will not become common practice unless they are anchored in a sustainable business model. Although we believe the MFR provides exactly this, we contend that this article is just the opening of a dialogue for advancing research and practice in this area.

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Section D: Technologies for Sustainability Transformation

Green Technology Foresight as Instrument in Governance for Sustainability

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There is increasing focus on foresight exercises as a tool in public governance of research and industrial innovation systems. Technology foresight has in recent years been carried out at the European level as well as in many individual countries e.g. Austria, France, UK, The Netherlands, Greece, and the Czech Republic. Technology foresight can be defined as systematic analysis and discussion about possible technology futures. The activities are in many cases set up as an input to research and technology policy and prioritisation, often with close connections to industrial policy and innovation policy. Apart from governmental institutions, innovation and engineering supporting institutions e.g. associations of engineers in Germany, Sweden, and Denmark have engaged in establishing technology foresight activities. Also people in the fields of technology studies and technology assessment are discussing technology foresight at present.

Green technology foresight (GTF), or environmentally oriented technology foresight, has occurred as part of this renewed and extended focus on technology foresight. The environmental and climate problems are widely acknowledged as serious problems facing the world today both locally and globally. Environment issues and thoughts about sustainability are if not high on, then at least visible, on the agenda in society in general. They have become part of the mainstream discussions. This has created a new area of relevance and legitimacy for technoscientific development and research and new opportunities and markets for environment technology are gaining importance. An integration of science and technology policy with environment policy seems more relevant and obvious than earlier. These things are reflected in the appearance of green technology foresight and also in the inclusion to some extent of environment aspects in more general technology foresight activities. Special methods of green technology foresight have been developed, as many normal technology foresight approaches are not suitable for dealing with environmental issues.

The foresight exercises usually happen in interaction with different actors e.g. from industries, science areas, and public governance and planning. The activities contribute to coordination and integration of expectations, knowledge and perspectives of the different areas. Thus foresight is a multi-actor activity that supports network developments across established institutional and sectorial borders. Green technology foresight can be seen as one of the important new instruments in the governance of the transformation of innovation and industry towards environmental sustainability. The chapter describes the character of green technology foresight and discusses critically the connections between technology foresight and environment. The description of green technology foresight is given primarily through presentation of examples of concrete projects. They are analysed with respect to: 1) the method employed, 2) the actors and organisations involved, including the embedment of the projects institutionally and in policy developments. The examples of green technology foresight are these:

1. 81 options – A Dutch Green Technology Foresight
2. The Danish Green Technology Foresight
3. Life cycle assessment and technology foresight
4. Precautionary principle and technology foresight

The main argument of the chapter is that green technology foresight can be a fruitful tool in environmentally oriented research and technology policy, but that technology deterministic understanding of innovation is still quite dominating in the normal foresight methods and hence alternative and specialised methods designs than these are needed. As an example of problem-oriented technology foresight, green technology foresight might be a useful element in a transformation of the innovation systems to sustainability as the experiences about integration of environment and technology development experiences from green technology foresight can be employed more generally in science and technology planning and discussion. When this is said, it shall also be emphasized that there still are only very few examples of actual green technology foresight exercises. There is not basis for saying that green technology foresight in general has so far had more than limited influence on environment policy, technology policy, science policy or the integration of these.

The perspective of the chapter builds on social studies of science, technology and society dynamics (STS), on governance studies, and on studies of the connections between environment problems and innovation. Before presentation of the specific approaches of green technology foresight, the chapter contains firstly an elaboration on the background for technology foresight, secondly a perspective on technology development and environment, and thirdly a brief description of environment issues in general technology foresight projects.

The chapter primarily describes green technology foresight as it appears in connection with public policy and planning processes at a central national or societal level. It does not deal with strategy processes internally in e.g. companies, research institutions etc. The chapter only considers activities, which are explicitly considered as technology foresight with focus on environmental/green issues. It does not claim to cover the huge amount of future-oriented discussions, scenario analyses, 'backcasting' etc. in one way or the other dealing with environment/sustainability and technology development. Neither does the chapter give a complete picture of strategic planning processes on environment and technology even though it discusses the role of green technology foresight in connection with planning and policy processes on environment, technology and science. Green technology foresight is but one of many ways to do strategy and policy processes on technology and environment.

Foresight and governance in a change-oriented society

The focus at technology foresight at present goes hand in hand with the tendency of an increasingly change-oriented culture (as pointed out by e.g. Giddens 1998). Contested technological futures are a central element in present time's policy discussions, agenda settings and power struggles (Brown et.al. 2001). Expectations and promises about the future play an increasingly significant role in science and technology development activities both at a macro, meso and micro level i.e. both at the levels of policy and planning, of industrial sectors and research programmes and of experiments and laboratory work (van Lente 1993, van Lente & Rip 1998). Generative visions are thus constructed and developed also by scientists and engineers (Borup 2001). At the same time the understanding of science and knowledge is under significant change. Science and knowledge are to an increasing extent considered strategic issues and objects of management and prioritisation. Knowledge production is by many considered the central driver of development and economy. This is captured in the term knowledge society. The relevance of science and scientific knowledge is not given by science internal assessment only. Science's new 'social contract' with society is under development and it is a challenge to develop knowledge that is socially robust (Gibbons 1999, Nowotny et.al. 2001). In this situation it is not surprising that technology foresight as a systematic tool for dealing with the future of not least research and science enjoys relatively high attention.

The significance of technology foresight is related also to the strong technology-orientation in general in society. Technological development and innovation are supported and encouraged in a multitude of ways. They are considered an important driving force for growth and societal development in general. When looking for solutions to the problems in the society of today, eyes are often turned in direction of technoscience and the promises of new technology. This technology deterministic understanding is reflected in technology foresight studies. The weight is predominately on technology push and science push issues and not on demand-pull or problem-oriented understandings. Technology foresight studies thus usually focus on the positive promises and potentials of new technologies.

Not least the climate and environmental problems have to some extent challenged the technology optimism and an un-reflected belief in future technology. Recent discussions on technology foresight have to a higher degree considered the complexity of technology development and its' dependency on many diverse factors. The character of dynamic co-evolution between many actors and the mutual integration of social and technological aspects are considered (e.g. Rip 2002). Renn (2002) points out five central characteristics of foresight:

- Foresight is based on the philosophy that future developments are contingent on human actions and decisions; this is why foresight is not a process of forecasting the future but rather an attempt to explore the space for human actions and interventions to shape the future
- Foresight is aimed at producing orientations rather than predictions; it provides guidance to all actors and reduces uncertainty
- Foresight includes multiple perspectives, multiple actors and multiple disciplines on different levels of governance
- Foresight is focused on opportunities and risks alike
- Foresight emphasis the interrelations between the technological, economic, social, political and cultural sector of society

In practice, there is however still focus on approaches that primarily include scientific and technological experts for example through expert-oriented questionnaires ('delphi studies') and expert panels. The 'delphi study' approach has to some degree been paradigmatic for technology foresight activities. In Europe, it is not least the

German and the British technology foresights employing the delphi approach that have been a common reference point for design of foresight projects.

Technology foresight and other of the 'new' governance approaches are governance in and by networks of actors. They focus on interaction and coordination between actors instead of having a hierarchical view on governance and they emphasise the importance of decentralised activities and the interplay between centralised and decentralised steering. As it is the point in the recent years' governance literature, directions and strategies for innovation and technology development occur not as a governmental dictate or as autonomous processes detached from governmental influence, but are developed in interaction between governmental authorities and policies and actors in the covered activity areas. This is described as well in governance literature on innovation and research specifically (Hackmann 2001a+b, Fuller 2000, Glynn et.al. 2001, Fèron & Crowley 2002, Goncalves 2003) as in the more general governance literature that often emphasise the connection between forms of governance approaches and the issue of democracy (March & Olsen 1995, Pierre 2000, Hirst 2000, Christiansen 1999). The question is not if there is interaction between government actors and actors relevant for the research areas to be managed, but which actor groups and networks are included in the processes, and which are excluded. Secondly, it is a question how, in which interaction processes and with which weight the different actors are represented and involved in the processes.

Technology foresight must however be understood primarily as a practical, pragmatic activity. The methods and approaches are not developed and fully analysed within an academic research perspective. There is a lack of systematic and independent analyses of the impact of technology foresight. The impact is clearly smaller than and not as thorough as promoters of foresight will say, when talking about the single technology foresight project. A study of the influence of technology foresight as a science and research policy means concludes that there is no or only very little effect on values and practice in academic research. Primarily the effect consists of a shifting and more open attitude towards industry (Henkel 2000). Other studies find that there can be important impacts from foresight, however very dependent of institutional relations in connection with the foresight (van der Meulen 1999; van der Meulen & Löhnberg 2001). Especially it is concluded that foresight in the Netherlands has had important impact on research in sustainable technology as well as in environmentally oriented technology policy. In some circles of environmental policy makers it raised awareness that as part of the environmental policy a technology policy is needed. While the impact is seldom significant concerning the single foresight processes, technology foresight might gain importance if it becomes a widespread activity and a normal tool in policy, planning and strategy processes in connection with technology. On four contemporary and partly overlapping foresight processes van der Meulen concludes that:

> "The interesting point however is that at the system level a new balance has been constructed. The four foresight processes together create a new balance of future oriented strategy development which includes different perspectives and interests." (van der Meulen 1999, p. 20)

Technology development and environment

In discussion of green technology foresight, it is relevant to draw on the perspective of the well-known classification of technologies in relation to environment issues:

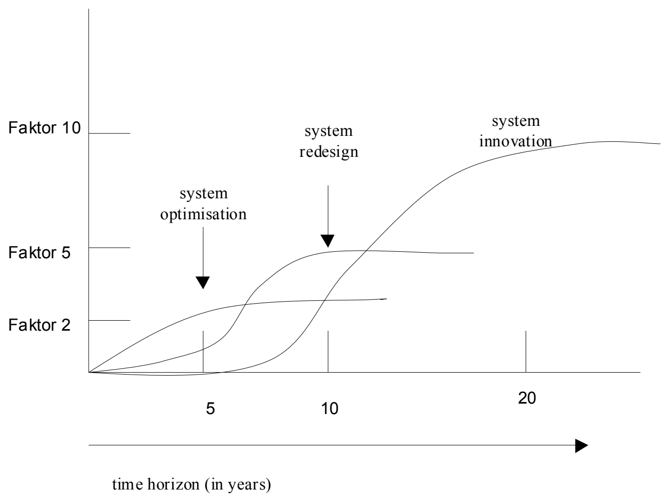
1. End-of-pipe and add-on solutions
2. Cleaner technology and integrated solutions
3. System changes for sustainability

The list can to some extent be seen as a historical development of environment technologies where end-of-pipe solutions were the first way of dealing with pollution and environment problems, then first cleaning technologies and later integrated solutions and cleaner production technologies appeared. And where sociotechnical system changes now are the 'environment technology' that shall be developed. However, there will still be a need for new cleaning technologies also in the future, and the third point on the list shall also be seen as a quality characteristics or a goal to employ as it points to a lack in many technology development activities. There are two dimensions in this: the system dimension and the value dimension. Firstly, the system changes indicate that changes at the level of the socio-technical systems, and not just in the single technological artefact or product, is needed if environmental sustainability shall be pursued. Approaches that include technology use and consumption patterns as well as institutional, organisational and market aspects are needed in order to obtain the radical reductions in resource and material consumption and in emissions that are required if sustainability shall be reached. This is often illustrated with figures like the one below that indicates that radical system innovations (and a factor 10 reduction rather than factor 5) are needed.

System changes for sustainability have to do with practices and norms within innovation and technology development:

> "...severe contradictions between innovation and sustainable development exist. ...we resume that the present practice of industrial innovation still stands in significant contradiction to sustainable development." (Meyer-Krahmer 1998)

> "...most if not all of the environmental problems facing the world ultimately derive from the long-run processes of technological change that began with the first industrial revolution." (Smith 2002)



Three types of changes for environment *(after Vollenbroek et al 1999).*

Thus system changes for sustainability also mean that changes in values and norms in direction of sustainability are a necessary element in connection with the technology development for sustainability. There will be no sustainable society if sustainability and environmentally awareness are not a part of the norm set in most areas and interaction arenas of society, including scientific and innovation oriented institutions.

A draw back of the three-step classification of environment technology is that it is a classification of technologies through the character of their positive environmental impacts, while negative environmental impacts are not in focus. Most technology developments in general are thus not covered and difficult to relate to the categories.

Environment aspects in general technology foresights

The amount of literature on environment and technology foresight is limited. An overview on the subject can be obtained through the proceedings of an OECD workshop on Technology Foresight and Sustainable Development (OECD 1999). This section also builds on a literature study on environment and technology foresights we have done for the Danish Ministry of Environment (Rasmussen et.al. 2003).

The typical picture in the general national technology foresights studies is that environmental issues appear clearly primarily in the two categories: 1) energy and 2) environment technology. To some extent environmental issues are also present in transport categories (energy efficiency and fuels). Energy is, whether defined in terms of a technology area, a sector, or in other terms, in many technology foresight studies among the overall main areas identified under which a number of sub-sectors and sub-technology areas are clustered. Typically there are between 4 and 15 of these main areas in a general national technology foresight. The sub areas within energy are for example energy savings technologies, energy production systems, renewable energy technology, fossil fuel clean technologies, and energy transport and storage. Environment aspects e.g. climate problems, resource consumption and efficiency, are a very central and explicit element in most parts of the energy main area.

Environmental technology categories have compared to energy not been among the typical overall main areas in the general technology foresight studies, but are found as smaller sub-areas subordinated other categories. Environment technology usually means cleaning technology and pollution and waste treatment technology in the technology foresight studies. Also environment monitoring and control technologies appear in this category.

There are exceptions of this general picture, for example in the Austrian technology foresight where 1) clean production and 2) biological (organic) food are among the seven overall areas in the technology and research oriented delphi study (ITA 1998). Environmental futures scenarios has been carried out in connection with recent rounds of the UK foresight programme (Eames & Skea 2002). Environment and Clean Production Technologies is one of the six key technology sectors selected in the European 'Futures Project', which builds on the various national technology foresight studies and has sustainable development as a priority concern (Cahill et.al. 1999). The 'high-ranked technologies for Europe' within this key sector and the energy key sector from this study are shown in the box. It is also found in this study, that examples of environment technologies and especially clean technologies can still be found within a number of sub-areas e.g. biodegradable plastic and carbondioxide fixation technologies within the area of material technology (the latter also within the biotech – agro food sector).

In a long range of other categories than energy and environment technology in the general technology foresight studies, environment aspects of future technologies are not or only to a very limited extent present. Environmental aspects are thus only dealt with in a minority of the areas and sub-areas covered, not because the potential future technologies are not connected with environment issues, changes in resource consumptions etc. but because technology foresights and their methods do not focus on this issue.

The Futures Project: Technology Map (Cahill et.al. 1999) High-ranked technologies for Europe in two main sectors Environmental and Clean Technologies and Energy	
Environmental and Clean Technologies	Recycling Separation New energy sources Solar cells Energy saving Global management of environment Clean production
Energy	Nuclear energy Fossil fuel clean technologies Renewable energy technologies Energy transport and storage Rational use of energy

Despite the fact that environment aspects are only dealt with in a minority of areas in the general technology foresight studies, the environmental dimension is usually explicitly present at the value level in the technology foresight studies and in the overall picture given of the relevance and legitimation of research and innovation. Sustainable development is generally viewed as a key future need to which science and technology should be directed (Fukasaku 1999). However, the connection from sustainability as overall value to practical method is not elaborated.

Some examples of environment-related issues identified in the different general technology foresight studies are listed below. The examples are from the Czech Republic foresight 2002 which as one of the cross cutting 'thematic panels' had an environment panel, from the classical delphi survey in UK 1995, and from the French 'critical technologies study' 1996 (the latter is shown in the appendix). Of course a list of issues is often a simplification and does not give the full picture of environmental aspects in the technology foresight studies. However in many cases, not least in the studies building primarily on the delphi method, the description of the individual technology or area is very brief. It is not unusual that a future technology is described through one sentence only, the 'delphi statement'. Some recent delphi surveys have adopted environmental criteria among the other criteria of importance like 'economic growth', 'competitiveness' that are briefly touched upon.

As the lists indicate the weight in the general technology foresight has mostly been on the single technology and on a number of individual changes in the future, treated more or less independently. The perspective is usually most often particularistic rather than systemic. It is also clear from the lists that it is the positive environmental effects of future technology developments that are described, while negative environmental impacts and risks seldom are represented. Important uncertainties are also often absent in the descriptions.

Technology Foresight in the Czech Republic: Thematic Panel Environment
(Ministry of Education, Youth and Sports of the CR 2002)

Expected trends in the Czech Republic in the next 10 years

- Expanding scientific discussion on key problems and methodology of their solution
- More attention will be paid to long-term effects of human activities on man and eco-systems
- Interconnection of environmental science and political agenda for sustainable development
- Concentration of research on the study of interactions between the environment and man and on possible ways of directing this interaction to a sustainable trajectory

Proposed key research directions in order of their importance

1. Technologies for the environment
2. Interaction between man and environment
3. Sustainable transport
4. Protection of natural resources and material flows
5. Sustainable power engineering
6. Environment and health
7. Economic and social context of sustainable development
8. Sustainable agriculture
9. Man and landscape
10. Long-term ecological research – LTER

United Kingdom Technology Foresight – Delphi Survey (Loveridge et.al. 1995)

Selection of environment related delphi statements from 'Top-10 Statements' within different sectors

- Widespread use of separation and membrane technologies and biotechnologies for waste management.
- Widespread use of genetically engineered plants and micro-organisms to control and/or reverse environmental contamination
- Development of an integrated approach to retrofitting existing buildings, using existing techniques and understanding, which improves the energy performance of refurbished buildings by 50%
- Widespread use of highly efficient (>20% improvement on current practice), low emission engines for transport.
- Development of cost-effective refinery processes that meet future requirements for clean transportation fuels
- New conversion/transmission techniques provide viable economic and environmentally acceptable alternative energy sources
- Widespread use of modelling techniques which predict and minimise waste products from an entire facility
- Development of novel and practical catalytic systems for SO_x/NO_x removal
- Widespread use of recycled building materials, composites incorporating synthetic materials such as plastics and alternative forest products, resulting from modified construction concepts and design standards

Part Two: Examples of Green Technology Foresight Projects

The number of specific green technology foresight projects is still very limited. Apart from examples that will be described below, there are however also other interesting activities. Some of the recent projects running currently which are worth keeping an eye on are e.g. The Science Forward Look 2004-2013 in the UK department for Environment, Food and Rural Areas (DEFRA 2003) and the project on Transitions towards sustainable production/consumption systems under the 'Factory of Tomorrow' programme in the Austrian Ministry of Transport, Innovation and Technology (Whitelegg & Weber 2003).

81 Options – A Dutch Environment-oriented Technology Foresight

The first example of an environment-oriented technology foresight study that shall be described here was carried out in the Netherlands in 1996-1997. The objective of this foresight study was "to find handles for policy to stimulate technological systems that are able to raise the environmental efficiency of products, processes and activities" (Weterings et.al. 1997). The study was commissioned by the Dutch Ministry of Housing, Physical Planning and the Environment in connection with attempts to gain a further elaborated understanding of the possibilities technology presents to reduce or to resolve current environmental problems. According to Vollenbroeck et.al. (1999), it was explicitly meant to contribute to re-alignment of technological development with the long-term goal of achieving sustainable development. The study was carried out by TNO, which is a semi-public contract research organisation on applied science, innovation etc. The Central Planning Bureau (part of the Ministry of Economic Affairs) also contributed, primarily on the scenario parts.

The participants in the study process were primarily the project team and other staff members at TNO. A panel of 7 external experts from e.g. universities, DTO (a Sustainable Technological Development programme) and from innovation and technology assessment institutions was established and consulted in some parts of the process. A project-following committee consisted mostly of people from the Dutch ministries, primarily from the Ministry of Housing, Physical Planning and the Environment. In addition, interviews with a number of individual experts on the future technology development were made in the beginning of the process.

The basic design of the study is a technology push – demand pull model of development and innovation, with the environmental perspective integrated in the technology push side. This is reflected in the two main lines of work that were followed:

Technology Push
- Mapping out of the technology developments that could lead to a substantial environmental load over the next 15 to 25 years, or to a considerable reduction in the current environmental problems.

Societal demand pull
- Investigating the main societal driving forces which are decisive for the resulting development

This was spelled out in three main phases in the method:

1. Inventory of potential technological developments
2. Assessment of the environmental relevance of the technological developments on a system level
3. Scenario analysis and analysis of societal driving forces

The inventory primarily built on existing foresight studies and end up with long list of 2,500 technology developments. The title of the final report "81 options – Technology for a sustainable development" refers to that the study from the 2,500 technology developments identifies 81 environmentally relevant technological systems, which could lead to changes (positive or negative) in the environmental efficiency of products, processes, and activities. The 81 technological systems were clustered in five categories: Energy systems, new (raw) material supplies, production systems, information & communication systems, and transport systems. Examples of the identified technological systems are:

- Advanced separation
- Cultivation of biological raw materials
- Coal gasification
- New generation of photovoltaics cells
- Hydrogen for driving vehicles
- Intermodal goods transport
- Domestic communication systems
- Novel protein foods
- Optimization of horticulture behind glass
- Industrial waste as building material

The environment-oriented technology foresight study is significantly different from most traditional technology foresights on a number of issues. Firstly, the inclusion of demand pull aspects, though most emphasis is still on the technology push side. Secondly, it diverges from other studies by the integration of the environmental aspects and by approaching future technologies not only as potential solutions to existing environmental problems, but also as potential sources of new environmental problems.

> "…encouraging technological development is no guarantee of environment improvements. For example, new technology can lead to new forms of pollution. In other words technology implies threats as well as opportunities." (Vollenbroeck, p.83)

> "…we did not approach technology solely as a potential solution to existing environmental problems, but we also took into account any potentially new problems that could result from technological development." (Weterings, p.98)

A limited number of environmental aspects where considered: Utilisation of fossil fuels (including CO_2, SO_X, and NO_X emissions), utilisation of scarce raw materials, emissions to air, water and soil, generation of hazardous and non-hazardous waste. Also space use where considered. In this assessment process also a number of external specialists and generalists were consulted. The environmental aspects of each potential technological system were assessed according to the sphere of application and specific *social function* for which the system is developed. The assessment was made relative to the currently dominant system on this function. It is based on unit of output. Developments in production volume or amount of consumption and behavioural changes were not taken into account. Though this static system comparison might have some important limitations, the system perspective in the assessment of the technological opportunities is also at this point significantly different from the traditional object understanding in technology foresight studies.

The conclusion on this part of the process was that around 60 of the 81 technological systems lead predominantly to improvement in environmental efficiency and 20 had, in addition to positive effects, also adverse effects. The assessment of the environmental future technological systems was often uncertain, difficult and problematic and it was also a conclusion that:

"It is impossible to make an unequivocal assessment of the environmental relevance of all the systems." (ibid p. 3)

The demand pull side of the project consisted of scenario analysis based on three macro-political and economical, global scenarios made by the Central Planning Bureau: 1) Balanced growth: towards a sustainable, multi-polar growth; 2) European Renaissance: new opportunities for Europe; 3) Global Shift: shifting the centre of economic growth to the Pacific Rim. The potential integration and role of the different technological systems in the story lines of the three scenarios were analysed and it was assessed if and how the integration could lead to also more radical innovations in the social functions of society. Changes in social functions and not just less radical redesigns and optimisations of the existing systems were considered needed in the long term if significant environmental improvements shall be obtained. The policy handles identified by comparing the scenarios with the technological systems are these:

1. **Regulatory price measures on fossil fuels** should be established as the price of oil, gas and coal 'is evidently the main obstacle standing in the way of environmentally-efficient technological systems', not only with regard to energy supply innovations but also to innovations in industrial production systems and transport systems.
2. **Supply dynamism** of technology development should be encouraged, e.g. by combined public and private R&D, by facilitating knowledge transfer between companies, or by pursuing a prevention-oriented technology policy
3. **Selective demand articulation** e.g. by government acting as pro-active party on a market or by introducing price measures which selectively lowers the threshold for introducing new systems
4. **Direct governmental control and intervening** in the development of technological systems which could lead to adverse environmental effects

The Dutch environment-oriented technology foresight has been used in policy development in the Netherlands e.g. in connection with the National Environmental Policy Plan III and the research-programme on Economy, Ecology and Technology. While the green technology foresight activities seems to have had important impact on a technology and research-oriented element in the environment policy, there are no indications that it has significantly influenced the general technology policy and science policy or been integrated in these areas.

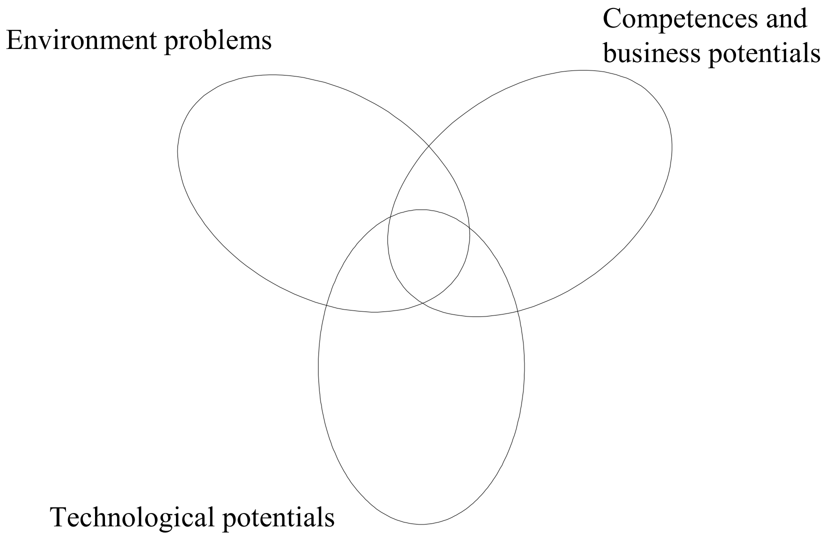
The Danish Green Technology Foresight

The Danish Green Technology Foresight is part of the national technology foresight programme that has been running since the beginning of 2001. The programme was first managed by the Ministry of Trade and Industry and then, after the change of Government in late 2001, by the Ministry of Science, Technology and Innovation. The Green Technology Foresight is one of the first three areas selected for a foresight exercise after the establishment of the programme and the initial definition of the foresight perspective employed. (The other areas are pervasive computing and bio & health technology). The work in the Danish Green Technology Foresight is carried out from early spring 2002 to spring 2003 (www.teknologiskfremsyn.dk, Erhvervsfremmestyrelsen 2001, Cowi 2002 (all in Danish)).

Under the general objective of identifying and debating technologies and scientific breakthroughs and assessing the opportunities and challenges in a Danish perspective, the specific objectives of the green technology foresight are:

1. to map the global environment problems in a 10-20 years perspective, including the aspects of behaviour and consumption that intensify the environmental problems
2. to identify and debate technological and institutional solutions

3. to map competences and potentials in Danish industry and the innovation system with departure in the identified environmental problems, driving forces, and solutions
4. to make recommendations on radical and outstanding environment innovations with business potentials and recommendations on which market and policy initiatives that are needed to support them



The process consists of four steps to a large extent corresponding to the four objectives: 1) The environmental challenge, 2) Technological advances with environmental potentials, 3) Danish competences and business potentials, 4) Integration of the three steps: Challenges for the technological development and definition of 'focus areas'. Most time is used on the last step. Schematically the method can be illustrated by this figure, where point four is represented in the middle.

The foresight is organised as an expert panel process, with five discussion meetings as the central element. There are 18 members of the panel, most of which both have technological, research and managerial background. 6 are industry managers, 6 public researchers, 2 from other innovation system institutions and 2 from environment NGOs. The last 2 members are respectively from a large investment institution and from the Ministry of Environment. The members of the panel are selected by the science ministry's project group, building on recommendation of persons made by e.g. members of the advisory group and scientific background group connected to the Danish technology foresight programme in general, who were also involved in the definition of the green technology foresight and its objectives. The expert panel discussion is supported by a consult group which acts as process consultant and secretariat that prepares presentations, background papers, reports etc. drawing also on the experience from other external experts and existing analyses.

With the many-sided and complex objectives, it is clear that the weighting and the specific integration of them will be decisive for the character of the results of the exercise. The mapping of the environmental problems (step 1) builds on analyses from a number of international organisations: OECD, World Watch Institute, European Environment Agency, World Resources Institute, UNEP, and the European Commission. The identification of technological solutions in step 2 builds among other things on other technology foresights and on interviews with external experts on environment-related technology. This step results in a first list of around 65 potential technological solutions of varying size and form within different areas. From the panel's discussions and prioritisations around one fourth of these were selected for deeper description and analysis.

The competences and potentials of Danish business and industry and of the knowledge and research institutions relevant for the selected technology solutions were mapped and discussed. Market potentials and use forms as well as institutional and regulatory opportunities and constraints were discussed. This also included so-called SWOT analyses (assessments of Strengths, Weaknesses, Opportunities and Threats).

The green technology foresight ends up with the identification and definition of four or five 'focus areas' as recommendations of technology innovations and connected business, production and consumption opportunities that could mean important environmental differences, if pursued. The focus areas can be said to represent important elements in the intersection of the environment problems, the technologies and the competences and business potentials, as indicated on the figure. The focus areas have character of socio-technical systems. They are comprehensive, integrated pictures of production and use patterns with emphasis on the role of technological changes. For example a potential focus area related to transport could be 'integration of public and private transport through traffic information technology and road pricing'. It would not be defined as 'public transport infrastructure' or new vehicles or engine types. A focus area on energy would similarly rather be defined as hybrid renewable energy supply systems rather than biomass waste systems or wind energy technology.

The selected focus areas are:

1. Flexible energy systems with increased wind energy
2. Systematic energy optimisation of buildings
3. More environmentally-friendly agriculture
   a. Precision agriculture
   b. Organic farming
4. Design of green products and material

The descriptions of the focus areas are typically a text of around 6-12 pages each and include sections on the related knowledge and innovation institutions and clusters and on market aspects, incentives, and regulatory elements. The level is not industrial sectors, rather sub-sectors. The same is the case concerning knowledge aspects where the focus is not on scientific areas or disciplines, but on different, more specific sub areas of development and research and the interaction between these.

Scenarios development processes supported the final discussion and selection of the focus areas. For each of the selected areas, four different scenarios (2x2, going along two axes) are presented. The dimensions of the axes are for example 1) technology object - integrated systems; 2) central – de-central solutions; and 3) market/product - regulation.

The results of the green technology foresight process are published in a report in May 2003. The target group is stated to be politicians, other decision-makers and the broad public. Until the publishing of the foresight report, the project is a closed process in the sense that it is not open for broad participation. The communication of the contents to a broader audience is a planned part of the activity. In connection with the public presentation of the report, an open debate conference is held in the parliament building. It is the intention that the green technology foresight shall create a broad political debate in Spring 2003. At first this goal is not reached as only few politicians participate in the conference and the mass media coverage is limited. However, a considerable number of relevant industry representatives attend the conference and the results of the exercise are employed in quite a number of discussions in the rest of 2003 both in industries, in NGOs and in public governance of innovation and research e.g. in the energy area.

It has been an idea in the planning of the Danish Green Technology Foresight, that the exercise shall function as a phase one in a two-phase process, where the first phase is a general study that points out a number of areas that can be analysed in more details in a phase two. Phase two will however not be carried out in the national technology foresight programme in the Ministry of Science, Technology and Innovation but by the Ministry of Environment and other ministries. How integrated the results of the Danish green technology study will be in the innovation policy and prioritisation is too early to say. Through the Phase two carried out by other ministries, the experiences and recommendations can be utilised within the specific areas. There is at the same time a risk that the identified potentials for research and innovation in the green technology foresight by the Phase Two will be left out of the general technology and innovation policy. If that happens, the potentials of integration of environment policy, science policy and technology policy will only partly be exploited.

For the time being two green technology foresight exercises are about to start under the Ministry of Environment: one relatively broad and general on design of environmentally friendly products and materials and the environment challenges and potentials of biotechnology, nanotechnology, and information and communication technology, and one specifically on environmentally-friendly agriculture. Both are to be carried out in 2004 – 2005. Whether the focus areas on energy will continue in a second phase is still an open question.

Summing up on the method structures in the Dutch and the Danish green technology foresight, it can be concluded that there are similarities in goals and methods but there are also important differences:

a) The Dutch foresight has a symmetrical method structure on the analysis of environmental aspects in the sense that both positive and negative impacts are included, while the Danish method only works systematically with the positive potential impacts and looks for solutions to the general environmental problems mapped in the initial phase.

b) The system perspective in the Danish foresight is integrated and multifaceted on the selected focus areas including specially developed scenarios, while the Dutch system perspective appear through a breakdown of the present overall society in a number of societal functions within which each future technological system is compared with the currently dominating system. The scenarios are external to this and are general macro-political scenarios. The main method structure of the Danish foresight does not include other social driving forces than the existing competences and potentials in industry areas and in research and innovation institutions.

c) The time dimension to some extent seems more spelled out in the Dutch project with its distinction between long-term radical changes of systems and shorter-term redesign and optimisation and with its inclusion of possible new environment problems through the changes. The Danish is more focused on the present business potentials and present environmental problems.

d) The Dutch foresight is carried out as a consultancy research project while the Danish is an expert panel discussion process. In both cases there is little emphasis on broader or public participation.

Life cycle assessment and technology foresight

In the last three years we have in our research group carried out projects that combine traditional technology foresight methods with life cycle assessment methods (LCA). The third example on green technology foresight is a project with this hybrid LCA and foresight approach in the wind energy area.

The key element in the methodological approach of life cycle assessment is an identification and analysis of all the different processes included in the entire lifecycle of a product or a technological system, including a careful accounting of the materials and energy flows associated with the processes. The method is primarily used for assessing the environmental impacts of industrial products. There is, however, increasingly focus on life cycle assessment as a tool in strategy, and planning processes, also on long-term issues, in scenario processes etc. (Frankl & Rubik 2000, Pesonen et.al 2000, Christiansen 2001).

LCA and technology foresight methods (like e.g. delphi surveys, brainstorming etc.) are very different and, in some respects, quite opposite. For example technology foresight usually addresses partial elements of the (future) technological systems in the sense of the main technical functionality, while LCA addresses all processes in the different life cycle phases and gives a more comprehensive picture of the actual technological system. LCA is in its traditional form a very detailed method, focusing on certainties and the most precise data available while foresight is more sketchy, process-oriented and at least to some extent trying to deal with the large uncertainties concerning future developments. Some of the typical characteristics are listed in the box. In practice, the differences can be used productively to structure the interaction process of green technology foresight especially designed according to the specific purpose and area.

The two frameworks, typical characteristics

Lifecycle Assessment	Technology Foresight
- Present	- Future, changes
- Products	- Technology
- Lifecycle perspective, processes of different phases	- Functionality, the single technical characteristics
- Comprehensive	- Partial
- Environmental impacts	- Not focus on environment
- Detailed	- Sketches, scenarios, strategies
- Objectified, results	- Interaction processes, actors
- Certainties	- Uncertainties

The green technology foresight project I will mention is entitled 'Environmentally sound design and recycling of windmills'. It is funded by the Energy Research Programme managed by the Danish Energy Agency. It is carried out in collaboration with the Wind Energy Department at Risø National Laboratory. The objectives of the project are, apart from the method development:

- in a long term perspective to analyse the environmental impact of the manufacturing and removal phases of windmills' life cycles
- to make societal recommendations on dismantling, recycling and waste handling of existing and future windmills

The focus on the production/manufacturing and removal phases of the life cycles of the windmills (and not on the important operation phase) is due to the fact that the environmental aspects of the operation phase are already relatively well-described (the main positive impact through green electricity production, the land use aspects, noise etc.)

There are several target groups of the project. The recommendations on the societal level go to among others the public planning authorities. The project contributes to the discussion on LCA guidelines and standards in the wind energy area at international and national level. And it is an input to actors in the energy sector, wind turbine manufacturers and windmills owners/operators on future design and handling of wind farms and windmills. The project has both been reported to the international and Danish wind energy community (Dannemand et.al. 2001, Borup et.al. 2002).

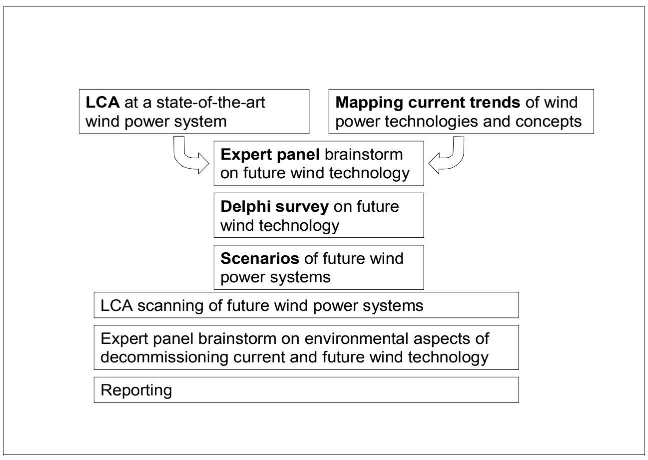
Though there are connections from the project to the national policy level and public authorities, the project is not in the same way as the above described green technology foresights part of the general research and technology policy. It is more a sector-oriented project. However, the life cycle assessment perspectives and the principles of the hybrid method might, with suitable adjustments and changes, be employed in national green technology foresight studies as well.

The different steps in the project's method design are shown in the figure below. All in all the method is quite complex and I will not go into all details here but elaborate briefly on a few points. The initial LCA is a traditional, complete and detailed LCA of present time wind power systems and their environmental impacts. (This is a whole project in itself and in fact this step is building on a separate, parallel LCA project and on existing LCAs on wind power systems).

The first expert panel step is a workshop identifying central elements and driving factors for the development of future windmill technology. The 10 participants in this panel were representatives of public research, wind turbine industry, power grid operators, wind farm operators, LCA consultants and a representative of an environmental NGO.

The delphi-like survey was a questionnaire with 24 statements building on future windmill technology. It was handed out to participants at a large international wind energy conference in Copenhagen 2001. Emphasis in the questionnaire as well as in the expert panel workshop was on technological factors (two third) while one third was on socio-economical and policy/regulatory issues. For each potential future development, the respondents were, in addition to the traditional delphi questions on when (if ever) the change is going to come true, asked about the environmental effects of the change on a scale from highly beneficial to highly harmful.

Phases of the project



The expert panel involved in the workshop on environmental aspects of decommissioning and removal is another one than the first panel. It is in its composition reflecting the end-of-life phase of the windmills. The 11 participants were representatives of consultants and knowledge institutions on dismantling, recycling and waste handling, removal/recovery companies, LCA consultants, and wind turbine manufacturers.

The discussions on the workshop were influenced on the life cycle and environmental considerations earlier in the project. The life cycle scanning elements and the scenarios were relatively simple sketches of different elements of future windmills and windfarms and their environmental aspects. They are both qualitative (e.g. on the future materials of the blades of the windmills) and quantitative (e.g. on the future sizes of windmills, blades and of the wind energy area.) A LCA comparing offshore and onshore windfarms was carried out in this period.

It is likely that the most important results of this green technology foresight occur through the interaction processes with and between the many different actors involved and through the outwards communications of the process during the project. The concrete results in terms of conclusions concerning the environmental aspects of future of wind energy systems and their handling are very diverse in character. Some of the results are e.g.:

- Environmental impacts
  - Windmill blades will constitute an important waste problem if the present development with large fibreglass blades continues (around 2020 it will be very visible in the fibre glass disposal statistics for a country like Denmark)
  - Future blades of carbon fibre constitute a similar problem
  - In future offshore windfarms far from the coast, the cables will constitute an important environmental impact
- Societal role of wind energy technology
  - Wind power can contribute with 10% of the electricity production in Europe at some point between 2011 and 2020
- Windmill concepts
  - Two-bladed flexible windmills will probably never have a radical breakthrough on the market
- Organisational and knowledge development
  - The institutional organisation of future removal phases is uncertain. Three models for the organisation and actor set-up were identified
  - There is a need for knowledge development on some of the recovery and waste handling processes
  - A short cut between the knowledge of dismounting/recycling actors and windmill designers is needed

The conclusion on the integration of the life cycle perspective in technology foresight method is first of all that environmental aspects of future technology and future socio-technical systems can be included with this approach. Not only the positive environmental potentials but also negative environmental aspects are included. Once the life cycle perspective is introduced through the detailed LCA early in the project, it helps maintaining the focus on environmental aspects throughout the project. The life cycle perspective in addition maps out the socio-technical system. Through this it also points to a number of actors and knowledge areas that are relevant to include in the technology foresight processes.

With the integration of life cycle assessment methods there is a risk that the foresight project will become too restricted to the socio-technical landscape of today, including the present institutional set-up, production and consumption patterns etc.

In addition there can be a tendency to focusing on the certainties, not giving enough attention to the uncertain aspects. The specific project design is most fruitful if the LCA elements are seen as parts of a learning process, rather than a 100% objective analysis.

There are similarities between the hybrid LCA-TF approach and the approach of the Dutch green technology foresight not least on the more or less symmetrical inclusion of both positive and negative environmental aspects and on working with demand pull factors. As life cycle assessments are becoming more and more normal in many industrial areas, it is likely that green technology foresight through integration of LCA with TF methods can be done more easily, as it can to a higher degree build on existing reports and data material.

Precautionary principle and technology foresight

A last example of method principle of environment-oriented technology foresight shall be mentioned. It is widely acknowledged that technology development is a central element in many of the most important risk issues facing society. Many efforts are made to deal with, minimize and avoid environmental risks in connection with new technological developments and to handle the high degree of uncertainty that is connected with these. The precautionary principle has been adopted in some policy areas at European level and in a number of national states as a way of dealing with the risks. The definition of the precautionary principle is still discussed both at the political level and at an operational level. Within technology assessment and foresight efforts are done to take the environmental risks, and not only the more certain environment impacts, into consideration (Hellström 2003). In connection with the work in the European STRATA project PRECAUPRI, combination of the precautionary principle with traditional technology foresights approaches is suggested as a way of doing technology foresight and assessment that include the environmental risk aspects (PRECAUPRI work, especially Stirling 2002).

The basic principle of the combination is that the precautionary principle and the technology foresight methods are complementary and opposite and that a combination of them will result in a more balanced perspective. Through this balanced perspective the environmental risks of potential future technologies will be treated adequately. (Another way around: that technology foresight methods can be employed in order to find solutions for risks problems, is an alternative, which is not offered so much attention in this connection.)

Put very briefly, the understanding is that technology foresight approaches usually are optimistic and positive to technology development. They focus on the positive opportunities in new technology and identify, develop and promote the promising expectations. Opposite to this, the precautionary principle is said to be sceptical and critical to new technology. It focuses attention to negative consequences of the technology. The precautionary principle identifies environmental risks etc., which are normally hidden in the technology foresights, and points to policy actions for how to deal with the risks.

"Of course, there are obvious constraints between precaution and foresight discourses. Whereas precaution reflects pessimistic and critical perspectives on technological innovation, foresight embodies more up-beat sentiments. Precaution addresses the restrictive aspects of social ambiguity and the dangers of ignorance. Foresight highlights the creative propensities of social diversity and the positive potentials of incertitude. For all these differences however, both precaution and foresight are concerned with intrinsic indeterminacy, social contingency and path dependency in processes of technological innovation. ... Together, they offer the prospects of more socially responsive technologies." (Stirling 2002, p.25)

A general model for instrumental implementation of precaution in connection with science and innovation is suggested. The model understands the treatment of the risks issues as a social process that takes place at a number of organisational and discursive levels and involves questions of institutional structure and process design. The combination of foresight and precaution is understood as a process between social actors and it is argued that it can lead to more social responsive technologies.

The work on the precautionary principle and technology foresight is at an experimental level. To my knowledge there is not yet carried out full-blown practical experiments with the approach. The approach is criticised for a too simple understanding of technology foresight and especially of the precautionary principle. It has been noted that while it is true that technology foresight is usually technology optimistic, the principle of precaution does not embed a general pessimistic and negative attitude to technology development. It is usually only on a single few specific aspects of the technology, that the precautionary principle is critical. Not on all aspects, and not on all technologies. The quality of the precautionary principle instead consists in its deliberate aspects. It can contribute to a more qualified and reflected view on future technologies. Despite the critique that can be raised against the precaution & foresight approach, it is important that work is done to find ways of including the aspects of environmental risk and the related uncertainties in technology foresight and similar strategy processes.

Concluding remarks

Contrary to the existing tradition of technology foresight in general which is not suitable for integrating environment and sustainability issues in technology policy and development, green technology foresight seems to have a large potential for making a valuable contribution to governance for sustainability. Usually, the method designs of the green technology foresight projects are system-oriented and capable of addressing future technology as integrated developments and solutions, instead of as isolated and partial technical function developments. Instead of technology push/science push aspects only, green technology foresight studies include 'pull' aspects of environment problems and social matters and address the complicated, mutual integration of push and pull aspects. The precautionary & foresight approach might, at the level it is developed so far, be an exception to this picture, however the approach emphasises the important aspects of including environmental risks and uncertainties in foresight activities. In all four examples, there is still large emphasis on technology push. The assumptions and details of this side might be more explicitly reflected. A symmetrical method in the sense that both environmentally negative and positive aspects are systematically considered seems also to be a reasonable requirement to green technology foresight.

While the Dutch green technology foresight activities have contributed to a technology-oriented dimension in the environment policy, the Danish green technology foresight exercise is an element of integration of environment issues in the general technology and innovation policy. However, with the Phase Two still to come in Denmark, the integration in environment policy issues might become at least as significant.

One of the aspects of technology foresight in general that still needs to be described, is the communication of the foresight to other actors. Who are the results and processes communicated to, what do they use it for, and how do the foresight activities relate to other strategy and policy activities. Though not always explicitly accounted for in the material I have used, it seems plausible that the green technology foresight projects, with their integrated and system-oriented perspectives, also can have an important function of contributing to development of new niches and networks of innovation.

The green technology foresights are interesting also for the area of technology foresight in general both at a national and European level. In connection with a more general integration of sustainability perspectives in technology development and innovation systems, the method principles of green technology foresight can play an important role. Moreover, the green technology foresight projects are examples on how technology foresight processes can be designed explicitly according to the specific purpose and target groups in case. Usually in technology foresight the influence on the specific perspective is, apart from the clear perspective of science and technology push, only implicitly reflected in the descriptions of the project designs.

It is a very common method element of technology foresight studies to build on the technology expectations of other technology foresight studies. The technology foresight community is across the single studies growing and maintaining a body of knowledge and technological futures which to some extent has its' own life and is independent of other policy and strategy processes. This might in many cases be an advantage and not a problem (and it is moreover a very normal feature of knowledge production). There is however a risk that this professionalized body of technological futures can gain too much weight and momentum, so that important new, maybe local opportunities are overlooked and the potentials of the diversity of research and technology areas are not used adequately. A similar thing might be the case concerning the environment problems where a limited number of global accounts, outlooks etc. from a limited number of institutions is employed across a large number of studies. Green technology foresights should be careful not only to rely on the global environment problems but also to deal with more local environment problems and with local forms of appearances of the global problems.

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Appendix

Critical environmental technologies in France

Source: Fukasaku 1999, referring to Ministere de l'Industrie (DGSI) 1996: Les 105 Technologies clés pour l'Industrie Francaise a l'Horizon, Paris

Health and environment area
- High yield crops for use as bio-fuels
- Genetic modification of plants
- Decontamination and remediation of polluted soil
- Biological purification of water
- Radioactive waste treatment and disposal
- Final treatment and disposal of harzardous wastes
- Measurement and monitoring of environmental pollution (air, water, solid wastes)
- Modelling the impact of industrial pollution
- Cleaning without using hazardous substances
- Recycling of polymers
- Treatment of urban wastes
- Treatment and quality control of drinking water
- Collection, stocking and compression of urban wastes
- Using 'filières transversales' for waste disposal

Transport area
- Improving the recyclability of cars
- Batteries for electric cars
- Traffic flow control and management system
- Reducing the fuel consumption of motors
- Clean combustion engine
- Reduction of the weight of cars by using lightweight materials
- Reducing noise of airplanes and rapid trains
- Reducing noise of automobiles

Materials
- Intelligent materials
- High temperature resistant materials

Energy
- Biomass conversion
- Clean and safe nuclear energy
- Photovoltaics
-

Housing and infrastructure
- Management of water resources

Production, instruments and measuring
- Intelligent sensors
- Catalysts
- Continous processing in steel
- Membrane separation processes

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Backcasting for Industrial Transformations and System Innovations Towards Sustainability: Relevance for Governance?

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1. Introduction

Radical changes to present production and consumption systems, especially in the developed world, are required to achieve sustainable development. Those changes on a system level are often described as industrial transformations, while terms like system innovations or transitions towards sustainability are also being used. These system changes or transformations require combinations of technological, cultural, social, institutional and organisational changes, while they affect many stakeholders when diffusing into society, and involve complex processes of social change on the long term. Questions have been raised so far about how to identify attractive and desirable system changes (system innovations, industrial transformations or transitions), how to explore these, how to get them started and implemented in practice, about the role of different stakeholder groups and stakeholder co-operation and how do they relate to the issue of governance. According to Quist et al (2002) bringing about system innovations requires *new integrated approaches* that should at least combine:

- The involvement of a broad range of stakeholders and actors from different societal groups including government, companies, public interest groups and knowledge bodies, not only when defining the problem but also when searching for solutions and conditions and developing shared visions.
- Incorporating not only the environmental component of sustainability, but also its economic and social component.
- Taking into account the demand side, consumption and the supply chain focussing on related production and consumption systems

Though these characteristics imply guidelines that give at least some direction, but they definitely do not give the full answer to the questions raised above. Yet backcasting might be an interesting candidate as an approach that meets the characteristics mentioned above and could be used for dealing with the questions mentioned. Backcasting has been proposed and tested in the Netherlands as a promising participatory planning approach to identify and explore such innovations towards sustainability (on a system level), while also aiming at follow-up and implementation in public research, companies, public interest groups and the government. Backcasting can be defined as first creating a desirable (sustainable) future vision or normative scenario, followed by looking back on how this desirable future could be achieved, before defining and planning follow-up activities and developing strategies leading towards that desirable future. While quite some results of participatory backcasting have been reported so far, rather little has been done on comparing different backcasting experiments, on conceptual issues, on the relevance for governance, and how it relates to other recently emerging approaches like transition management and strategic niche management.

This chapter aims to explore how backcasting relates to the issues and questions raised above. It provides an overview of the developments and varieties in backcasting that occurred during several decades. It elaborates how backcasting can be seen as an integrated approach for bringing about sustainability on a system level and describes its key characteristics including the issue of involving stakeholders. It also describes and compares two backcasting experiments and discusses the relationship with other emerging system oriented participatory approaches in sustainability studies. This chapter is structured as follows. Section 2 gives a brief history of backcasting starting with its origin in the 1970s in energy studies and its further elaboration and application for sustainability issues especially in Sweden and the Netherlands. It concludes that participatory backcasting is the most recent and emerging variety. Next, section 3 elaborates upon methodological and theoretical aspects of participatory backcasting. It proposes a general scheme based on different varieties of backcasting developed and tested before. It also deals briefly with some key mechanisms and elements underpinning participatory backcasting. Section 4 and Section 5 present and analyse two participatory backcasting cases from the Netherlands in the area of food production and consumption. Those are derived from the governmental Sustainable Technology Development (STD) Programme and the international spin-off research project 'Strategies towards the Sustainable Household (SusHouse) and deal with how backcasting has been applied and what kind of follow-up and implementation results have been achieved (so far). Finally, section 6 contains conclusions and discussion with respect to backcasting and its broader relevance, while also attention is paid how the approach relates to other approaches like transition management and strategic management and to the relevance for governance.

2. Back-casting: a brief history

This section explores the existing literature analysing different conceptualisations and practices of backcasting, from its early emergence in the 1970s till now, and focusing on sustainability applications. In fact, there seems to be more or less a family of related approaches all using desirable futures or normative scenarios. Interestingly, the history of backcasting goes back to the same origin as the strategic and multiple scenario approaches, which were so advantageous to Shell during the first oil crisis in the early 1970s.

2.1. Backcasting in Energy studies: soft energy paths

The origin of backcasting goes back to Amory Lovins, who proposed backcasting as an alternative planning technique for electricity supply and demand in the 1970s[1] (Robinson 1982, Anderson 2001). According to Robinson (1982) Lovins mentioned the method originally 'backwards-looking analysis', while Robinson introduced the term Energy backcasting. Assuming that future demand is mainly a function of current policy decisions, Lovins originally suggested that it would be beneficial to describe a desirable future (or a range of futures) and to assess how such a future could be achieved instead of focussing on likely futures alone. After having identified the strategic objective in a particular future, it would be possible to work backwards to determine what policy measures should be implemented to guide the energy industry in its transformation towards the future required energy industry.

This type of backcasting studies was especially concerned with so called soft energy (policy) paths, taking as a starting point a low energy demand society that relies on renewable energy technologies. The focus was on analysis and on achieving policy goals, while the 'backcasts' of different alternative energy futures were also meant to reveal the relative implications of different policy goals (Robinson 1982: 337-338), and to determine the freedom of action for policy making. From the beginning, it was strongly emphasised that the purpose of backcasting was not to produce blueprints, but to compare relative feasibility and implications of different energy futures (including social, environmental and political implications) under the assumption of a clear relationship between goal setting and policy planning.

Robinson (1982) also elaborated the principles set by Lovins into a sequential six-step methodology for energy and electricity futures. The central step was to develop an outline of the future economy through the construction of a model of the economy in a final future state followed by developing an energy demand scenario corresponding to the results of the model. Recently, Anderson (2001: 612) has commented that the proposed future step in the original approach applied by Lovins and Robinson included a model that was dependent on long-term economic predictions. Anderson (2001) has therefore suggested an alternative model in which both supply and demand are treated as endogenous factors in the process of policy making. He has adapted the energy backcasting approach aiming to reconcile the electricity industry with sustainable development. The adapted approach assumes wider environmental and social responsibilities, a broadening of necessary knowledge (from a range of disciplines and including so-called non-expert knowledge) and a more flexible and responsible policy agenda.

However, both Robinson and Anderson emphasise the potential of backcasting for policy analysis and policy development, but especially from a governmental perspective. They refer to policy analysis in the traditional sense of supporting policy and policymakers with information on different future options and 'to indicate the relative feasibility and implications of different policy goals' (Robinson 1990: 823). Furthermore, the early focus in backcasting was not yet on the wider applicability for dealing with sustainability issues, but on exploring and assessing energy futures.

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1 The original publications of Amory Lovins are referred to by Robinson (1982). It includes Lovins' paper entitled 'Energy strategy: the road not taken?', which was published in Foreign Affairs in October 1976 and his book entitled 'Soft Energy Paths', published by FOE/Ballinger in 1977. Additionally, Robinson (1982) contains a comprehensive list of the soft energy path backcasting studies, which were especially carried out in Canada.

2.2. Backcasting for sustainability in Sweden

Those who applied backcasting must have realized that it had a much wider potential for application, due to its normative nature. For instance, Robinson (1988) dealt with wider conceptual and methodological issues, including the role of learning (and unlearning) about the future, the issue of broadening the process to a larger group of potential users, and to alter the hegemony of existing theoretical perspectives. Elsewhere, Robinson (1990: 822) mentioned that backcasting is not only about how desirable futures can be attained, but that it can also be used to analyse the degree to which undesirable futures can be avoided or responded to. However, the focus is on desirable futures, and backcasting is described as an explicitly normative approach involving working backwards from a particular desirable future endpoint to the present, in order to determine the physical feasibility of that future and what policy measures would be required to reach that point.

Robinson's (1990) paper marked the move towards sustainability applications of backcasting. It also links to the origin of the backcasting practice in Sweden as the paper reports on a study funded by the Swedish Energy Research Commission. This was followed by substantial efforts in practical backcasting and conceptual thinking (e.g. Dreborg 1996, Holmberg 1998, Bannister et al 2000, Hojer and Mattsson 2000). For instance, Dreborg (1996) mentions that traditional forecasting is based on dominant trends and is therefore unlikely to generate solutions based on trend-breaches. He argues that backcasting approaches due to their problem-solving character are much better suited for long-term problems and long-term sustainability solutions, while it is more useful to consider backcasting as an approach within in a range methods can be applied, than as a specific method (1996: 818). According to Dreborg backcasting studies should aim at providing images of the future as a background for opinion forming and decision making to policy makers and the interested general public. Interestingly, Dreborg emphasises that our perception of what is possible or reasonable may be a major obstacle to real change, which refers to earlier remarks (Robinson 1988) about (un)learning and the dominance of existing perspectives. The scenarios of a backcasting project should therefore broaden the scope of solutions to be considered by describing new options and different futures. Dreborg (1996: 816) also argues when backcasting is especially promising. This is in case of: (1) complex problems, (2) when there is a need for a major change, (3) when dominant trends are part of the problem, (4) when externalities cannot be solved by a market approach (in a satisfying way), and (5) when there is a need for long time horizons. Sustainability problems are then clear examples of such problems (Dreborg 1996).

Interestingly, Dreborg also focuses on the conceptual level beyond the stepwise method of Robinson, and relates backcasting to the field of Constructive Technology Assessment. This enables to distinguish between the practical and analytical side and the constructive process-oriented side. Concerning the practical and analytical side the main product of backcasting studies are alternative images of the future, thoroughly analysed as to their feasibility and consequences. Concerning the process and constructive oriented side, backcasting studies should be addressed, according to Dreborg (1996), to many actors including political parties, governmental authorities, municipalities, organisations, enterprises and an informed general public. In addition, the studies are also meant for providing input to a policy developing process in which these actors should also be involved. Dreborg also argues that it is essential that backcasting studies provide alternative images of the future that are assessed on their consequences in a credible way, while the results are not meant to form a basis for a single big decision nor as a detailed plan or a blueprint.

Also working within the Swedish backcasting community, Hojer and Mattsson (2000) suggest that backcasting and different forecasting approaches are complementary, favouring backcasting especially in cases where current trends are leading towards an unfavourable state. They include a step in which forecasts and a desired vision is compared with each other. If the vision cannot be reached according to the most reliable forecasts, model calculations, and other estimates, the task of the backcasting study should be to generate images of the future or scenarios that fulfil the targets expressed in the vision. The images must be scrutinised to examine potential effects. Furthermore, in addition to the normative scenario-forming side of backcasting, Hojer and Mattsson (2000: 630) also emphasise what they call the analytical and critical side of backcasting, by asking themselves how is it possibly to attain a state that has been identified as desirable? They mean here that it is not only important to develop the normative future vision solving certain problems, but that it is as important to work back from that desirable future to check the physical and social feasibility of the route towards that future, and the necessary measures and actions for bringing about that future. Furthermore, Hojer and Mattsson (2000) emphasise that the use of models and tools helping to quantify the consequences of different measures is as important as constructing the future visions. With respect to the consequences, regular forecasting tools can be necessary, while tools from the field of impact assessment and technology assessment can contribute too.

In Sweden backcasting has also been elaborated as a methodology for strategic planning for sustainability (Holmberg 1998), which has become known as the Natural Step methodology and has been advocated and popularised by Robert. Though Robert considers it more as 'backcasting from principles', rather than as 'backcasting from scenarios', it could be said that satisfying the principles takes place in a future state. This variety of backcasting has been applied quite successfully in corporations like Ikea, the carpet producer Interface and Scandic hotels (Holmberg 1998, for a detailed account see Nattrass and Altomare, 1999). It starts with support by the CEO or owner and includes broad participation of as many employees as possible. It also includes consultation of all levels for generating ideas how to become a sustainable corporation. It goes beyond good housekeeping and regular environmental management and aims at making the business itself sustainable over the full production chain. This example shows that it is possible to apply backcasting both on a system or societal level and on the level of particular organisations.

2.3. Backcasting in the Netherlands

Since the 1990s backcasting has also been applied in the Netherlands, first at the governmental programme for Sustainable Technology Development (STD) that ran from 1993 up to 2001, and in its EU funded spin-off, the research project 'Strategies towards the Sustainable Household (SusHouse) that ran from 1998 to 2000. Both initiatives focused on achieving sustainable need fulfilment in the far future using a backcasting approach that included broad stakeholder participation, future visions or normative scenarios, and the use of creativity for getting beyond present mind sets, paradigms and actor reference frameworks. Vergragt and Jansen (1993), inspired by the Swedish example, mentioned backcasting as part of the philosophy of the STD programme. They described the basic idea (1993: 136) as *to create a robust picture of the future situation as a starting point, and start to think about which (technical and other) means are necessary to reach this state of affairs. Such a view of reality is not a scenario or a product of forecasting, but should be seen as a solid picture that can be accepted by the technological spokesmen right now*. Furthermore, Vergragt and Jansen emphasised – like Dreborg (1996) in Sweden – the link with Constructive Technology Assessment concepts and approaches referring to the broadening of technology development processes with sustainability aspects and the participation of social actors like public interest groups in addition to the traditional participants in such processes. Elsewhere, Vergragt and Van der Wel (1998: 173) go beyond the desirable future – like Hojer and Mattsson (2000) also did – and emphasise implementation and planning for action. *Future visions alone are not* *enough: Backcasting implies an operational plan for the present that is designed to move toward anticipated future states. Backcasting, then, is not based on the extrapolation of the present into the future – rather, it involves the extrapolation of desired or inevitable futures back into the present. Such a plan should be built around processes characterised as interactive (many stakeholders are involved) and iterative (feedback is continuous between future visions and present actions).* Elsewhere, Weaver et al (2001: 74) reporting on approach and results of the STD programme. They describe backcasting as a possible tool for establishing shared visions of desirable future system states, while securing a 'systems' perspective on the transition process and of help in defining feasible short-term actions that can lead to trend-breaking change. Interestingly, Weaver et al (2002: 72-78) refer to backcasting as a tool, as a full methodology, as a concept, as an operational approach and also as a specific step in the full methodology. This seems to reveal the need for clear definitions and distinctions.

The aim of the SusHouse project was to develop and test strategies for sustainable households in the future. The researchers referred in general to the SusHouse approach, but in fact it was a backcasting approach that used stakeholder workshops, creativity methods, normative scenarios, scenario assessments and backcasting analysis (Vergragt 2000, Quist et al 2001, Green and Vergragt 2002). Contrary to the STD programme, the emphasis was less on the technology and more on achieving cultural and lifestyle changes contributing to sustainability. Though it was originally planned that all backcasting activities could be concentrated in a single workshop, it appeared that these took place throughout the whole project, not only during the stakeholder workshops, but also during the scenario elaboration and scenario analysis activities by the research teams (Quist et al 2000). Furthermore, Quist et al (2000: 8-16) also mention the link with CTA, social shaping theories of technology development (from which CTA originally was derived). Furthermore they mention the connections with the field of Creative Problem Solving (e.g. Isaksen 2000), the importance of defining steps contributing to developing such a sustainable desirable and the importance of (conceptual) learning by stakeholders and involved researchers facilitating the process.

Taking a more reflexive perspective and looking back to the participatory backcasting experiments in the Netherlands, Vergragt (2001: 11) emphasises that future visions that are shared among stakeholders are a necessary but not sufficient condition for achieving implementation and follow-up. It is also important to understand the culture and interests of stakeholders, their motives for both participation in the backcasting study and for the desired follow-up after the backcasting study has been completed.

Backcasting has become a popular approach in the Netherlands. It has been applied rather widely and influenced the Dutch strategies for sustainability considerably (AWT 1998) and long-term strategic thinking in the Netherlands in general. For instance, backcasting and normative future visions have been applied in strategic reorientation of the research programmes at DLO, the major Dutch research organisation for agriculture and rural development (Grin 2003). Partidario has elaborated and applied an approach rather similar to the SusHouse approach for studying future prospects for sustainability in paint chains in the Netherlands and Portugal (Partidario 2002). Van de Kerkhof et al (2003) have developed a backcasting approach focussing on the diversity in views, visions and interests among stakeholders involved in a debate on different futures meeting Kyoto targets with respect to reducing greenhouse gas emissions. Geurs and Van Wee (2000) have applied backcasting as a tool to develop sustainable transport scenarios. Rotmans et al (2001) working on transition management also refer to backcasting from the future within their approach. Finally, Jansen (2003) pays attention to backcasting in national foresighting programmes and compares these to the Dutch practice in backcasting at the STD programme.

2.4. Conclusions so far

Backcasting originates from the 1970s and was originally developed as an alternative for traditional forecasting and planning. It was originally considered as an additional policy analysis tool for energy planning, using normative or sometimes also possible scenarios emphasising its analytical nature, while later on since the 1990s the emphasis shifted towards its potential for identifying and exploring sustainability solutions, towards broad stakeholder participation, and to multi-actor interaction processes, towards enhanced normativity of scenarios based on strong visions shared and supported by stakeholders, and to the importance of conceptual learning. So, participatory backcasting is the most recent variety and an emerging approach. Interestingly, the shift to participatory backcasting has, quite independent from the developments in the Netherlands, taken place in Canada (Robinson 2003) and more recently, also in Belgium (Keune & Goorden 2002) and in Sweden (Carlsson-Kanyama et al 2003).

Furthermore, it can be concluded from the literature review that backcasting can refer to a concept or philosophy, a study, an approach, a methodology, an interaction process among participating stakeholders, an assessment/analysis (sometimes referred to as a backcast) or the specific step of looking back from the desired future within an overall stepwise (but iterative) approach or methodology. This implies also that backcasting can be dealt with on the conceptual or holistic level, the level of social or multi-actor processes, the level of overall approaches and methodologies containing multiple steps, methods and instruments, and on the level of specific steps, methods or instruments within such an overall approach or overall methodology. This implies that backcasting is more than looking back from a desirable future, and when using the term backcasting reference should be made to the level and the activity.

3. Methodological and theoretical aspects of participatory backcasting

This section starts dealing with methodological aspects, before proposing an elaboration of five stages, and ends mentioning some key mechanisms and concepts underpinning participatory backcasting.

3.1. Activities, toolkit and possible goals for participatory backcasting

Though backcasting has not always been applied as a participatory approach, stakeholder involvement is strongly emphasised in recent backcasting experiments for sustainability (Weaver et al 2000, Quist et al 2001, Green & Vergragt 2002, Robinson 2003, Van de Kerkhof et al 2003). Therefore, in this section is focussed on the methodological aspects and characteristics of participatory backcasting.

From a methodological viewpoint, it is possible to distinguish four major activities that are necessary within a participatory backcasting framework. These are:

- Orientation (on the problem);
- Design (of the future vision or normative scenario and of the process)
- Assessment and analysis
- Participation of stakeholders

This implies that backcasting uses very different methods and tools that relate quite strongly to the major activities distinguished above. So, backcasting requires tools and methods for *stakeholder participation*, for *design and development* of future vision, for the process, and for analyses and assessments. In addition to the participatory tools, tools and methods for process and stakeholder management are an important category too. It is necessary to make this distinction, as these are different from participatory tools focussing on interaction and involvement. Furthermore, there is not a specific group of tools connected to the *orientation*, but here tools and methods can be used from each category of tools and methods distinguished below. Furthermore, the orientation should include setting normative assumptions and goals. So, four categories of tools and methods can be distinguished in a participatory backcasting framework:

- *Participatory tools and methods*. This category concerns all tools and methods that are useful for involving stakeholders and generating and guiding interactivity among stakeholders. It includes specific workshop tools, tools for stakeholder creativity and tools helping stakeholders in specific backcasting activities and tools for participatory vision and scenario construction. Mayer (1997) has given an interesting overview of participatory tools and methods.
- *Design tools*. This category includes not only scenario construction, but also elaboration and detailing systems and process design tools. De Bruijn et al (2002) dealt with process design methodologies, while design methods for scenarios and for defining and elaborating (socio-technical) systems are widely available.
- *Analytical tools and methods*. Those relate not only to assessment of scenarios and designs, for instance consumer acceptance studies, environmental assessments, economic analysis, but include also methods for process analysis and evaluation, stakeholder identification and stakeholder analysis.
- *Overall process management and stakeholder management tools and methods*. Apart from specific participatory methods, there are methods that are relevant for the overall approach and the overall process, but which are more specific than the overall backcasting approach. It includes methods, which can be applied for shaping and maintaining stakeholder networks that originate from the backcasting study. Some mention this process management (e.g. De Bruijn et al 1998), while there are also methods in Constructive Technology Assessment (Van den Ende et al 1998).

In the literature on energy backcasting, there is a considerable goal orientation. However, this relates to goals connected to the desirable future states. Here, backcasting is considered as an approach applied in a study of limited time, which can be several months to several years. Possible goals for backcasting studies include:

- Generation of normative options for the future and putting these on the agenda of relevant arena's;
- Future visions or normative scenarios;
- A follow-up agenda containing activities for different groups of stakeholders contributing to bringing about the desirable future;
- Stakeholder learning with respect to the options, the consequences and the opinions of others.

It is important to realise that the main activities, the groups of tools and the different goals identified here, imply the usage of different types of knowledge and skills not only from different stakeholder groups but also from different disciplines and different professional groups and that it requires interaction between different stakeholder and professional groups. This means that it is not only multi-disciplinary, but also trans-disciplinary. This implies not only clear knowledge demands, but equally important – and even more difficult to be met - clear process demands and process management.

3.2. A five-stage approach for backcasting

Though most approaches found in the literature show differences in methods applied, ways of stakeholder involvement and number of steps (Robinson 1990, Holmberg 1998, Weaver et al 2000, Quist et al 2001), it is possible to generalise and translate the approaches identified in the literature into a general description for participatory backcasting consisting of five stages (or steps). The five main stages, as distinguished here, are:

- Strategic Problem Orientation
- Construction of sustainable future visions or scenarios
- Backcasting stage
- Elaboration, analysis and defining follow-up activities and action agenda
- Embedding of action agenda, activities and generating follow-up *and* implementation

It is necessary to address a few points here. First, it is assumed that setting the normative assumptions and goals are part of the first stage, as is achieving agreement on the normative assumptions among stakeholders involved. However, sometimes these are set before the problem orientation starts or have already been set within an overall frame. This was for instance the case in the Netherlands at the STD programme, where the time horizon of 40 years, the factor 20 and the focus on sustainable need fulfilment were set as general assumptions, and were approved by key persons of participating ministries and some leading industries in the Netherlands before specific backcasting studies were initiated.

Second, if there are more than five steps distinguished in a backcasting approach, it is in general possible to see specific steps as part of the suggested five stages. Next, it has been suggested (e.g. Holmberg 1998) that the fourth and the fifth stage could be combined into one. Furthermore, it may also be argued that because it is so difficult to finish the fifth step in particular projects, the end of the backcasting study should be positioned early in the fifth stage, leaving out implementation and the generation of follow-up – like was done in the SusHouse project (Quist et al 2001). However, as embedding and initiating follow-up and implementation are so crucially important, it is argued here that is justified to distinguish it as a separate stage in the approach.

Fourth, it must be mentioned that though the approach is depicted stepwise and linear, it definitely is not. Iteration cycles are possible, while there is also a mutual influence between two steps following one to another. Although it might be interesting to conceptualise it as a set of activities that all need to be done, instead of in a linear sense, in practical applications it remains necessary to combine it with a transparent time frame that can be communicated with stakeholders involved. So, due to the time and process constraints, it has to be depicted as linear in time. Five, the backcasting process has a dynamic nature, which means that stakeholders might leave the process, while new stakeholders might join it.

In addition, each stage of the backcasting approach requires in general tools and methods from all four categories distinguished; though it may be different tools and methods in particular stages. Finally, four major societal groups can be distinguished: companies, research bodies, government and related bodies and last but definitely not least public interest groups and the public. Of course, identifying appropriate organisations and relevant individuals within these organisations, also reflecting all stages of the supply chain and the related consumption system is to be done within specific backcasting studies.

3.3. Brief elaboration of the stages in participatory backcasting

Five stages can be distinguished in participatory backcasting. This subsection deals with each stage and pays also attention to the variety that can be found in a specific stage.

Stage 1: Strategic Problem Orientation

This stage includes - if this has not been done yet - setting normative assumptions and targets, which can also be done through stakeholder participation. This stage aims at exploring the problem from a systemic viewpoint, possible problem definitions, main unsustainabilities, opportunities, and possible solutions, identifying and involving relevant stakeholders. In addition, it should be analysed how the problem is perceived by different stakeholders, how it relates to need and function fulfilment on an appropriate level – which is often a societal level or the level of socio-technical systems (Quist 2003), how other stakeholders evaluate and judge the different problem formulations according to their own mind set, values and interests, and how supply chain and demand side are interdependent and influence each other. It is important to take an integral viewpoint, while taking into account related consumption and production systems and present trends and developments for the whole system. Involving stakeholders is also important because they are experts in the field or system under study (of a part from it). The table below provides a preliminary checklist that can be applied.

Table 1: A preliminary Checklist for a Strategic Problem Orientation Stage
What is the problem (at stake)? Who is (are) the problem-owner(s) What are major trends and developments? Who are stakeholders and future stakeholders? What are their problem definitions and problem perceptions? What are their interests, relations and resources? What kind of possible solutions or solution directions do stakeholders see? How do other stakeholders perceive these? Who might have an interest concerning this solution? Who does not?

Stage 2: Construction of sustainable future visions or scenarios

The results of the Strategic Problem Orientation stage are the starting point for construction of sustainable future visions or scenarios in which the identified unsustainabilities and problems have been solved. Stakeholder participation is important here, so workshops are an important tool in this stage, though different types of workshops and other participatory methods are also possible. The relevant question is how this societal need or function can be fulfilled in a sustainable way in the far future, assuming that it is always possible to define a societal need or function in a particular backcasting study.

Furthermore, different types of future visions are possible. For instance, within the STD programme a generic sustainable future vision was generated that contained several solutions for different major unsustainabilities, while in the SusHouse project several sustainable and more detailed scenarios were generated that depicted different sustainable lifestyles that could be seen as each other's substitutes. In addition, SusHouse scenarios did not only contain a vision and a description of main characteristics, but were elaborated with storyboards depicting daily life stories within a specific scenario, proposals for product-service systems supporting the sustainable scenario, and sometimes with images. It seems that generating single visions or several scenarios have each specific advantages and drawbacks, but a systematic evaluation of this has not been done yet. Furthermore, quite a number of specific methods are available for constructing future visions and normative scenarios. Scenarios or future visions can either stress the vision part, the feasibility, or the creative part. It is also possible to add first estimates or preliminary assessments for particular aspects like environmental improvement potential, consumer acceptance, socio-economic aspects, etc.

Stage 3: Backcasting – setting out sustainable alternatives

Though the overall approach is named after this stage, it is actually the stage that is least elaborated and described in the backcasting literature. Aarts (2000: 36-40) refers to realising the gap between a sustainable future and the present situation, and to look backwards seeking for ideas, leapfrog technologies and trend breaches. She mentions as methods elaboration of future visions, writing essays, explorative research, expert workshops and stakeholder workshops. Quist et al (2000) try to guide the backcasting stage with a specific guiding question 'What are the necessary changes to realise this future vision or scenario'. So, different varieties can be distinguished in this stage:

- A quick one just meant for identifying attractive solutions or clusters that would enable radically increased eco-efficiency. This was, for instance, done at the STD programme (Weaver et al 2000).
- A more elaborated variety, asking for the changes necessary for achieving a specific future vision or sustainable normative scenario, which was applied in the SusHouse project (Quist et al 2000). This meta-question can be split into specific questions for which technological changes are necessary, which cultural and behavioural changes are necessary, which structural-institutional changes are necessary and which organisational changes are necessary for realising the desirable sustainable future state.
- A very detailed one defining and describing also in-between states. For instance, if the final state is set in 2040, reasoning back from 2040 the state of 2030 can be described, before describing the state of 2020 and 2010. Though this variety is commonly used for explaining backcasting, it has hardly been applied in professional practice.

Stage 4: Elaboration and defining follow-up activities and agendas

Elaboration can take many forms and depends strongly on capacity, budget and time available. Assessments, analyses and feasibility studies are important in the first part of this stage, while defining follow up activities and agendas that enable implementation and realisation on the longer term are important in the second part of this stage. Differences can be noticed too. For instance, in the SusHouse project, it were the normative scenarios that were elaborated and assessed by small research teams dealing with two case studies and for each case study several scenarios. At the STD programme, backcasting was used to identify promising clusters and directions within a single future vision, and those clusters were subjected to feasibility study and further elaboration in particular projects. This enabled to involve more specialised researchers, while stakeholders involvement was more focussed too.

Stage 5: Embedding of action agenda and generating follow-up

As the aim of backcasting for sustainable strategies is to bring about change processes, system innovations or transitions towards sustainability, it is important that the outcomes of the backcasting study are embedded and taken further by stakeholders of groups of stakeholders. It has already been mentioned that each societal group has to deliver its contribution, while it cannot be blueprinted due to the complex nature of social change and social learning processes. Nevertheless, the future vision can act as a guiding image or leitmotiv, while R&D and action agenda contain a bundle of possible roads and suggestions that must be elaborated by appropriate stakeholders.

3.4. Theoretical aspects of participatory backcasting

This subsection briefly deals with some theoretical aspects and key mechanisms underpinning the approach of participatory backcasting. But before that, we want to stress here that backcasting is inherently of a normative nature – sustainability is a normative concept -, while this is combined with the recognition that our society is socially shaped. This means that the results of backcasting approaches stem from processes of social interaction involving various social actors and taking into account the plural character of present societies.

Future visions

It has been shown that visions are important in technology development as guiding images that are endorsed by actors. This has led in Germany to a body of literature on *leitbilder* (in analogy with *leitmotiv*) in technology studies. For instance, Grin and Grunwald (2000: 1) assume *that one way to shape socio-technological systems is through the visions that guide their development… the assumption is that these visions exist already in most societal sectors, that these visions tend to reproduce the ways in which these sectors have developed hitherto, and that a critical discussion of these visions is a prerequisite for changing the course of development.* In addition, they ask .. [I]*s it possible to provide some orientation to long-term development in a way that it may contributes to meeting challenges like the need for sustainability, while ensuring public legitimacy and avoiding the risk of authoritarian blueprints.* Their preliminary answer is in fact positive. They distinguish two main features of visions (Grin and Grunwald 2000: 11). First, mental images of attainable futures shaped by a collection of actors. Second, it guides the actions of and the interactions between these actors (see also Quist et al 2001). Furthermore, these visions can be used for broadening the debate on changing socio-technical systems, and it could lead to conceptual learning and adjustments in technological designs and design processes resulting in an improved alignment of technology and society. In addition, visions may have the potential for dealing with problems for which there are no rules or institutions available (Grin 2003, Quist 2003). Sustainability problems are clear examples.

Stakeholder learning

Another important element is higher order or conceptual actor learning. Social interaction between actors and negotiations can lead to learning processes not only on the cognitive level but also with respect to values, attitudes and underlying convictions. The latter is also known as higher order learning for which several conceptualisations have been made (for a discussion on this, Brown et al 2003). In policy oriented learning, for instance, it involves redefining policy goals and adjusting problem definition and strategies, while in organisational learning it involves changes in norms, values, goals and operating procedures governing the decision-making process and actions of organisations. This is of great importance in case of complex problems with opposing actors having a different mental framework or action theory (Grin et al 1997). The approach of action theories is of interest here as it links the mental framework with the space for behavioural alternatives. The assumption here is that higher order learning leads to changes in the mind set or reference framework and thereby broadens the space for actions and behavioural alternatives.

Process aspects

Next, process aspects and dynamics are not only relevant for explaining the outcomes immediately after a backcasting experiment, but include relevant factors enabling and constraining the realisation follow-up and implementation supporting the direction of the defined (desirable) transformation of the socio-technical system (Quist 2003). Backcasting experiments around normative future visions are in fact complex processes and involve numerous actors having different reference frameworks, value sets and interests. So, tactic and strategic behaviour can take place, there are power issues and dependencies at stake, while it also concerns negotiation on problem definitions, normative goal setting, creating a sense of urgency on the short term, etc. Therefore, process management is also relevant here (e.g. De Bruijn et al 2002).

4. Case I: STD programme: Novel Protein Foods

4.1. Background of the STD programme

After the history, the methodological aspects, and some theoretical issues, we present here two cases in which participatory backcasting was applied. Early in the 1990s the governmental programme for Sustainable Technological Development (STD) was initiated in the Netherlands aiming not only at exploring system innovations towards sustainability, but also to explore opportunities and possibilities for developing sustainable technologies. This was then not as straightforward as it is nowadays in many developed countries. At that time the focus of policy makers, technology developers and corporations was mainly on clean technologies and end-op-pipe solutions, while there was still a strong debate, if technology was the major cause of environmental problems or if technology could also be part of a solution. The STD programme ran from 1993 until 2001. Taking the factor 20 increase in environmental efficiency of need fulfilment as a challenge for technology development at the STD-programme, and applying an interactive and stakeholder-oriented backcasting approach, a number of societal needs like nutrition, water, mobility and housing were explored focusing on future sustainable alternatives for fulfilling these societal needs.

This was done by developing future visions for the sustainable fulfilment of these needs using the expertise of stakeholders from government, companies, research bodies and public interest groups (STD 1997, Weaver et al 2000). These future visions were analysed as alternative solutions having the potential to meet the factor challenge, which were elaborated in projects. Examples of factor 20 projects at the STD programme included the mobile hydrogen fuel cell (Vergragt and Van Noort 1996, Weaver et al. 2000), Urban Underground Freight Transport (STD 1997), Novel Protein Foods (Quist et al 1996; Weaver et al 2000), Sustainable Multiple Land Use in which function integration and reduction environmental burden in rural areas were combined (STD 1997), Sustainable Urban Renewal in the city of Rotterdam, C1-chemistry based on biomass (Weaver et al 2000) Sustainable Municipal Water Systems (Weaver et al 2000). For an overview of all projects and results, see STD (1997), while Weaver et al (2000) give a more detailed analysis of 7 projects.

The projects at the STD programmes included not only radical technological innovations that met the factor challenge but also the identification of cultural and structural conditions for development and implementation. Projects could also be described as complex multi-actor processes around a socio-technological solution aiming at a factor 20 reductions in environmental burden in fulfilling societal needs in the future. Objectives of these projects included future visions or designs, research programmes for developing the fundamental scientific knowledge required for realising the identified sustainable technology, networks around the identified technology, development paths or trajectories, sight on short term spin-off and embedded follow-up activities by stakeholders.

In general, the STD programme was considered to be very successful in identifying alternative solutions having the potential for achieving considerable environmental reduction factors, and in developing follow-up agendas and strategic research programmes, though the programme did not succeed in all projects to establish follow-up. Furthermore, during the STD programme it appeared that quite a number of sustainable technologies are available (or 'on the shelf'), but that present cultural and structural conditions restrict further development and implementation (Aarts 1997).

4.2. Approach at the STD programme

A participatory backcasting approach was applied at the STD programme, but how was it applied? Following the description of Weaver et al (2000: 76), it was an approach of 7 steps as depicted in Figure 1. According to Weaver et al (2000: 76), Step 1-3 are meant for developing ave solutions for sustainable need fulfilment. Step 4 and step 5 were meant to clarify the short-term actions that are needed to realise that future which can be seen as a joint action, R&D and policy agenda. Step 6 and step 7 focused on implementation and realising the action agenda and plan. This was meant to be done by stakeholders involved in the backcasting process by setting up co-operations enabling implementation o long-term vision based on a strategic review of how a need might be met in the future in a sustainable way and using backwards analysis to set out alternatif a research agenda. The STD programme facilitated this as far as possible.

Figure 1: The STD methodology (Weaver et al 2000, Vergragt 2001)

Develop long term vision	Develop short term actions	Implementation
1 Strategic problem orientation and definition 2. Develop Future Vision 3. Back-casting	4. Explore solution options 5. Select among options: set up action plan	6. Set up cooperation agreement-define roles 7. Implement research agenda

The 7-step approach applied at the STD programme agrees well with the approach of five stages described earlier, as Table 3 also shows. Steps 1-3 of the STD approach are similar to the stages 1-3 as proposed in this chapter. In addition, step 4 and step 5 of the STD approach matches with stage 4 in this chapter, while step 6 and step 7 are similar with stage 5. So, in comparison with the general description, at the STD programme both stage 4 and stage 5 were split into two steps.

Table 3: Comparison of the backcasting approach proposed and the STD approach

Backcasting approach	STD approach
1. Strategic problem orientation	Step 1
2. Construction of desirable (normative) scenario or future vision	Step 2
3. Backcasting stage	Step 3
4. Elaboration (design *and* analysis) and defining follow-up activities and action agenda	Step 4, step 5,
5 Embedding of action agenda, activities and generating follow-up *and* implementation	Step 6, Step 7

The approach at the STD programme was applied in an iterative way, while sometimes parts of the visioning were redone later in the process, for instance to involve newly entered stakeholders. This can be illustrated for the exploration of nutrition. The construction of a sustainable future for the need of nutrition led to the identification of several alternative solutions like multiple sustainable land-use and novel protein foods as an alternative for present meat consumption and production. The next step – step 4 in the description of Weaver et al and stage 4 as proposed here – would be to explore this solution further. This is shown below when dealing with the example of Novel Protein Foods.

4.3. Novel Protein Foods case: outline and results

Novel Protein Foods emerged from the participatory stakeholder analysis for nutrition as a sustainable alternative for present meat consumption and production, while also having the potential to meet the Factor 20 challenge. Targeting meat consumption itself, or the production of meat, as environmental improvement strategies was recognised but not included in this case. After a feasibility study a project was developed to elaborate the option of Novel Protein Foods that was co-financed by major companies from the food supply system in the Netherlands and bringing together consumer scientists, economists, food technologists and Life Cycle Assessment (LCA) researchers. During the project a more detailed future vision was developed. The key of the future vision was that Novel Protein Foods could replace 40% of meat consumption in 2040. Looking from a backcasting perspective, this implied that food technology had to be improved considerably enabling to produce protein foods similar superior in taste and structure as meat, while it was also assumed that Novel Protein Foods should have similar nutritional value as meat. It also implied cultural changes not only related to the role and status of meat and meat consumption, but also related to the role and status of protein foods from other sources than animals. This future vision also implied structural changes, as the meat sector would decrease, while new protein food chains would emerge.

It was concluded when finishing the project in 1996 (Quist et al 1996), that these new protein foods could be produced 10-30 times more environmentally efficient, compared to production of pork meat at that time. It was also concluded that NPFs could be attractive to both consumers ('taste is the deciding factor') and producers ('lower production costs than of meat'), while socio-economic effects remain relatively limited when compared to present autonomous development and foresights. In addition, it was concluded that the development and large-scale introduction of NPFs in the future is possible, but that new knowledge, research and development were required (STD 1997, Quist et al 1996). Results included a set of different NPFs analysed with respect to consumer acceptance and benefits, environmental impact, production costs and socio-economic effects and opportunities; R&D-programmes to develop lacking fundamental and applied knowledge, and a development trajectory towards 2040 containing 7 clusters of follow-up and implementation activities for both the short-term and the long-term (see Table 2). Furthermore, a strategy was proposed that NPFs would be especially beneficial in the processed segment (burgers, sausages, etc) and as assembled dishes and foods like pizzas and ready-mades.

Table 2: Action agenda for development and introduction of Novel Protein Foods

1. Communication with the general public and supply of adequate information
2. Professional education and transfer of new knowledge
3. Consumer research and development marketing instruments
4. Fundamental research and chain organisation
5. Novel Protein Foods product development (both as food *and* as ingredient)
6. Improvement environmental reduction factor and improving LCA-instrument
7. Necessary legislature and social measures (facilitating both the growth of a novel protein food chain and the decrease of the meat sector).

4.4. Backcasting approach in the Novel Protein Foods case

The previous section clearly showed that the normative future vision was a central element and could be used for identifying necessary major technological, cultural and structural changes. Those findings were elaborated in a set of promising NPFs based on several vegetable and microbial sources. So, next to developing and designing a future vision and its backcasting, elaboration and research activities took place. The latter included that several NPFs were designed and defined in the sense of food products for which specific design tools were applied by the food technology researchers in the project. Furthermore, defining the set of NPFs enabled to detail the future vision of 40% meat replacement and to assess socio-economic consequences and environmental improvement, while the set of products enabled the study for each NPF of its consumer attractiveness, the environmental improvement factor and the production costs.

So, the option of Novel Protein Foods was explored using a combination of design, backcasting and analysis activities before defining a possible development trajectory containing the 7 clusters of activities in Table 2. The list of activity clusters in Table 2 can be seen as a policy and action agenda for sustainable technological development around the option of Novel Protein Foods. The elaboration of this agenda included the societal groups and specific stakeholders who should take the lead in certain clusters or specific activities.

From the viewpoint of stakeholder participation, it is important to present how stakeholder involvement was organised? First of all, relevant research bodies did the research during the project. This was not only done from the viewpoint that researchers and their institutes would bring relevant knowledge, this was also important from the viewpoint that research institutes are important players in the relevant national innovation system. Second, participation was guaranteed trough funding from relevant ministries and two major private industries. Those stakeholders were members of an advisory board, which was extended with key persons from research and public interest groups. Third, Constructive Technology Assessment was used for involving a broader range of stakeholders from the four societal groups distinguished earlier. The "Future Images for Consumers" (Fonk 1994)) methodology was applied (Weaver et al 2000: Chapter 6, Fonk & Hamstra 1996) for organising and structuring a dialogue among the stakeholders involved. Participating stakeholders met during three workshops in which progress, opportunities and dilemmas were discussed, while it was completed with a statement containing both agreements and disagreements. Fourth, there were less focussed ways of involvement through for instance consumer research, general communication, etc. In addition, the importance of participation for achieving stakeholder learning has been explained. It was therefore evaluated if learning, especially on the higher or conceptual level, took place (Loeber 1997). It was found that this was indeed the case.

4.5. Follow-up and impact

An important premise underpinning backcasting is that conceptual or higher order learning by stakeholders is a condition for endorsement and supporting/participating follow-up and impacts. While follow-up relates more to concrete activities, impact concerns a broader term that includes learning effects and what is sometimes called the utilisation of knowledge. So it is interesting to discuss to which extent follow-up has been accomplished (see also Loeber 1997). First of all, a large research project (entitled "Profetas", www.profetas.nl) is carried out dealing both with the technological issues and the socio-economic and cultural aspects of the production and consumption of NPFs. Several major food companies in the Netherlands are involved in this project and are also working on this type of foods in their own R&D. Furthermore, NPFs are discussed occasionally by a major supermarket chain in their consumer magazine, while this issue is incorporated in the sustainable consumption activities of the Ministry of the Environment. Further, several new stakeholder co-operations are emerging that become visible at meetings and conferences focusing on the production and the consumption of NPFs, and bringing together producers, public interest groups (including environmental groups and the association for vegetarians), consumer organisations and representatives from research bodies and other chain parties. In addition, the interest of consumers for protein foods, not being meat from animals, is growing due to recent affairs like BSE and the mad cow diseases. However, it must be realised that the growing consciousness due to this is not automatically long lasting. On the other hand, from history it is known, as for instance shown by Geels (2002) and numerous others, that contextual factors can be important for transitions and transformations.

The emerging question is now if the follow-up and impacts are the signs of an emerging transformation or transition of the present meat production and consumption system towards a more sustainable socio-technical system having a considerable share of Novel Protein Foods (or 'meat-like products' as NPFs were originally called).

Though a major research project strongly entrenched in the innovation system for food production and agriculture, specific development projects and occasional recurring discussions are good results, it might be not enough to ensure the societal embedding of this innovation as it is the majority of ordinary consumers which must change their consumption pattern before the environmental promise of NPFs will be realised. More research is necessary to investigate how, under which conditions, a transition to a NPF system could be brought about. Backcasting can (again) play a role in this follow-up research.

5. Case II: SusHouse project

The second case presented and discussed here is the case study on Shopping, Cooking and Eating, which was carried out in the Netherlands as part of the SusHouse project. This case took the demand side of the food production and consumption system as a starting point for exploring future sustainable options.

5.1. Background

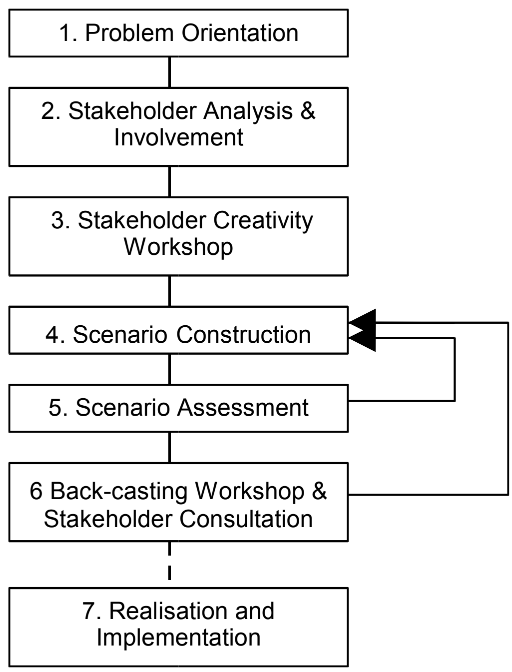
The EU funded SusHouse (Strategies towards the Sustainable Household) project, was concerned with developing and evaluating strategies for transitions to sustainable households. The starting point of the SusHouse project was that a combination of technological, cultural and structural changes is necessary to achieve a Factor 20 environmental gain in the next 50 years through system innovations, while both consumption and its interconnection with production through products and product usage taking into account (Green and Vergragt 2002, Vergragt 2000, Quist et al 2001). Another important starting point was to involve stakeholders in the process of (re) designing the fulfilment of a household's needs compatible with the concept of sustainable development. Three household functions were studied (1) Clothing Care, (2) Shelter and (3) Shopping, Cooking and Eating (SCE) or Nutrition, while six research groups in five European countries were involved (Vergragt 2000).

5.2. Approach

The Project's approach was earlier applied from in the Sustainable Washing project at the STD programme (Vergragt and Van der Wel 1998) before it was developed, elaborated and extended further. Here we describe it briefly. For each household function studied in each country, an extensive process of *stakeholder identification* was performed, covering stakeholders on the demand side, the supply side, research bodies, government and public interest groups. Selected stakeholders participated in stakeholder *creativity workshops* aimed at identifying sustainable ways of future function fulfilment. The results were used for *scenario construction*. These normative scenarios were not only assessed in terms of environmental gain, consumer acceptance and economic credibility – this part of the SusHouse approach is not dealt with in this chapter -, but they were also used for a scenario-specific second round of stakeholder identification. Old and newly identified stakeholders were invited to a second set of workshops in which scenarios and assessment results were discussed, followed by developing implementation proposals, research agendas and policy recommendations for achieving the scenarios. Objectives of case studies in the SusHouse project included normative scenarios for the fulfilment of functions of the sustainable household, endorsed by a range of social partners, scenario assessments and construction of follow-up agendas containing implementation proposals, policy recommendations, research question for solving knowledge gaps and (new) stakeholder alliances (Vergragt 2000).

The Figure below shows the overall SusHouse approach existing of 6 stages, while the 7th stage 'Realisation and Implementation' was actually not part of the SusHouse project. It was an important aim of the project to stimulate and prepare follow-up, but achieving it was not part of the project. A more extensive elaboration on the overall SusHouse methodology are given by Vergragt (2000), Quist et al (2000), Quist et al (2001) and Green and Vergragt (2002).

Figure 2: The stages in the SusHouse project.



Next, table 4 shows how the generic backcasting approach proposed earlier relates to the SusHouse approach discussed here. It shows clearly that the steps of the Sus-House approach can be positioned in the backcasting approach proposed in this chapter.

Table 4: Comparison of general backcasting approach and the SusHouse approach

Backcasting approach	**SusHouse approach**
1. Strategic problem orientation	Step 1 & step 2
2. Construction of desirable (normative) scenario or future vision	Step 3 & step 4
3. Backcasting stage	Step 4, step 6
4. Elaboration (design *and* analysis) and defining follow-up activities and action agenda	Step 4, step 5, step 6
5 Embedding of action agenda, activities and generating follow-up *and* implementation	Step 6, Step 7

5.3. Nutrition case study in the Netherlands

Scenario construction for Nutritition or SCE in the Netherlands was based on the results of a stakeholder creativity workshop and the Design Orienting Scenario methodology of Jegou and Manzini (2000) and its elaboration given by Young et al (2001). During the workshop stakeholders from different societal groups generated ideas for future sustainable fulfilment of the SCE function guided by the question 'How can we eat in a sustainable way in 2050'. Generation of ideas was followed by clustering and elaboration of proto-scenarios by the participants. Table 5 summarises the SCE scenarios briefly, while Table 5 shows key features of the three scenarios.

Table 5: Brief descriptions of the three scenarios

Intelligent Cooking and Storing (ICS) is about a household that can be characterised by high-tech, convenience, do-it-yourself and a fast way of living. Kitchen and food management is optimised with help of intelligent technology, which also organises ordering (electronically), and delivery with help of a so-called Intelligent Front Door. Water and energy are re-used where possible through cascade usage. Meals are either based on a mixture of sustainable ready-made and pre-prepared components (including vegetarian or novel protein foods replacing meat) or ready-made meals containing a microchip communicating cooking instructions with the microwave oven. Packaging is biodegradable and contains a (plastic) microchip with relevant consumer information about origin, treatment and preparation.
Super-Rant (SR) combines elements from the present supermarket and restaurant, but these are shaped into a neighbourhood food centre within a compact city. Here you can go for a meal (e.g. by a subscription to the neighbourhood cook), for food shopping, to purchase a take-away meal or to eat together for different prices. In many households only the microwave oven, a water cooker and a small fridge are left. Waste is collected for local energy production. Food is grown in a sustainable way.
In **Local and Green (L&G)** household members grow a considerable share of their foods themselves. Additionally, they buy and eat seasonal foods that are locally grown and purchased at local shops, small supermarkets, or are bought direct from the grower or hobby garden as 'fresh' unprocessed ingredients. Regional specialities are important and are consumed in the region by both inhabitants and tourists. Imported products are still available but expensive, because environmental costs are incorporated in the price. Furthermore, there is a strong green consumer demand in this scenario.

These scenarios can be seen as depicting more sustainable alternatives for possible present and future ways of living. These are not meant to select the most sustainable scenario and develop a strategy to bring everyone towards the most sustainable scenario. That would be as worse as any traditional blueprint planning and would deny individual autonomy and present plural society.

Table 6: Stakeholder panorama and backcasting results for the Intelligent Cooking and Storing scenario

Stakeholder panorama Key stakeholders for realisation of this scenario include consumers, retailers, food processors & manufacturers, packaging producers, kitchen equipment & appliances producers, government. **Necessary changes (preliminary back-casting analysis)** • Technological: novel kitchen technology **and** appliances (including a huge efficiency increase), new ICT for kitchen systems and production chain management, plastic chips, biodegradable packaging, cascade usage for water and energy, sustainable transportation, distribution and delivery systems. • Cultural/behavioural: sustainability for granted, further shift towards ready-mades and convenience, acceptance of new technologies, shift towards more sustainable substitutes (e.g. vegetable based Novel Protein Foods in stead of meat), shift towards services. • Structural/Organisational: role supermarkets will change due to large scale delivery and change towards food management services, kitchen manufacturers deliver complete automated systems that communicate instead of single kitchens and single appliances, close co-operation and joint management over the complete production chain and information available to consumers; sustainable food production (regional or efficient large scale production where this can most environmentally efficient).

Table 5 uses the Intelligent Cooking and Storing (ICS) scenario as an example to show the stakeholder panorama and results from a preliminary backcasting analysis based on an identification of the for achieving the scenario. Backcasting analysis refers here to the analysis, which is done by looking backwards from the scenario using the leading question 'What technological, cultural, and institutional-organisational changes are necessary for realising this scenario'.

Three scenario assessments were conducted The first is an *environmental assessment* using a system analysis approach with indicators to assess if the scenarios achieve a Factor 20 reduction in household environmental impacts. The *economic assessment* used a questionnaire to assess each scenario for economic aspects like competition, employment etc. Finally, the *consumer acceptance analysis* used consumer focus groups to evaluate the acceptability of the scenarios to consumers and to identify adopter profiles. In short, the assessments revealed that the Intelligent Cooking & Storing scenario and the Local & Green scenario would reduce the environmental burden considerably. However, quite surprisingly, for the Super-Rant scenario it was found that - using energy data from present restaurants - the energy requirement would even increase. It was concluded that better data would be necessary, and that there is a huge potential for environmental improvement in the Dutch food service sector.

Scenarios and assessment results were fed into a second stakeholder workshop focussing on implementation, follow-up and the construction of action and follow-up agendas. In addition, implementation proposals were elaborated, policy recommendations were developed, and even new innovative ideas were proposed. Furthermore, the unprocessed results contained the 'raw material' for policy recommendations and also for the construction of an action agenda.

5.4. Follow-up and impact

So, what kind of follow-up was achieved in this case (Quist et al 2002)? Concrete stakeholder co-operation, new partnerships and alliances around proposals were scarce in the last workshop. Nevertheless, there was considerable interest from stakeholders, and also concrete intentions to continue the process aiming at concrete follow-up, co-operation around concrete proposals and activities, and at imbedding of results in processes taking place in other networks. Additional activities after the workshops appeared therefore to be necessary for realising follow-up towards implementation. Furthermore, a number of initiatives were started, but it proved to be hard to get these funded.

However, concrete co-operation developed between stakeholders around ideas and proposals. It led for instance to a workshop focusing on domestic appliances for treating Novel Protein Foods at home, organised jointly by a research body and a company, while other stakeholders (many of them not involved in the SusHouse project) were recruited. After the workshop the organising parties developed a concrete research proposal on optimising kitchen appliances and food supply chains from an environmental point of view. It was supported by a number of stakeholders from different societal groups. Furthermore, the Dutch research group originally involved in the SusHouse project developed also new proposals including a programme proposal for a transition towards sustainability in eating-out and the food-service sector. It has been nominated for funding and aims at bringing together innovative parties from the food-service sector in the Netherlands. Finally, results and conclusions from the SusHouse SCE function were used as input for the policy process of the Dutch Ministry of the Environment on sustainable food consumption.

Nevertheless, the SusHouse project can be characterized as a successful application of backcasting for generating ideas and bringing together stakeholders around these ideas. However, in terms of implementation, kicking off concrete innovations, multi-stakeholder coalitions, or systemic changes, the project has not reached its aims. Apparently, also here more is needed in terms of governance or innovative capacity.

6. Conclusions

6.1. Backcasting approach

This chapter has presented participatory backcasting as a novel, innovative and promising approach for long-term strategising for sustainability, based on stakeholder involvement, construction of normative sustainable futures, stakeholder learning, in combination with design and analysis activities an construction of follow-up agendas meant for guiding implementation. Participatory backcasting has potential for planning in sustainable development, for identification and exploration of promising sustainable technologies, sustainable system innovations and transitions, for guiding technology choices and for generating alternative more sustainable trajectories for present dominant trends and developments.

We have described how backcasting originated from the 1970s and how it originally was developed as an alternative for traditional forecasting and planning. Its original focus was on policy analysis for energy planning. It evolved to sustainability issues, while later on utilisation of knowledge and the implementation of outcomes became much more important. Participatory backcasting using normative scenarios should be seen as rather opposite to the so called strategic scenario approaches using a range of possible futures and having become popular after the success of Shell – though there is agreement on the importance of learning (see e.g. Van der Heijden 1996). One of the differences is that Shell uses the scenarios to scan and understand possible changes in its business environment, so that the company can anticipate on these. This can be contrasted to developing normative visions on the future direction of a company or of society as a whole.

We also have found that backcasting can refer to a concept or philosophy, a study, an approach, a methodology, or an interaction process among participating stakeholders. In addition, it can refer to an assessment/analysis (sometimes referred to as the backcast) or to the specific step of looking back from the desired future within an overall stepwise (but iterative) approach or methodology. This implies also that backcasting can be dealt with on the conceptual or holistic level, the level of social or multi-actor processes, the level of overall approaches and methodologies containing of multiple steps, methods and instruments and on the level of specific steps, methods or instruments within such an overall approach or overall methodology. So, this makes very clear that backcasting is more than looking back from a desirable future. However, it also implies that further work needs to be done to define the approach and to distinguish this clearly from other elements within the approach for which also the term backcasting is used.

Participatory backcasting has a number of key features and elements. First, there is the explicit normative nature of backcasting approaches, which can be made explicit in the early beginning of the backcasting process, and which leads to normative future visions or normative scenarios. Other important elements include broad stakeholder participation – which is meant from the major societal groups distinguished here: companies, research, government and public interest -, conceptual learning by stakeholders involved - with respect to sustainability solutions, possible sustainable futures and the possible contributions from themselves and other stakeholders, and last but not least the process and its transparency. . Important background assumptions are a social shaping or constructivist perspective, the importance of interaction among participating stakeholders, and the recognition that existing rules and structures are not or not well equipped to deal with sustainable development and sustainable solutions.

This chapter has also proposed a general scheme for participatory backcasting consisting of five stages, while distinguishing four major activities: 1) Orientation; 2) Design; 3) Assessment; and 4) Participation. This implies that different tools and methods are necessary within a backcasting framework for which also four groups have been proposed: design tools; participatory tools; assessment tools and process (management) tools. It is important to realise that the backcasting approach is not only multi-disciplinary, but also trans-disciplinary. This implies not only clear knowledge demands, but equally important – and even more difficult to be met - clear process demands.

It seems possible to position backcasting approaches in a family of approaches using normative scenarios and stakeholder participation. For instance, Rotmans et al (2000) report on normative scenarios for sustainable areas in Europe in which stakeholders were involved, while Street (1997) reports on the use of scenario workshops as a participatory approach to sustainable urban living. Concerning the latter, which involved four groups, namely citizens, local policy makers, the private sector and technology experts, the scenario workshop approach included (1) creating visions and (2) looking at ways of turning those into reality. However, further study is necessary on how these relate to backcasting.

6.2. STD Novel Protein Foods case and SusHouse Nutrition (SCE) case

Concerning the NPF case at the STD programme, it can be concluded that backcasting was applied successfully and led to a sustainable future vision, stakeholder involvement from the four major societal groups distinguished here: companies, research bodies, government and public interest groups. The vision and elaboration also led to the identification of attractive NPF examples from different vegetable and fungal sources analysed for their consumer aspects, cost aspects, environmental potential, possible socio-economic impacts and the fundamental and applied knowledge that is presently lacking. To bridge the knowledge gap R&D programmes were defined and elaborated, while also a possible development trajectory was sketched.

Furthermore, considerable follow-up was realised both in public R&D and in private R&D, while also NPF related activities were found at the ministry of the Environment and public interest groups.

Concerning the SCE case at the SusHouse project, it can be concluded that backcasting was also successfully applied and led to several sustainable future visions and stakeholder involvement from the four major societal groups. The sustainable future visions were successfully elaborated and analysed on environmental improvement, consumer attractiveness, economic aspects, the necessary changes for realisation and action agendas and implementation proposals were defined and elaborated during stakeholder workshops. However, follow-up was much smaller than in the NPF case.

So, from the two case studies reported in this chapter it can be concluded that backcasting can be a strong approach for developing alternative sustainable future visions utilising the expertise and knowledge of a broad range of stakeholders. Backcasting analysis, further elaboration of attractive clusters and ideas and additional assessments can further lead to definition of follow-up agendas, containing R&D-activities and programmes and other important activities concerning implementation, strategy development, policy recommendations and short term proposals attractive for single stakeholders or co-operating stakeholders. However, the cases reveal differences. A major difference is the difference in follow-up and implementation. While the NPF case of the STD programme appeared to be rather successful in this sense, the SCE case of the SusHouse project seems to have much less impact concerning follow-up, stakeholder endorsement and conceptual learning among stakeholders.

The question emerging now is what could be a possible explanation for this difference between the two cases? Both were successful in involving stakeholders and in constructing, elaborating and analysing sustainable alternatives for future need and function fulfilment. Both cases led to follow-up agendas and ideas for implementation and activities, but only in case of the Novel Protein Foods, there was obviously utilisation of the results and concrete follow-up and implementation of the outcomes. Was it the difference in the organisational and institutional setting? Five ministries establishing the STD programme versus the European Union and academic self-organisation in the SusHouse project? Would it have to do with the type and level of stakeholders involved? Or was how the process is organised and managed decisive? It could also have to do with the system 'outside' the backcasting experiment as it can be both enabling and constraining. Enabling in the sense that it is open for the outcomes and constraining in the sense of ignoring or fighting back. No clear answer can be given, but further study could increase our understanding. So, further evaluation of existing backcasting experiments and backcasting practices seems to be necessary, and it might give answers to questions raised here, and might contribute to improving the effectiveness with respect of follow-up and explanation through improving our understanding of the factors enabling and constraining this. A research agenda has been proposed for this (Quist 2003).

Another, more fundamental, question that arises here is the viability of a backcasting approach as a first step to a large-scale structural and cultural social and technological change process (called a 'transition' in present Dutch policy literature (Rotmans et al 2001). Obviously, backcasting works well as a tool of generating visions and scenarios that do not fit in present-day trends, and that spur stakeholders to think 'out-of-the-box'. However, the implementation of major change is a long-term process involving innovation and governance by multiple stakeholders. Elsewhere one of us (Vergragt 2001) has argued that future visions, which are shared among stakeholders, are a necessary but not sufficient condition for achieving system innovation towards sustainability. Stakeholder management is also very important and should take into account the culture and the interests of stakeholders, trying to understand their motives for collaboration, and understanding in which phase of the process they can play a role. Further dealing with stakeholders in these types of innovations is extremely time-consuming and therefore costly. This is increasingly the case when future options deviate from existing development paths and explore new cultural and structural options.

6.3. Backcasting and related approaches

It is possible to relate backcasting to at least three categories of approaches. The first one is scenario-based foresighting approaches. These include the already mentioned strategic scenario approaches as known from Shell, the socio-technical scenario approach as proposed by Elzen et al (2002), and the earlier varieties of backcasting. However, in this type of approaches, the analytical relevance is in general stressed and construction is in general done by the researchers themselves sometimes based on expert consultation, while one of the core issues in participatory backcasting is broad stakeholder involvement representing different mindsets.

The second category is the one of participatory approaches like practiced in Constructive Technology Assessment. Here, the core issue is broadening the development and design process of technologies and artefacts with societal actors and aspects. However, it does not automatically lead to sustainability as it depends on the incorporation aspects and the participating actors, and it does not automatically include normative visions as a starting point. An emerging methodology is Strategic Niche Management (e.g. Hoogma et al 2002). Strategic Niche Management refers to experimenting with new technological options in a space protected (by the government) from market pressures, in order to enable stakeholders (both producers, users, regulators) to learn about the new technology and the embedding in its context. This approach is not so much strategic and long-term oriented, but focuses on concrete technologies and artefacts that are already available. SNM may be part of a long term strategy which includes implementation of new technologies, as for instance can be set out with participatory backcasting. However, it is yet unclear how the removal of the protection mechanisms (as suggested in SNM) could take place in a balanced way, on the one hand without killing the technology in an early phase, on the other hand without offering protection that cannot be continued in the long term.

A third category related to backcasting includes all participatory approaches using normative future visions, while ensuring broad stakeholder involvement. Examples have already been mentioned (e.g. Street 1997, Rotmans et al 2000). An important emerging one is transition management as proposed by Rotmans et al (2001), which currently has a strong influence on environmental policy in the Netherlands. It is also meant for achieving transformations or system innovations towards sustainability taking at least decades. Like backcasting it has characteristics like (Rotmans et al 2001) long term thinking as a framework for guiding or shaping short-term actions, a focus on learning and mutli-actor involvement. Participatory backcasting, however, does not focus so much on keeping a large number of options open, nor does it include improvement of existing systems. The key of backcasting is to identify possible alternatives and to explore and develop trajectories (recognising the constructive and evolutionary nature of such trajectories). Furthermore, transition management emphasises the governance and leading role by the government, while participatory backcasting, as dealt with in this chapter, emphasises that the governance of system innovations towards sustainability needs to include its multi-actor character (in a smart way). Furthermore, participatory backcasting assumes that future visions can be seen as multi-actor constructed and may therefore have the potential to develop into so called guiding visions or images (Grin & Grunwald 2000). The latter is much more difficult, if all options are kept open as long as possible, as is proposed in transition management.

Despite these differences, it might be possible that transition management and participatory backcasting could be seen as complementary. Backcasting seems to be a strong approach for constructing future visions endorsed by a wide range of stakeholders and for identifying and exploring alternative socio-technical systems, while transition management might be strong in implementation and managing the implementation process necessary for realising the transition on the long term. However, further study is needed in order to improve our understanding on this issue.

6.4. Backcasting: relevance for government and governance

Change processes towards sustainability on the level of system innovations require the participation and contribution of all four societal groups distinguished in this chapter, which were business, government, research and the public & public interest groups. Business is important for producing sustainable products and services. Researchers and research bodies are important for developing the knowledge necessary for future sustainable alternatives. The public is important for at least two major reasons: democratic legitimisation and as consumers, as sustainable alternatives need to be consumed before the environmental benefits can be realised. In general, it can be said that it is important to mention that it is not only important that societal groups or specific stakeholders play their role, but also that interaction takes place between and among stakeholders contributing to shared visions and, if appropriate, joint or co-ordinated action.

But what should be the government role[2] and what kind of governance could facilitate system innovations or transformations towards sustainability? We argue that the role of the government is indispensable because of the long time horizon, the complexity of the processes, and the need for an actor that guards the general direction of sustainable development. However, government needs to reflect upon its own functioning, and has to develop a concept of governance that is suitable for influencing transitions.

Government participation seems to be crucial for further development, implementation and embedding of the results of a backcasting experiment. Government could be part of backcasting in various roles. First of all, like in the STD Programme, government agencies could actually set up and finance backcasting activities as part of their long-term oriented strategic research policy, for instance for sustainable development. In this way, backcasting activities acquire the credibility and the legitimating that is necessary to attract major stakeholders. As an example, in the STD Program it was a very important feature that the Programme was organised by five Ministries jointly, and that they accepted the challenge of factor 20 environmental efficiency as a long-term goal as a legitimate starting point for the Programme. Secondly, government agencies and employees can participate in workshops and other activities that are part of the backcasting activities aiming at system innovations towards sustainability. They can participate in their role as experts, as representatives of their department or agencies, or as individuals that can perform boundary-spinning roles, connecting the thinking within government agencies with thinking in other multi-stakeholder arenas. Thirdly, government agencies can set rules and regulations and more generally change the regulatory environment in order to endorse projects and activities that are part of the backcasting endeavour. For instance, in the case of Novel Protein Foods, governments could regulate the meat chain and the alternative (novel protein) chains in such a way that the more sustainable alternative might acquire a competitive advance with respect to the incumbent production and consumption chain. As an example, the California Zero Emission mandate of 1990 has spurred a

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2 It should be realised that governments are plural in itself and that therefore specific actors or stakeholders can be distinguished in the government.

lot of research and development activities both in electric vehicles and in fuel cell developments. Here, backcasting can be used again for exploring possible zero emission futures.

Concerning the governance of system innovations or transformations towards sustainability, Grin et al (2003) have explored the contours of a novel governance policy concept for governing system innovations or transitions. They argue that governments need to develop a third generation of environmental policy in addition to the second generation based on stakeholder orientation and social learning. The boundaries for this second-generation environmental policy have been reached because of structural impediments in society: the physical infrastructure, social conventions, existing regulations, available knowledge and the knowledge infrastructure. The challenge is how to formulate a policy that addresses this cultural and structural entrenchment without falling into the trap of planning by blueprints They argue that it requires not a huge planned attack on the existing system, but system changes may be brought about by "….*concrete contextual practices that, to a certain extend, do not follow the existing rules….*". Various practices may reinforce each other and eventually may lead to a system innovation. For the government there are two roles: foster innovative practices, and foster mutual reinforcement of these practices. The former was also recommended elsewhere (Irwin et al 1994, Vergragt 2000). Mutual reinforcements of innovative practices may be achieved by developing connective infrastructures, regulation on a more general level, technologies that fulfil social needs in various contexts, and research programs aimed at investigation of knowledge gaps. It may be added that forms of network management aiming explicitly at connecting innovative practices may be useful here.

So, what does this mean practically in cases of plural multi-actor contexts and multi-actor processes in our constructive world, while there are no rule sets and institutions available (as mentioned already in Section 3.4 when dealing with the theoretical aspects of backcasting)? It should aim at higher order institutional and policy learning through participatory development and exploration of long-term future visions. However, it needs to be investigated further how future visions play a role in contextualising and connecting individual innovative practices, and how to provide them with a meaning that goes beyond the innovative practice itself.

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Environmental Policy Shift

Through Technological Innovation

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1. Technological Environmental Innovations (TEIs) and Metabolic Consistency

Environmental innovation includes any kind of innovations – technical, economic, legal, institutional, organisational, behavioural – that lead to an improvement of ecological quality, regardless of any additional advantage or motive (Klemmer et al. 1999 25, also Hemmelskamp/Rennings/Leone 2000).

This chapter just deals with technological environmental innovations (TEIs). A technology is a body of knowledge, especially know-how, but also includes some theoretical know-why as well as know-what-for (also Freeman 1987 235, Kemp 1997 pp7). As far as know-how is concerned, a technology is a method of applying a specific knowledge base for achieving a specified operative purpose by special operative means such as tools (instruments, materials, machinery, plant equipment, infrastructures) and practices. Products – as much as production processes and services – are specific instrumental manifestations, or apparatus-like implementations of a technology. Products, processes and services tend to be marketable, commercialised applications of a technology.

In order to qualify as a TEI for entry into the database of this study, technological innovations had to meet one or several aspects of the environmental innovation strategies as listed in Table 1.

Table 1: Selected concepts of technological environmental innovation according to the realm of innovation where they most apply

Realm / Approach	Energy incl. vehicles propulsion, heating	Raw materials. Natural resources	Agri-culture	Chemistry, Chemicals	Materials processing and repro-cessing	End-pro-ducts: Buil-ding, vehic-les, utility goods	Emissions control, waste processing
Industrial symbiosis. Zero-emission processes. Circulatory economy	x	x	x	x	x	x	x
Sustainable resource management	x	x	x	x	x	x	
Cleaner technologies	x	x	x	x	x	x	
Benign substitution				x	x	x	
Product design for environment				x	x	x	
Bionics				x	x	x	
Add-on purification technology							x

Another, and perhaps more coherent way of deciding whether a technological innovation qualifies as an environmental innovation, is to determine whether a new technology or product contributes to significantly increasing eco-efficiency and/or improving ecological or metabolic consistency. These terms are closely linked to the sustainability discourse and to the concept of industrial metabolism (Ayres 1996), or industrial ecology respectively. Criticism of the shortcomings of the previous sustainability discourse has been a key element in the more recent discourse on ecological modernisation (Andersen/Massa 2000, Mol/ Sonnenfeld 2000), and within this context it was the starting point of the concept of ecological or metabolic consistency (Huber 2004, 2000), sometimes also referred to as eco-effectiveness (Braungart/McDonough 2002 103–117).

Metabolic consistency focuses on the structural, qualitative side of technology, not just input-output-quantities within basically given structures. Ecological consistency is about how to re-embed the industrial metabolism within nature's metabolism by introducing new technosystems, regimes and practices, thus changing technological structures and the metabolic qualities of products and processes, rather than mere quantity of turnover within old structures. E.g., energy demand on giga and tera levels may not be an ecological problem as such if the energy were based on clean fuels such as hydrogen, or represented fuelless energy from solar, wind, hydro and geothermal sources. Whereas an efficiency approach primarily appeals to green savings com-missioners, a consistency approach calls for green inventors and investors.

In terms of various lines of ecological discourse, TEIs can thus be characterised as being the operative tool-set of technological regimes aimed at ecological modernisation, i.e. structural change towards benign or at least strain-relieving effects on resources, sinks, ecosystems and the biosphere. TEIs eliminate, or reduce, or help to control environmental hazard (risk). TEIs create metabolic consistency and optimise eco-efficiency. TEIs can be add-on as well as integrated, although integrated solutions are in almost any case preferable from an ecological point of view.

2. Collection of TEIs and database

The criteria of TEIs and its systematics emerged in the course of long-standing empirical research, which has since 2001 also been carried out in connection with the Key Environmental Innovations group of the German Federal Research Ministry's Initiative on Sustainability and Innovation. An explorative databank has been created which now numbers 305 datasets, with a total of more than 500 examples of TEIs.

Corresponding to the approaches of innovation life cycle analysis and product chain analysis, the datasets include information on a technology (products, materials, processes, practices), its structural impact, the life cycle stage of development and diffusion, on rival like technologies, competitiveness and adoptability, as well as ecological properties and environmental improvements which have been achieved or can be expected.

The databank has been fed by a continuous survey of innovations as they were reported in articles in a number of specialised journals and newsletters from the beginning of 2000, partly earlier, through to March 2003.

3. Some examples and trends of TEIs

- Typical examples and trends of TEIs include the following. They all represent innovative regime shifts from mature conventional technologies to new ones that are metabolically more consistent, and normally also much more efficient than previous like technologies:
- Replacement of fossil fuels with clean-burn hydrogen, the use of which does not require additional end-of-pipe purification of emissions
- Substitution of clean electrochemical fuel cells for pollutant furnaces and combustion engines in manifold applications, from power stations to vehicle propulsion
- Clean coal, notably in zero-emission central power plants on the basis of IGCC technology (integrated gasifier combined cycle) and CO_2 sequestration. The purpose of these power plants is to produce hydrogen by steam reformation as much as to generate electricity.
- Fuelless energy such as photovoltaics and further regenerative energies which make use of sun radiation, geothermal flows, or wind and water currents
- Decentral micropower, i.e. new sources of electricity generation that are leading towards distributed power generation (which includes a certain number of large central stations). Over-centralised power generation and one-way distribution will thus be replaced by an integrated two-way-flow grid management.
- Transgenic biochemistry which makes use of enzymes and microorganisms especially designed and bred for various production tasks, thus replacing the conventional high-temperature high-pressure chemistry that poses a heavy burden on the environment and human health
- Substitution of high-hazard chemicals for more benign low-impact substances and new specialty chemicals which are, among other things, biodegradable, non-persistent, non-accumulative and non-toxic
- Biofeedstocks replacing petrol as a raw material to a certain extent
- New materials which are simultaneously ultra-light and ultra-strong, saving larger volumes of conventional materials and energy
- Micromachines and nanotechnology which relieve pressure on resources and sinks compared to larger conventional machines and chemical production
- Substituting sonar, photonic and microfluidic analyses for cumbersome conventional methods involving many hazardous ingredients, and thus considerably improving quality and performance of production

- Circular production processes in which water, auxiliary substances, metals, bulk minerals and fibres are recycled at an optimum rate
- Last but not least, overcoming the ecologically devastating practices of today's over-intensified and inappropriately chemicalised agriculture by introducing sound ecological practices in combination with high-tech precision farming and, again, modern biotechnology which makes use of transgenic organisms.

Since biotechnology is a sensitive issue, it may deserve a brief comment: genetic engineering in agriculture, as well as transgenic biotechnology in chemistry, nanotechnology, materials processing, waste management, pharmacology and medicine, has to be considered as an important field of TEIs, full in the knowledge that such an assessment will certainly remain controversial for another one or two decades to come. As tends to be the case with true key innovations of major structural importance, people's sense of security is undermined. Conservative opposition and risk aversion are strong. It takes time to replace uncertain expectations with realistic experience. Not all feelings of uneasiness are unfounded, but in most cases it has turned out that in fact they were. Almost all transgenic innovations seem to spur efficiency, and most of the examples represented in the database are environmentally benign in that they allow to substitute, e.g., for conventional high-temperature high-pressure processes, hazardous chemicals, resources input and emissions output. Biotechnologies improve on productivity and product quality. In comparison to these advantages, fears of particular disadvantages are dwarfed, or are untenable in face of the facts. But not all applications – such as pesticide-resistant crops – can be said to be metabolically consistent. Some are not, or not yet.

4. TEIs tend to be upstream the product chain and upstream a technology's life cycle

In terms of integrated solutions versus add-on measures, 85% of TEIs in the database represent integrated solutions, 15% environmental add-on technology. This is hardly surprising, serving to confirm what was to be expected. Of the 85% integrated solutions, 49% can be said to be driven mainly by ecological motives so that these are TEIs by prime intention, whereas in 36% of the examples ecological motives, though these may also be considered, cannot be said to be the main reason behind that innovation.

The central finding which emerges from the present investigation is that most TEIs, and also the most important TEIs in terms of structural impact, tend to be upstream in the manufacturing chain, and upstream the learning curve in the life cycle of a technology or product. The upstream tendency of TEIs is all the more true if we consider energy technology to be upstream in any production function in that it is a primary basic input component at each step in the manufacturing chain.

In the environmental literature, the term 'life cycle analysis' is often used interchangeably with 'product chain analysis' or 'eco-balances' that try to gauge the environmental impact of a product from first input by extraction of raw materials to last output by being definitely phased out as waste. What they represent more precisely, however, is analysis of the vertical manufacturing chain or product chain as shown in Figure 1. By contrast, another meaning of life cycle analysis refers to an innovation life cycle or technology life cycle as shown in Figure 2, i.e. the evolutive existence of a technology or product species.

Figure 1: The product chain

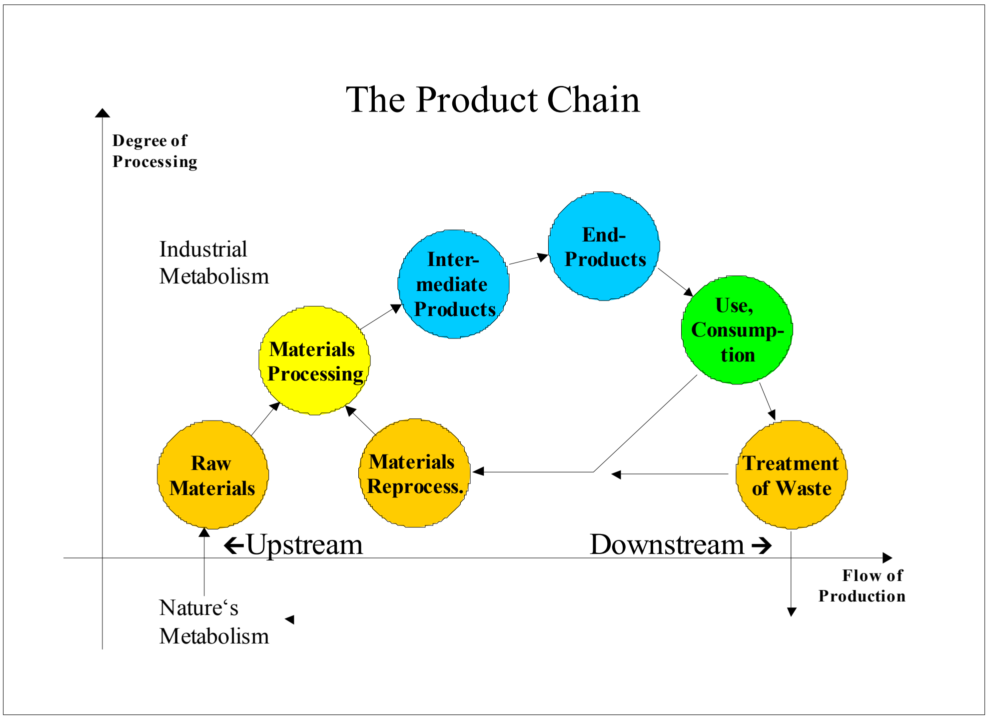
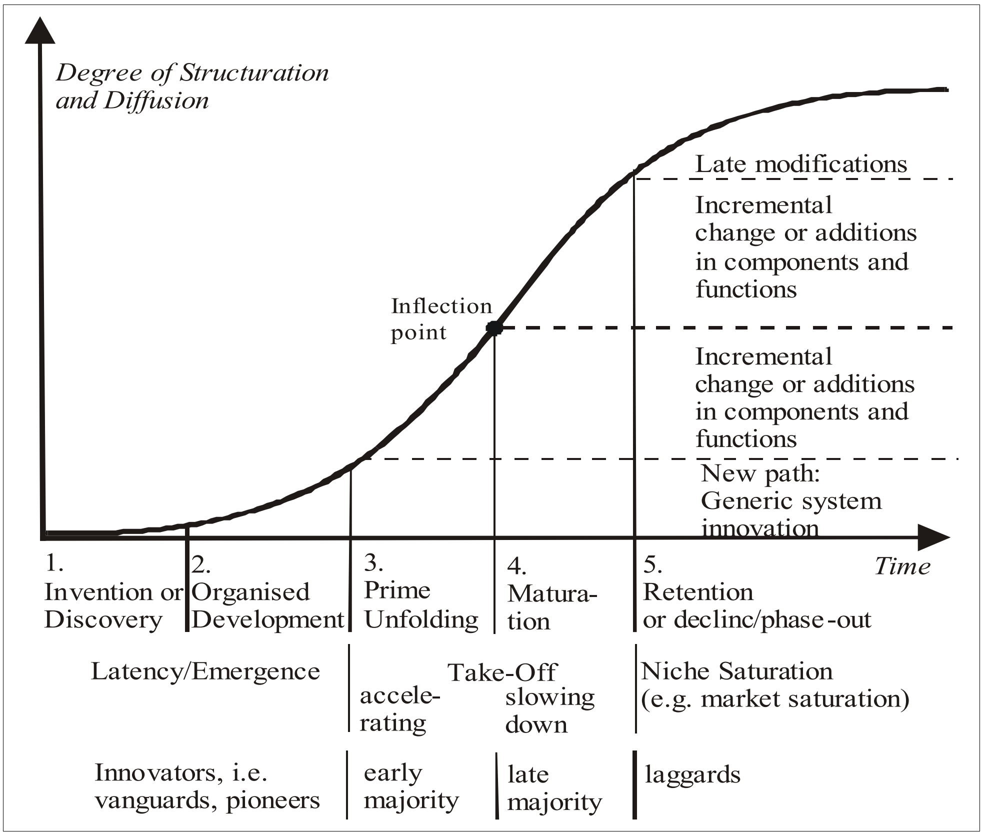
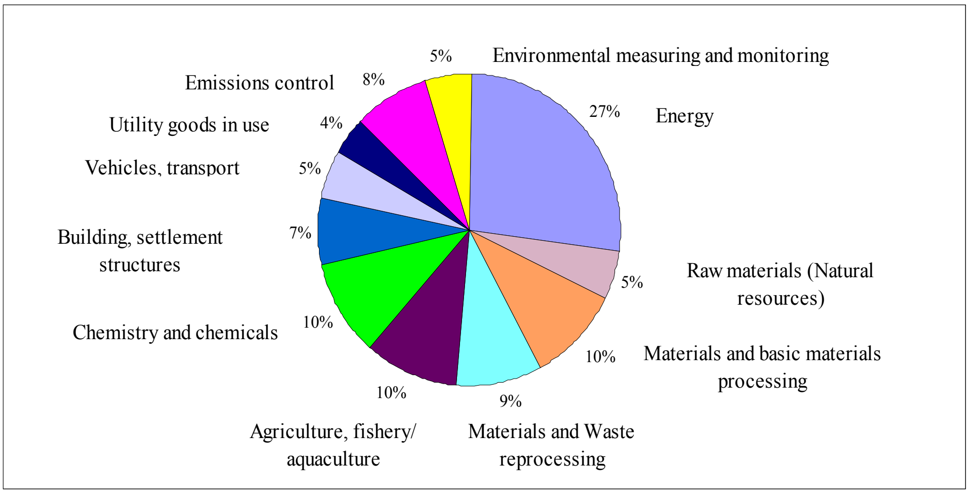


Figure 2: The innovation life cycle



As can be seen in Figure 3, more than a quarter of the datasets (27%) relate to energy, including vehicle propulsion and energy design of buildings (not however innovations related to energy demand of appliances). The number of TEIs in the realm of energy is matched only by 24% of technologies relating to the extraction, processing and reprocessing of materials, which accounts for 34% if agriculture is included, and 44% if TEIs in the realm the chemical industry, 52% if emissions control is added to this.

Figure 3: TEIs according to realm of innovation (n = 298)



We can try to specifically ascribe energy technologies and emissions control to the sectors where they actually occur within the vertical manufacturing chain. We can thus make a distinction between end-products on the one hand, and intermediate products, and primary or base products, both representing pre-products, on the other hand. We can furthermore distinguish user or consumer behaviour (practices) from producer practices (behaviour and regime rules). We again exclude TEIs regarding off-site measuring and monitoring. This results in the categories of (a) primary or base production and materials, (b) materials processing and intermediate productions, (c) final productions and products, and (d) user behaviour or consumer practices as shown in Table 2.

In this way the upstream concentration of TEIs emerges even more markedly. Primary productions and base products represent the biggest slice with 44%, materials processing and intermediate products 27%, making up 71% of the TEIs in primary and intermediate productions. Final productions and end-products represent 25%. Most of this relates to building and vehicles rather than office and household appliances and consumer goods. By contrast, innovative practices regarding consumption and private user behaviour (such as soft driving, car-sharing, leasing instead of buying, avoiding overheating of rooms, etc.) at 4% do not count for much. Even if this figure were doubled or tripled, the finding and its message would basically remain the same: TEIs are upstream rather than downstream in the manufacturing chain.

As a rule of thumb one can say the more products and production processes are placed chain-upwards, the more important the potential of their environmental impact is. This is particularly the case with regard to the difference between all of the steps of extracting and successively (re)processing materials, which regularly cause large environmental impact, and the final assembly or finishing of final products, which causes comparatively less impact. In the same sense it can be said that it is the processes of production rather than the use of products which cause environmental impact.

Table 2: TEIs (products, processes, practices) according to chain position

<table>
<tr><td>Primary productions or base products
e.g. raw materials, primary fuels, power stations, agriculture, forestry, base materials (steel, cement, pulping, tanning, …), secondary raw materials from recycling, also incl. related add-on-purification technology</td><td rowspan="2">Pre-products and pre-producer practices

71 %</td><td>44 %</td></tr>
<tr><td>Materials processing and intermediate products
e.g. metal and surface working, paper making, wood processing, furniture, textiles manuf., production of cycleware, dyeing/coating, food processing, etc., including related
energy technology (e.g. industrial furnaces, stoves, burners), also incl. related add-on-purification technology</td><td>27 %</td></tr>
<tr><td colspan="2">Final productions, end-products
Buildings, vehicles, utility and consumer goods, including related energy technology (e.g. car propulsion, house heating, electr. demand of appliances), also incl. related add-on-purification technology, and producer practices</td><td>25 %</td></tr>
<tr><td colspan="2">User behaviour, consumer practices</td><td>4 %</td></tr>
<tr><td colspan="2">n = 288</td><td>100 %</td></tr>
</table>

There is, however, an important exception: long-lived complex energy apparatus such as motors in cars, jet engines, power plants, heating systems and electric appliances which consume large quantities of fuel. Food, feed and fuels have a metabolic rate of almost 100%. This makes a big difference to use-materials which by and large keep their physical structure when used. If there are important, unresolved environmental problems to be found in the use of final products, they indeed have in most cases to do with the fuels and the energy apparatus involved in using those products.

As regards the innovation life cycle stage of TEIs, as summarised in Table 3, 3% are just an idea on paper, 10% are in an early stage of research and laboratory demonstration, 26% in a more advanced stage of development, i.e. 36% in the development stage. 35% then are at market launch or shortly thereafter, or otherwise being introduced to regular practice. 16% are in experiencing growing adoption, though this does not always represent an impressive take-off. The remaining 10% represent mature technologies in a rather late stage of structuration and diffusion.

Table 3: TEIs according to stage of life cycle

Idea, concept on paper	3 %
Early stage of research and laboratory demonstration	10 %
Advanced stage of development	26 %
About market launch or introduction, or shortly thereafter	35 %
Experiencing growing adoption	16 %
Mature stage	10 %
n = 289	100 %

The distribution in Table 3 was to be expected. Ideas and early experiments are normally not communicated to a broader public, just as technologies in a late stage of their life cycle are normally not subject to public attention since nothing particular is occurring any more. It is nonetheless important to have this documented empirically, because it confirms one of the basic recommendations that can be drawn from life cycle analysis: true progress which includes structural change, particularly regarding a change in the ecological consistency of the industrial metabolism, requires a change in path; i.e. it requires the development and implementation of new technologies rather than the modification of mature systems already in place.

It is important here to understand that with technologies, as with living organisms, the key features of a novel thing and its life course are determined upstream rather than downstream, i.e. with regard to an organism, in its genetic code and in its early days of growth, experiencing and learning; and similarly with regard to technologies, in their conceptualisation and design, in the early stages of research and development, i.e. the early stages of structuration and diffusion. What remains to be determined during later stages, consists of incremental changes and modifications of minor importance, after the point of inflection of a learning curve has been passed. Most of the environmental pressure which is caused by producing and using a certain kind of product or technology is determined right at the beginning with the conceptualisation and design of that product or technology. Once in place, there is not much left which one can do about it, aside from some improvements in later new-generation variants of that product, some percentage points of materials and energy savings in the factory, and a few percentage points by being a good consumer.

As is shown in Table 4, most TEIs do indeed bring about change in ecological consistency. In about a quarter of the TEIs, there are significant efficiency increases without a change in metabolic properties. Typical examples of this include reuse of parts and recycling of materials, e.g. of solvents or sulphuric acid, or increased fuel-efficiency in internal-combustion engines. Three quarters, however, involve some consistency change.

The biggest share, at 41%, is that of examples where there are both consistency improvements and efficiency increases, e.g. latest-generation solar cells, fuel cells of any kind, and many biotech applications of where there is simultaneously less or no environmental pressure and higher yield. The percentage of such double-surplus-TEIs is nevertheless lower than was hypothetically supposed, whereas the number of cases in which there is less inconsistency rather than really benign improvements are more than was expected.

Table 4: TEIs according to ecological consistency and efficiency

Consistency improvement without efficiency change, or efficiency unclear, or even slightly decreased	16 %
Consistency change in the sense of lesser degree of inconsistency without efficiency change, or efficiency unclear, or even slightly decreased	8 %
Consistency change in the sense of lesser degree of inconsistency combined with increase in efficiency	12 %
Both consistency improvement and efficiency increase	41 %
Mere efficiency increase without actual change in ecological consistency	23 %
n = 281	100 %

Typical examples of lesser degree of inconsistency without efficiency change include exhaust catalysts, transmutation of nuclear waste, GM crops tolerant of agrochemicals, or HCFC-22 (chlorodifluoromethane) as a halocarbon replacements for conventional CFCs.

Replacement with SF_6 then is an example of lesser degree of inconsistency combined with some efficiency increase, because on eco-balance SF_6 helps to save CO_2 emissions. Further examples in this category tend to be incremental process innovations which help to reduce hazardous auxiliaries or materials-content while simultaneously increasing output.

An example of benign consistency improvements without efficiency changes are hydrogen-fuelled internal-combustion engines. Previous generations of solar cells and wind power, though clearly clean and metabolically consistent, even came with less efficiency than conventional like technologies.

5. Conclusions: Paradigm shift from downstream to upstream the product chain and technology life cycles

The central message from the above findings concerns a paradigm shift from downstream to upstream in the vertical product chain and in technology life cycles. I would like to mention four aspects of such an upstreaming of environmental action and policies.

First, if environmentally significant technological innovations are to be found chain-upwards rather than chain-downwards, then priorities would need to be refocused onto those industrial operations where large environmental impact actually occurs – in energy, raw materials, agriculture, chemistry and base industries, partly also in building and vehicles.

Second, the key actor groups that have to be mobilised are technology developers, product designers and producers rather than users and consumers. With a focus on products and production, one would not be spending too much time with user behaviour and consumer demand. New technologies do not occur by way of demand pull. Important environmental innovations originate on the supply side. They are science-driven and technology-pushed, induced by ideas and interests, one of which may be solving environmental problems – though further selective impulses from the side of regulation, government and user demand certainly come in later on.

The fact that most environmental impacts are determined and caused upstream in the life cycle and upstream in the product chain puts final consumption in a somewhat paradoxical role. This ecological paradox of consumption is as follows: On the one hand, expectations of high and still rising levels of affluence are indeed among the main driving forces behind the ongoing growth of industrial production and the large volumes of turnover of the industrial metabolism; on the other hand, however, the immediate contribution of consumer behaviour to the industrial metabolism is rather low, about 5–15% to gauge it generously. This is because most of the environmental pressure, the big ecological footprints or materials rucksacks of consumer society, occur during the different steps upstream in the product chain, and are determined by the basic principles of a technology and the physical design of a product, in the early stages of their life cycle. In contrast, consumption in service businesses and private households entails final steps downstream in the product chain. Approaches such as 'sustainable consumption' or 'sustainable household' can, in the end indeed, not be particularly effective in changing the industrial metabolism.

Third, in upstreaming environmental activities, chain management by key manufacturers and trade businesses has a particular role to play. It is the manufacturers of complex end-products such as buildings, vehicles, appliances, and also large retailers such as mail order firms, who are in the position to effectively implement supply chain management. This is none of a user's nor of a government's business.

Final demand may be decisive with regard to the diffusion of innovations. Demand itself, however, cannot innovate, it cannot 'buy into existence' things which do not exist, i.e. things which are not on the market yet – with one exception, which is the demand by key manufacturers and large trade businesses, because they have, or can have if they wish so, a decisive influence on suppliers along the product chain, and a defining influence on the design and redesign of products.

Fourth, as far as government is concerned, upstreaming environmental policy would induce a shift of emphasis from regulation to innovation. Environmental policy, much more than has hitherto been the case, would have to become a policy of technology development, or will have to cooperate systematically with technological R&D policy. In consequence there would have to be a shift in the pattern of environmental policy from bureaucratic procedural control to co-ordination of national innovation networks, European at the EU level, including suitable and well balanced financial support by granting regular research funds and seed money, as well as providing venture capital and introductory aids in appropriate ways. What has to stay, though, is to set strict environmental performance standards (Ashford 1985, Kemp 1997 pp.317, Hemmelskamp/Rennings/Leone 2000). This remains by far the most effective controls instrument for environment and innovation alike (which is not astonishing given the fact that environmental standards are, or immediately translate into, technical standards).

In face of the discussed findings on TEIs one could go as far as to say: environmental awareness and will-building, regulation by law and environmental authorities, green marketing, and even green business management remain ultimately pointless in the absence of a prior strategy of technological environmental *upstream* innovation to give a common focus to environmental policies.

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Industrial Ecology –

A New Platform for Planning Sustainable Societies

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Introduction

"Whereas conventional economics deals with the flow of money through the economic system, Industrial Ecology or the "economics of resources" deals with the flow of resources through the economic system"[1]

This chapter deals with the relatively new field of Industrial Ecology. The principal basis of Industrial Ecology is that, to develop sustainable societies, it is necessary to perceive the system as a whole, understand the flows of resources through the system and consider finding solutions at a systemic level. The economic planning processes should involve an understanding of how resources flow through the system, with a view to optimizing such flows. The word "resources" refers to material, energy, human and other identified resources and not just to monetary resources.

The scope of Industrial Ecology could be depicted as in Figure 1 As can be seen from this figure, the perspective encompasses, not just industry as it is normally understood, but other components of the socio-economic system as well.

What is Industrial Ecology?

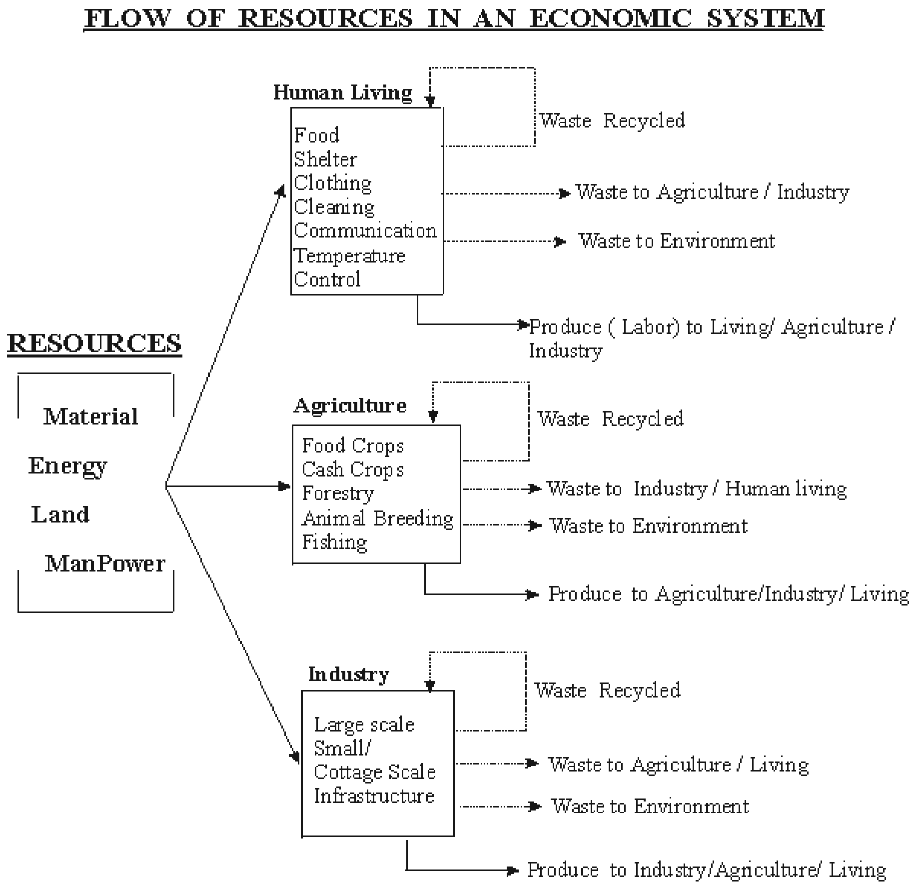
Industrial Ecology explores the assumption that industrial system can be seen as a certain kind of ecosystem. After all, the industrial system, just as natural ecosystems, can be described as a particular distribution of materials, energy, and information flows. Further, the entire industrial system relies on resources and services provided by the Biosphere, from which it cannot be dissociated

[1] Ramaswamy, Ramesh, Relevance of Industrial Ecology in Developing Countries, Perspectives on Industrial Ecology, Greenleaf Publishing, UK, 2003

The key elements of an Industrial Ecology perspective are:

a) it is a systemic, comprehensive, integrated view of all the components of the industrial economy and their relations with the Biosphere.
b) it emphasizes the biophysical substratum of human activities, i. e. the complex patterns of material flows within and outside the industrial system, in contrast with current approaches which mostly consider the economy in terms of abstract monetary units, or alternatively on energy flows.
c) it considers technological dynamics, i.e. the long term evolution (technological trajectories) of clusters of key technologies as a crucial (but not exclusive) element for the transition from the actual unsustainable industrial system to a viable industrial ecosystem.

Figure 1: The Scope of Industrial Ecology



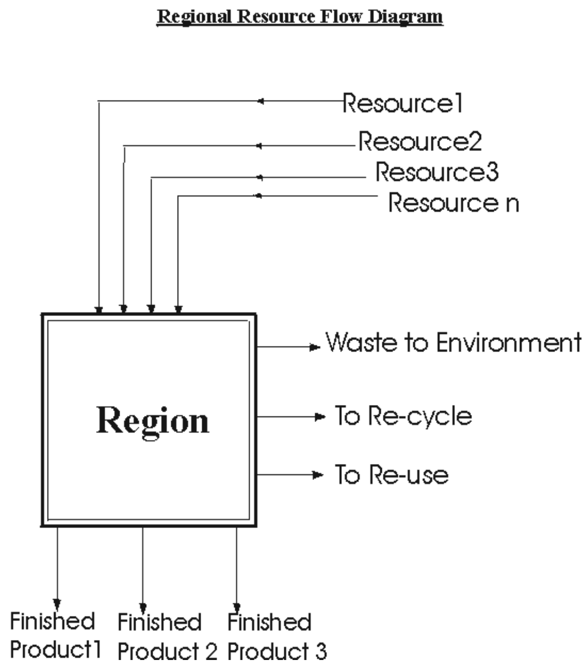
Application of Industrial Ecology in Developing Countries

The concepts of Industrial Ecology can be effectively used in developing countries. Although some of these countries are considered to be rich in natural resources, their availability to the local society is often extremely limited. Any effort to improve the productivity of resources would greatly enhance their economies, quality of life, and sustainability. Principles of Industrial Ecology, which aim to maximize resource productivity, should be central to the economic and development planning process.

Four studies were carried out in India during the period 1995 to 1998 that highlight the use of Material Flow Analysis, the core methodology in Industrial Ecology, in developing a planning platform. In the context of developing countries, since the discussion centers around resources, it has been referred to as Resource Flow Analysis or RFA. A fifth case on a Corporate Sugar Complex in India has been included in this set of cases, that points to new approaches to corporate planning, in the context of Industrial Ecology.

The base format that has been used in the analysis of resource flows in all the four cases presented is shown in Figure 2.

Figure 2: Regional Resource Flow Diagram



This format would help to understand the flow of resources through the system (material, energy, land and manpower). Such an understanding could help societies to assess the opportunities available to them by maximization of the productivity of limited resources, and to more fully assess the threats from their use (or misuse).

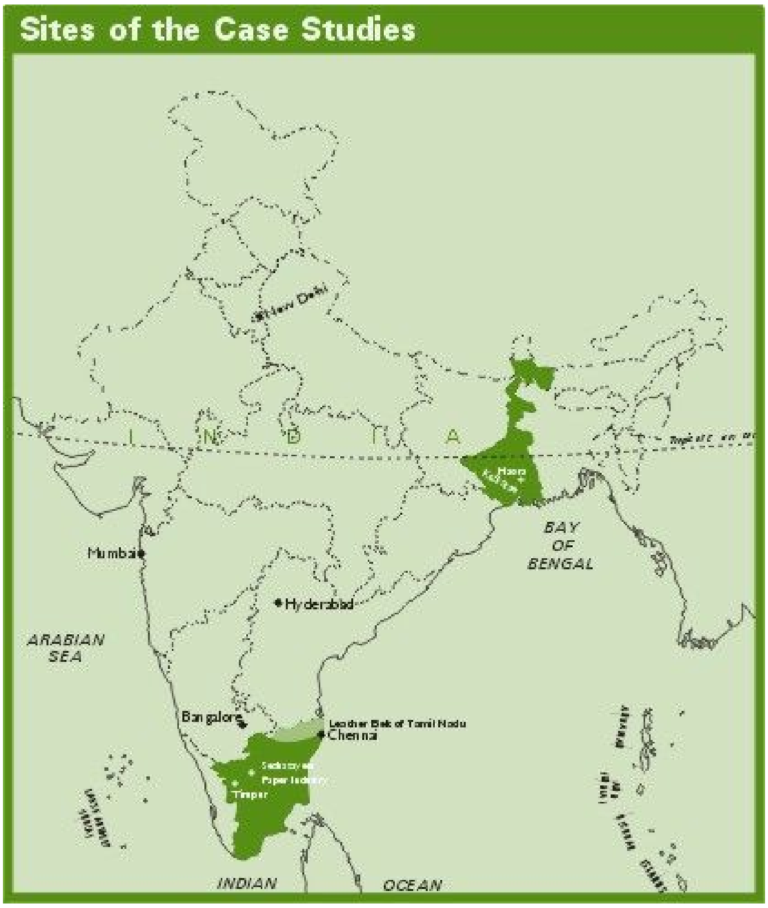
The case studies from India showcase the utility of this approach. Each of these cases illustrates in a specific way the relevance and utility of the Industrial Ecology perspective in planning.

Case Studies From India[2]

Although the data has not been updated (the data pertains to the early and mid 1990s), the core issues have remained unchanged over the years and are adequate for the purpose for which they are presented here. Figure 3, shows the sites of the case studies in India.

2 Erkman Suren & Ramaswamy Ramesh, Applied Industrial Ecology – A New Platform for Planning Sustainable Societies, AICRA Publishing, India, 2003

Figure 3



Case Study of the Textile Industry in Tirupur

Tirupur is a major center for the production of knitted cotton hosiery. The town is located in the south of India and has a population of about 300,000. The 4,000 small units in the town specialize in different aspects of the manufacturing process.

The aggregate annual value of production in the town is around US $ 825 million. Much of the produce is exported bringing in very valuable foreign exchange. Till about the 1980s, for decades, the center was only manufacturing white undershirts called "banians", which are commonly worn by men in India. The industry then discovered the lucrative international market for colored T-shirts, which led to a boom in exports. This enormous growth in the production of colored textiles, led to an increase in the dyeing operations in the town.

Water is scarce in the area and the wet processing of textiles (particularly dyeing) has rendered the groundwater unusable. A large quantity of salt is used in the dyeing process and the process wastewater (90 million liters per day) is highly saline and is contaminated with a variety of dyes and chemicals. As there is hardly any other source of freshwater nearby, trucks bring in water from groundwater sources (which are yet to be polluted) as far as 50 km away at an enormous cost. The industry has internalized the cost of transporting water in its operations

The shortages of clean water have been a source of great concern, as the people in the area have no water for their domestic needs. The water pollution has also totally ruined the agricultural operations in the region. The pollution control authorities have been striving hard to stop the industries from polluting the water

A massive US$ 30 million project is under way to treat the wastewater at Common Effluent Treatment Facilities. After such expensive treatment, the water will still be unusable, as the facility does not include any system for desalination of the wastewater.

A RFA (Figure 4) was carried out for the town. Only when the figures were aggregated did the industrialists realize that they were collectively spending over US$ 7 million annually on buying water and in addition, the annual maintenance cost of the effluent treatment plant would be an enormous burden.

Since water is used at so many different points and the industrialists had internalized the cost of buying water in their operations, neither the total volume of water used in the town nor the amount of money collectively spent by the industry in buying water, were immediately obvious. An RFA for the town opened the eyes of the industry to the magnitude of resources consumed.

These aggregate figures also showed that water could be recycled profitably. On the basis of the study, a private entrepreneur developed a water recycling system, which could be installed in each dyeing unit. The system used the waste heat from the boilers already working in the dyeing units for the recycling process. This is a relatively low cost system, which is gaining popularity in the town.

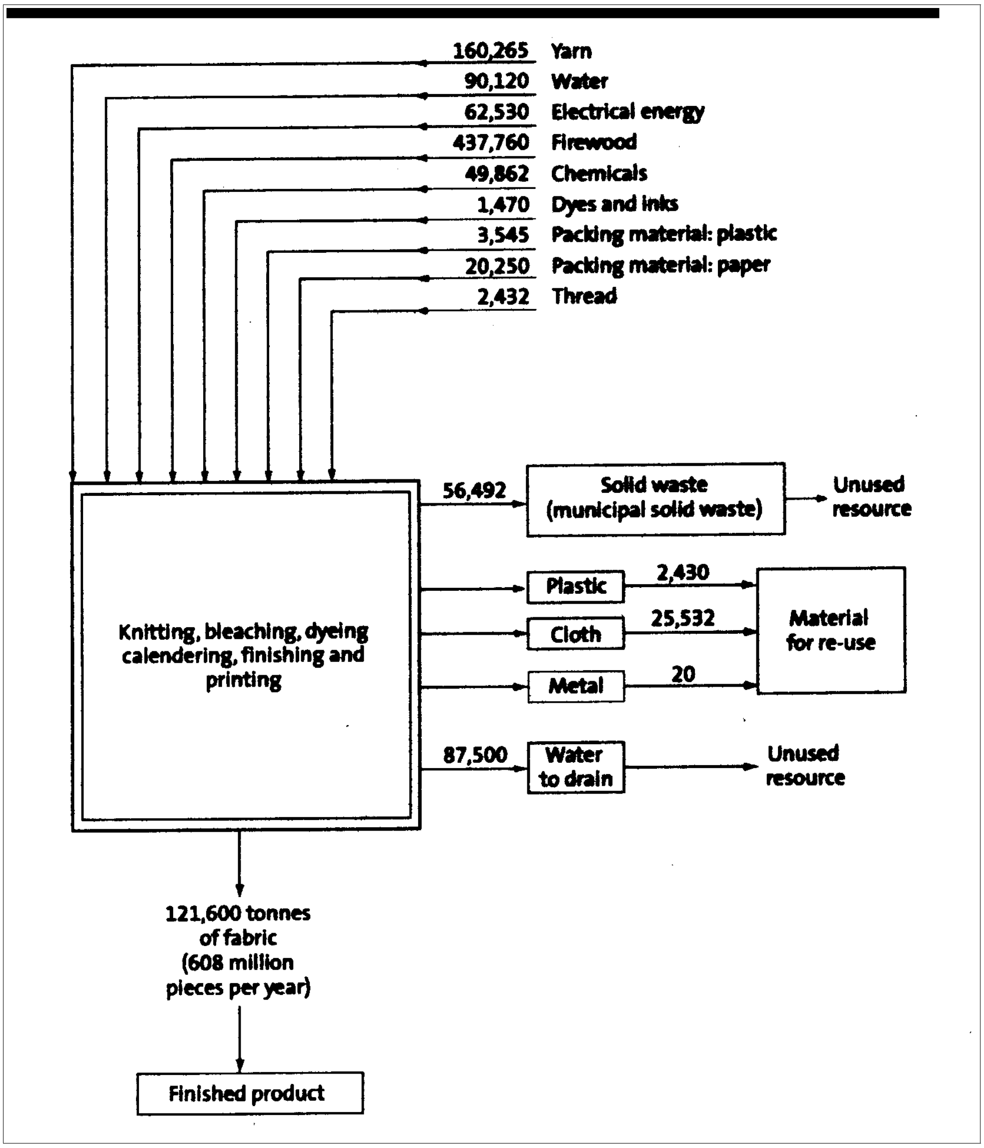
Similarly, since the use of the firewood is distributed over nearly 1200 points, it was not obvious that nearly 500,000 tonnes of firewood were being used annually in the town. There is grave concern over rapid deforestation in India. The possibility of setting up a central steam source, with the option of solar preheating, was suggested as a way to reduce the consumption of firewood.

Another outcome of the study was that it highlighted the fact that the calorific value of the municipal solid waste (garbage) was high as it contained large quantities of textile and paper wastes. This could be used effectively to partially replace the firewood being consumed in the town.

The case illustrates the significance of the Industrial Ecology approach in the context of a developing country. For many years a number of research and development institutions have carried out "pollution control" & "cleaner production" studies in Tirupur to minimize water use, minimize use of dyes and to "improve" the quality of the effluent. No references could be found to any study aimed at evaluating the possibility of profitably recycling the wastewater in the town, which should have been the first priority, from the point of view of Industrial Ecology. Again, since "pollution control" was seen as the only issue, no attempt appeared to have been made either to minimize the use of scarce firewood or to leverage the high calorific value of the solid waste in the town.

The case clearly illustrates the use of an RFA to understand various material flows in an area and its use for planning.

Figure 4: RFA for the textile industry in Tirupur. Units: water: thousand liters per day, electrical energy: thousand kWh per year, others: tonnes per year



Case Study of the Foundries in Haora

There are nearly 500 cast iron foundries in Haora, a suburb of Kolkata (formerly Calcutta), in Eastern India. The air pollution from the foundries has been a source of concern. The pollution control authorities have been insisting on the foundries installing pollution control systems to mitigate the emissions. The poor health of the engineering industry in the eastern region has affected the financial health of the foundries here, which now subsist on manufacturing very low value-added products like manhole covers. Since pollution from the foundries was a major source of concern for the state authorities and a matter of public debate, a number of agencies had launched studies to develop and set up technologies and equipment for limiting air pollution.

One of the governmental research agencies had developed a process to use natural gas instead of coke (the major cause of pollution) that the foundries were presently using. This process was in an advanced stage of development. It was considered likely that the environment protection authorities may insist on the foundries in Haora using this new technology to eliminate the pollution problem. Since natural gas is not available in the region, the use of this new technology could substantially increase the cost of production and the foundries would not be competitive any more.

An RFA of the region showed that the industry could adapt the new technology to use coke oven gases instead of natural gas. As the eastern region is a major coal producing area and as there are many independent coke ovens, coke oven gas is easily available locally and is often wasted. Depending on the economics, either the foundries could be relocated near the coke ovens or the coke oven gases could be transported to the foundries.

The study highlights the relevance of an RFA to an Industry planner, as it would point to unused resources (by-products or "wastes") in a region. The Industry (or a group of industries) could consider how they might leverage the availability of any of these unused resources to their advantage and for their sustained operations. This could be done by establishing new linkages between industries in different sectors (like foundries and coke ovens). This is far from obvious, unless an RFA facilitates detecting such resources in a systematic way

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Case Study of the Leather Industry in Tamil Nadu

Tamil Nadu, a state in the south of India, is the premier center in India for the processing of leather. Water is scarce in Tamil Nadu. India had traditionally been a major center for the export of hides and skins. In the 1970s, the government of India banned the export of raw hides and skins with a view to improving the value addition of production, and thereby enhancing the inflow of scarce foreign exchange. Environmental issues were not an important part of the agenda of in India those days.

Table 1: Leather Industries in India. Source: Report on the Capacity Utilization & Scope for modernization in Indian Tanning Industry. CLRI, Adyar, Chennai, 1990

	State	Small Scale	Large Scale	Total	Percentage Share
1	Tamil Nadu	536	41	577	53.3
2	West Bengal	227	6	233	21.5
3	Uttar Pradesh	140	7	147	13.6
4	Andhra Pradesh	18	5	23	2.1
5	Maharashtra	27	3	30	2.8
6	Karnataka	15	1	16	1.5
7	Punjab	8	3	11	1.0
8	Other States	37	9	46	4.2
	Total	1008	75	1083	100

This boosted the leather processing activity in India in general and in Tamil Nadu in particular. The industry is a major foreign exchange earner and important to the economy of the state and to the country. Meanwhile, compliance with strict environment regulations has rendered the processing very expensive in the developed world.

The leather industry (which is made up of thousands of small industries) is a major user of water, as each tonne of hide/skin needs 30,000 to 50,000 liters of water for processing. This is a large volume, as the average per capita water availability for urban settlements in India is estimated at around 30 liters per day. Table 1 gives details of the number of large and small leather processing industries in different parts of India.

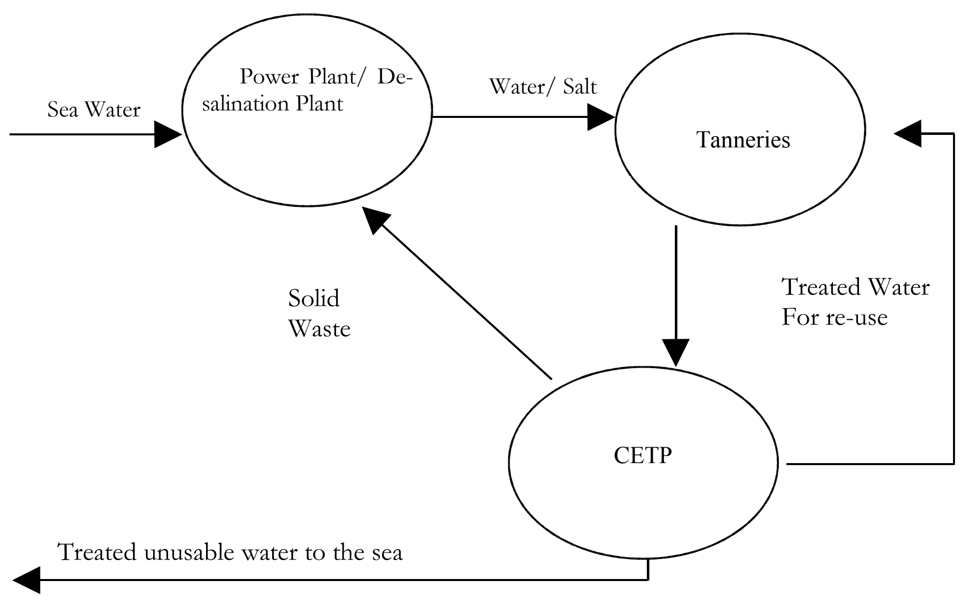
The growth of the industry has resulted in extremely high water pollution in the regions where the tanneries are concentrated. The leather industry has been under pressure from the pollution control authorities and many have subscribed to a Common Effluent Treatment Plant. The water after treatment continues to be unusable, as it is very saline. The sludge from water treatment continues to be a serious problem.

A detailed study in the context of Industrial Ecology helped in redefining the problem, which till then had been only viewed as a "pollution control" issue, as the effluents did not meet the specifications, laid down by the law. Many academic studies have been undertaken to ensure that the effluent quality "comes as close as possible" to the standards using the "Best Available Technology".

However, the problem is much more serious. The tanneries are using a resource; water, which is extremely scarce in the region. It is also contaminating groundwater resources of the local community, which is causing great hardship to the population, as it is depriving them of desperately needed water. It will not be long before the social pressure and the law courts bring the leather industry to a halt. In the context of Industrial Ecology, the first priority is to focus on the use of the local resource, water. The local community cannot afford to spare water for the industry. One option would be to relocate the tanneries along the coast, where they could draw seawater instead of using valuable freshwater. If the industry is unable to develop processes that can use seawater as it is, it will have to desalinate the seawater for its use. The treated wastewater could be discharged into the sea, as long as all pollutants other than salt are removed.

Figure 5 gives a perspective of a possible new scheme for the industry.

Figure 5: A Perspective For The Development Of The Leather Industry



The study points to a new strategy option for sustainability of the leather industry in the region, by re-definition of a problem with a focus on resources. The second significance of the case study is to point to the need for industries or industry groups to carry out studies on resource availability in the region, while establishing new manufacturing centers or expanding the present centers. This could be critical to their long-term survival and their peaceful co-existence with the local community.

Case Study of the Damodar Valley Region

The River Damodar basin, in the eastern part of India, covers a vast area. This mineral-rich region (near Kolkata) is the source of much of the coal produced in India. Coal is a major energy source in the country. Many large power utilities and steel plants are located here, in addition to industries associated with coal, such as coal washeries and coke ovens. The region is considered very highly polluted. An industrial metabolism study was undertaken in the region. The quantities of the "flow" of two of the major local resources, the waters of the River Damodar and coal, were studied. The results of the study gave a good overview of how the waters of the river and coal are used in the system.

Since agriculture consumes nearly 85% of the waters of the river, it was critical to estimate the impact on the agricultural produce, of the thousands of tonnes of potentially toxic wastes dumped into the river, resulting from the high levels of industrial activity upstream. The study pointed (quantitatively) to the extent of dangers and the need to monitor the flows of these toxins through the river and the groundwater, the two sources of water for the population. The study also pointed to the need to monitor the possible danger of the toxins moving up the food chain through the fish in the river and the food crops cultivated in the region. No such evaluation had yet been done.

All along, to reduce the high levels of air pollution, the policy of the regulatory authorities had been to focus on the "major" polluters, which in their opinion were the steel and power plants. These plants have access to some of the best available technologies for controlling their pollution. However, a study of the flow of coal gave surprising results. Huge quantities of coal are consumed in millions of homes and in the informal sector. In this sector, coal is used in very inefficient combustion systems, obviously without any pollution control systems, which makes the whole area extremely polluted. It was obvious that if the air had to be clean, a new fuel policy would have to be evolved. Some new systems of transportation of coal also need to be evolved to minimize the spillages during transportation, a major contributor to the dust levels of the region.

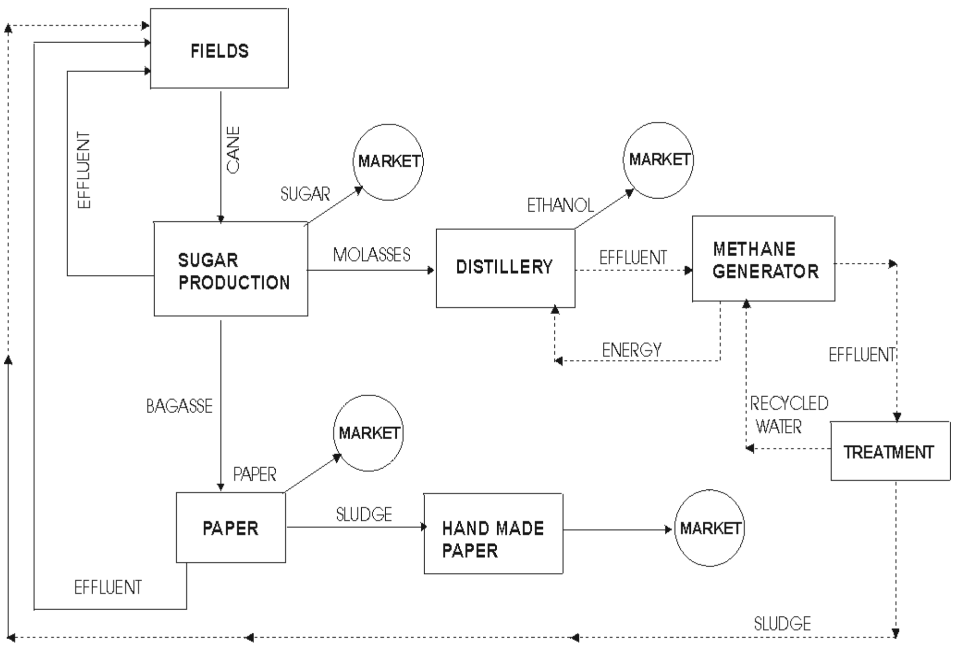
This case highlight the importance of a quantitative study of the resource flows in a region. Even a broad understanding of the "flow" of the resources serves as a guide to the policy maker and gives a new perspective and a direction for policy planning.

The case also highlights another important issue. In developing countries, the consumption of materials and the consequent dangers to health and environment from the informal and domestic sectors could be very large as compared to those from the formal industrial sector. It is just not enough to study the industrial sector. An Industrial Ecology based system-level perspective is essential to identify the major flows of materials in a region for planning resource optimization and for solving environmental problems.

Case Study of a Corporate Paper–Sugar Complex

Industrial Ecology offers the possibility of an alternative corporate planning model. This is illustrated by the case of a paper company, Seshasayee Paper and Board Ltd (SPB), in Tamil Nadu. SPB started a paper mill, which went into commercial production in 1962. In order to ensure regular supply of raw material, a sugar mill was set up. The waste from the sugar mill (called bagasse) was used as a raw material for papermaking. Another waste from the sugar mill, molasses, was used in a distillery nearby for the production of ethyl alcohol. In order to ensure regular supply of sugarcane for the sugar mill, the company took interest in the cultivation of sugarcane by organizing the farmers in the region. The company struck long-term agreements with the farmers to buy back their produce and, in turn, took the responsibility of supplying them with water. Much of the water supplied for cultivation was the treated wastewater from the paper manufacturing operations. The company also used bagasse pith (a waste after the paper making) and other combustible agricultural wastes in the region, as an energy source in their captive power plant. The company had developed an interesting complex of industries, which could be depicted as in Figure 6.

Figure 6: The Paper-Sugar Complex Of Seshasayee Paper And Boards Limited, India



This case study is intended to highlight an alternative corporate planning model, which is compatible with the concepts of Industrial Ecology. Usually, a company plans its growth within a product-market matrix. It tries to define its business as specifically as possible such that its energies in acquisition of capabilities and skills are clearly focused. Many organizations would be reluctant to enter into areas unfamiliar to them. Environmental issues are often seen as secondary to the main goals of the company.

A model where a company sets up not one, but a complex of diverse industries, where one industry uses the wastes of another, is a viable option for sustainable industrial growth in developing countries. The case of SPB also shows that there is a high potential for Industrial Ecology in rural areas, where integrated agro-industrial complexes can benefit the local community through efficient use of resources.

Conclusion

In addition to attempting better resource management, the relevance of Industrial Ecology to governance in developing countries is important in two aspects.

- All along most policy making has often laid greater focus on the manufacturing step, more specifically in the large organized industry. This is clearly not adequate. A systemic approach such as Industrial Ecology takes into account the other sec-

tors of the socio economy, as well as consumption patterns and attempts a more holistic solution
- In particular, in developing countries, where the “Large Formal Industry” contributes to a very small part of the material flow through the system, it is imperative to factor in the material flows in the massive “informal small sector”. The RFA presented in this chapter provides one such format that could integrate such material flows.

The case studies presented illustrate this view.

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Section E: New Instruments

Assessing the Link Between Environmental Management Systems and the Environmental Performance of Companies:

An Eco-Efficiency Approach

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1. Introduction

Policy instruments that rely on voluntarism, learning processes and procedural change, rather than direct regulatory control have in recent years come to play a more prominent role in the environmental policy mix of many industrialised countries. They have been promoted by those who maintain that traditional hierarchical regulation is ill-equipped to promote environmental improvement and that environmental policy should become more decentralised and based on shared responsibility. Critics, on the other hand, are sceptical that soft instruments can deliver real environmental improvements.

This chapter contributes to the debate on the impact of new environmental policy instruments by presenting evidence on the effectiveness of one of the most prominent of these instruments: environmental management systems (EMS). It draws on the Measuring Environmental Performance of Industry (MEPI) project, which collected and analysed environmental performance data for 280 companies and 430 production sites in 5 manufacturing sectors in 6 EU countries.

The first section discusses the rationale behind the increasing adoption of voluntary and procedurally-based instruments in general, and EMS in particular. We then review existing empirical evidence regarding the link between EMS and environmental performance, based on research carried out in Germany, Austria, Switzerland, the UK and Finland. The main part of the chapter presents the authors' own analysis. It is based on data collected during the MEPI research project and uses three different methods: 1) Statistical analysis on the firm-level (multiple regressions); 2) Statistical analysis on the production site-level (simple regressions); and 3) Longitudinal analysis on the production site-level. The final part draws conclusions about the potentials and limits of environmental management systems, and briefly explores the wider implications of the analysis for the role of soft policy instruments in the environmental policy mix.

2. Soft policy instruments and the EMS / performance link

Much has been written about a shift from traditional hierarchical regulation towards a different set of instruments in environmental policy-making (Gunningham and Grabosky 1998). The widely used term 'new instruments' includes a range of different coordinating and steering mechanisms including economic, procedural, information-based, self-regulatory, co-regulatory and voluntary instruments. They have in common that they aim to achieve their objectives by means other than the hierarchical prescription of legally-binding rules and standards which can be enforced by public authorities.

Although it can be argued whether new policies complement or replace the 'command and control' approach, it is now widely accepted that the use of alternative instruments is indeed increasing in many countries (Jordan et al 2003). Looking empirically at the factors that have led to the adoption of new environmental policy instruments in eight industrialised countries, Jordan and colleagues (2003a: 202-205) have identified a range of different drivers, some of which relate to changing ideas and beliefs, while others stem from organisational, political and economic factors. One of the key drivers is seen to be the assumption that new instruments are a more effective way of achieving environmental improvements.

Whether this assumption is borne out in reality has been widely discussed, especially with regard to economic instruments (Tietenberg 1991; Newell et al. 1999). Here, we focus on a different range of policies that have been called 'soft instrument-s'. This term describes instruments that aim to achieve environmental aims without employing direct coercion through law, or induce change by altering relative prices. They include voluntary, procedural and information-based policies. Although the term ‘soft’ may appear vague, it accurately describes the main characteristics of these policies: to attain environmental policy objectives without introducing legal or economic (i.e. ‘hard’) constraints. Prominent examples of soft policy instruments are environmental management systems, environmental product labelling, public disclosure requirements, best practice dissemination, industry codes of practice, and voluntary agreements[1]. Although soft instruments do not impose legally binding standards of environmental performance or behaviour, they do have in many cases a legal basis.

Why should we assume that instruments that provide information, attempt to modify procedures and rely on the motivations of actors are more effective than legally-binding rules and regulations? Critics have often argued that the new emphasis on soft instruments is not so much driven by changing ideas about governance, but have emerged as an attempt to scale-back environmental policy in the face of global competition, economic recession and powerful economic interest groups. We would not

[1] Here, we understand voluntary agreements as those without legally-binding commitments, sanctioning mechanisms and other enforcement procedures.

dispute that actors who aim to prevent a strengthening of environmental policies have often been supporters of soft instruments. However, soft instruments are based on a specific rationale and on a distinct model of behaviour and decision-making with regard to the environment.

The intellectual basis of soft instruments is provided by a wide range of recent theories in the social sciences that can be described as cognitive approaches (for example Schön 1983; Dryzek 1987; Fischer 1995; Weick 1996). Cognitive approaches argue that the behaviour of actors is to a large degree determined by their subjective interpretation of reality, rather than being the outcome of 'objective' and rationally-determined interests. It follows that any attempt to change behaviour needs to be based on an understanding of the frames of interpretation, discourses and knowledge sets which influence how these actors make sense of their world and action within it, and how they respond to changes in interpretive frames, discourses and so on. More specifically, soft instruments are based on the assumption that polluting behaviour is (at least in part) the result of institutionally-situated perceptions of reality (or ignorance about the state of things). Interpretive frames that stand in the way of environmentally beneficial decisions could be, for example, the assumption that reducing environmental damage is always associated with costs, that companies do not have any environmental responsibilities beyond legal compliance, or that environmental resources are free goods.

Closely related to the first, a second assumption is that by changing the sense-making of individuals and organisations, it is possible to change the attitudes and behaviours of those individuals and organisations – which, in turn, will ultimately have an impact on the environmental impacts of behaviours. This could be achieved by providing information (for example about environmental costs or best practice), through more subtle and long-term processes of learning and capacity-building, or through processes of awareness-raising about the liabilities and responsibilities of the polluter.

A third, more implicit, assumption is that 'hard' barriers should not stand in the way of the behavioural changes induced by a policy instrument. There appears to be a strong link with the Porter hypothesis that equates pollution with both environmental and economic inefficiency, and asserts that business has large potentials for cost-effective environmental measures. In this view, the well-established fact that organisations do not always exploit win-win potentials (e.g. Sorrell et al 2002) results from imperfect information, cognitive limits and inappropriate organisational structures within firms (Porter and van der Linde 1995: 131).

By encouraging organisational change, EMS are thought to have a direct impact on environmental performance. For instance, the preamble to the EMAS (Eco-Management and Audit Scheme) regulation of the European Union states:

"The objective of EMAS shall be to promote continual improvements in the environmental performance of organisations" (EMAS regulation, Art 1.2)

These improvements in performance are to be achieved through the imposition of management controls. However, this link between management and performance cannot be taken for granted. Research has documented that improving environmental performance is not usually the principal motive in a company's decision to adopt an EMS. A business survey carried out amongst Swiss firms identified 14 reasons for implementing an EMS which were considered to be 'very important' or 'quite important' by at least half of the 158 respondents (Hamschmidt 2000). The benefits included in this list ranged from 'strengthening innovation' and 'customer loyalty' to 'prevention of new environmental legislation', with 'enhancement of corporate public image' ranking highest. Only three of the 14 had a direct relationship with performance ('risk minimisation', 'certainty of legal compliance' and 'support of ecological transformation of the line of business'), and they were ranked at positions 4, 9 and 12 (Hamschmidt 2000: 4).

3. EMS and environmental performance: Evidence from other studies

Studying the effectiveness of EMS

Since the European and international environmental management standards were introduced in the mid 1990s, it is estimated that approximately 63,500 companies and production sites have adopted a certified or registered EMS[2] worldwide, and many more systems not audited by third parties exist. The fact that there is substantial experience with environmental management in companies has triggered a large number of research projects, evaluations, dissertations and doctoral theses into the effects of EMS. It is surprising that despite the recent growth of this literature (for recent reviews see for example Dyllick and Hamschmidt 1999; Steger 2000; Ammenberg 2001; Ankele et al 2002), empirical evidence about the environmental effectiveness of EMS is still sparse. One of the reasons is that many studies have focused on the direct economic costs and benefits associated with EMS. Economic benefits, are not, however, a reliable indicator of environmental effectiveness because savings can be made without reducing pollution. For example, a company can save costs by organising environmental responsibilities better or by identifying cheaper methods of waste disposal. Conversely, the adoption of an EMS may lead to unanticipated and costly pollution abating measures. For example if the use of an EMS revealed that the firm was in breach of regulation, investment in abatement technology might be obligatory.

Even those researchers who have attempted to assess the link between EMS and environmental performance have rarely been able to make valid statements about the overall environmental effectiveness of EMS. Several reasons may be given for this apparent anomaly. Of greatest importance, many studies suffer from a shortage of environmental performance data. In most countries, environmental reporting is not mandatory and most companies prefer not to publish quantitative performance data. ISO 14001 does not require disclosure of environmental information. Even where data on emissions, materials use or non-compliance incidents are provided in environmental reports or EMAS site statements, it is rarely presented in a comparable format. Despite the activity of organisations such as the Global Reporting Initiative, there is no standard approach to environmental reporting and measurement. Public emissions registers exist only in a few countries such as Britain, the United States and the Netherlands, and the quality and usability of the data in these registers varies. With data being sparse and from heterogeneous sources, only a few research projects have had the capacity to carry out the costly and time-consuming data work necessary to conduct comprehensive studies of the environmental performance consequences of EMS. Most studies only look at a very small number of companies and rely on data generated through companies' self-assessment due to the absence of verified performance information.

The quantitative analysis of environmental performance of companies also poses a series of conceptual and methodological challenges. First, environmental performance is a complex and multi-dimensional issue. There is no universally accepted approach to the inherently subjective task of weighing different environmental impacts against each other. Any overall assessment or ranking based on a judgement of how green-

[2] There are around 3,500 EMAS registrations in the EU and more than 60,000 ISO 14001 certifications world wide. Data source: EMAS website (http://europa.eu.int/comm/environment/emas) [page accessed 20 June 2004] and ISO World / Umweltbundesamt (http://www.ecology.or.jp/isoworld/english/analy14k.htm) [page accessed 20 June 2004].

house gas emissions compare to chemical spills or special waste will produce highly contested results. It is also debatable whether the fact that companies operate in different natural environments should be taken into account when considering pollution that has local impacts. Second, companies carry out distinct business activities under different economic, technological and regulatory conditions. Some businesses will always find it more difficult to improve their environmental performance than others, even if they operate in the same sector. For example, it may be that the specific demands placed on a company by its customers prevent the adoption of a cleaner technology. Third, it is difficult to decide where the system boundaries should be set with regard to environmental performance. Are companies only responsible for damage caused by operations within the firm gates or should issues such as the supply of raw materials and components, transportation to and from the company, product use and disposal be included in the assessment of environmental performance?

Given these difficulties in establishing a robust framework for performance evaluation, most studies have used proxies that can be measured through postal or telephone surveys, for example satisfaction with the EMS, perceived environmental benefits, or types of measures put in place. Although this is a justifiable response to the challenges outlined above, the reliance on 'effort indicators' and self-assessment limits the validity of the findings. It is important to recognise that conclusions are often based on the (empirically informed) judgement of researchers and their interviewees rather than on quantitative evidence. In the remainder of this section, we summarise the results of some of the larger and more performance-oriented studies (see Table 1).

Results from key studies

There is a surprising consistency in the broad direction of the findings, even though some studies (such as UNI/ASU 1997; Kuisma et al 2001) adopt a generally more optimistic tone than others (for example FEU 1998; Jäger et al 1998; Steger 2000; Wagner 2002). In general, researchers found that a majority of respondents reported a moderate level of environmental effectiveness stemming from EMS adoption, although a considerable variability between companies was also observed (UNI/ASU 1997; Steinle and Baumast 1997; Kuisma et al 2001). For example, 60% of firms surveyed by a study in Switzerland perceived small improvements, 10% thought that their EMS had led to large environmental improvements, and the remaining 30% experienced deterioration or were unable to make a judgement (Hamschmidt 2000). When measured in economic terms, the short-term benefits (e.g. due to lower water and energy bills) were often thought to be of a scale comparable to the costs of adopting the EMS. An overall link between profitability and EMS presence has not been found in a large sample of German manufacturing firms (Wagner 2002).

Table 1: Key studies on the environmental effectiveness of EMS

Study	Funder	Approach and sample	Results regarding EMS / environmental performance link
Dahlström et al 2003	UK Environment Agency (EA)	statistical analysis of the link between EMS and regulator's assessment of performance for 800 sites	better procedural performance but no impact on likelihood of incidents, complaints or non-compliance events
Kuisma et al 2001	Finnish Ministry of the Environment	in-depth study of Finnish paper industry; qualitative and quantitative	improvements in waste and risk management; weak on product development
Hamschmidt 2000	Swiss Agency for the Environment	self-assessment by 158 companies	10%: large improvement 60%: small improvement 30%: deterioration / unknown
Steger 2000	Ministries for the Environment in Germany and Austria	review of 24 empirical studies, most based on self-assessment questionnaire	better compliance, some cases of improvement identified but no fundamental change
FEU 1998	German Ministry for the Environment	self-assessment of 27 companies, analysis of 200 env'l statements	better compliance but no quantitative information on performance
UNI/ASU 1997	German Federal Foundation for the Environment	self-assessment of 723 companies, largely qualitative	cases of improvement identified but no quantitative information on performance

EMS appears to be related to improvements in the traditional areas of environmental management. Empirical studies of EMS in operation show that most companies focus on on-site production efficiency. The most significant improvements appear to have been made in the areas of waste management, energy use and water consumption (UNI/ASU 1997; Kuisma 2001; Steinle and Baumast 1997; Dyllick and Hamschmidt 1999). Interestingly, all of these are areas in which direct cost savings can be made because the environmental goods involved have to be purchased.

There is widespread agreement that EMS have largely failed to broaden the scope of corporate environmental management because they do not systematically address environmental concerns outside the factory gate, for example transport and logistics, sourcing of raw materials and other inputs, product design and end-of-life considerations (cf Steger 2000; Hamschmidt 2000; Kuisma et al 2001; Jäger et al 1998; Ankele et al 2002). There were also few indications that EMS has driven continuous environmental improvement (Jäger et al 1998; Steger 2000).

There is mixed evidence regarding the effect of EMS on legal compliance with environmental regulation. Steger (2000) and Jäger et al (1998) conclude that EMS do support compliance. Steger points out, however, that it is difficult to determine the actual environmental effects of better compliance because non-compliance is often concerned with formal infringements rather than material breaches. In contrast, Dahlström et al's (2003) study was unable to confirm this link. The study - which is one of the few analyses that draw on a comprehensive set of independent performance assessments - found that EMS sites have a better procedural performance (as assessed by the regulator) but did not find a significant correlation between EMS and the likelihood of incidents, complaints and non-compliance events.

There are also doubts about whether EMS represent an *autonomous* driver of performance improvements. In Steger's study (2000), most respondents held the view that the environmental objectives of the company could also have been attained without an EMS. Hamschmidt (2000) reports that while most would agree that an EMS had some influence on environmental performance, only a few saw it as a key factor. EMS do not appear to lead to fundamentally different environmental objectives and strategies, but promote streamlining of existing environmental responsibilities. Interestingly, external stakeholders tended to have a more positive view of the costs and benefits than companies themselves (Steger 2000).

4. Analysing the link between EMS and organisational environmental performance

The MEPI approach

The following analysis reports research carried out in the context of the Measuring Environmental Performance of Industry (MEPI) study (cf Berkhout et al 2001; Tyteca et al 2001) in which the authors were investigators. The MEPI project operationalised performance as the environmental efficiency of the production process: *the level of input of energy and materials and the level of output of waste and pollution per unit of product output*. Where there was insufficient data on production output, environmental indicators were normalised on turnover or number of employees. All inputs and outputs were measured in physical terms such as weight or volume (with the exception of some sectors where product output was captured as monetary value). The project covered six industrial sectors (electricity generation, pulp and paper, fertilisers, textile finishing, book and magazine printing, and computer manufacture) and six European countries (Austria, Germany, Italy, Belgium, the Netherlands and the UK). Within this limited scope, the project team aimed to collect data on environmental performance for as many companies and production sites as possible. Data were collected from four sources: corporate environmental reports; national pollution inventories (UK and Netherlands); EMAS statements; and completed surveys in the fertiliser, printing and textile sectors. We estimate that for the more concentrated sectors (paper, electricity and fertilisers) the MEPI data set covers between 50 and 80 % of production in the six countries (see table 2).

Table 2: Number of firms for which data was collected (by sector and country)

Country	Computer	Electricity	Fertilisers	Paper	Printing	Textile	All
Austria	0	9	0	8	2	1	20
Belgium	n.a.	2	4	4	4	5	19
Germany	5	27	2	43	33	13	123
Italy	4	6	7	10	5	11	43
Netherlands	0	4	7	17	0	14	42
United Kingdom	0	10	6	8	2	1	27
All countries	9	58	26	90	46	45	274

While the database with more than 15,000 performance data points for 274 firms and around 400 production sites provides a valuable research resource, it also has a number of limitations:

- The data set is incomplete, with many missing values. On average, only 28% of the performance indicators for which we collected data were available for a given firm or site in a given year. Principal component analysis (PCA) was carried out to establish that environmental performance could adequately be reflected by a subset of all indicators. For example, CO2 emissions were found to be indicative of all air emissions in the electricity sector (cf Berkhout et al 2001). This enabled us to restrict the analysis to a smaller number of indicators for which data were more complete and to reduce the need to aggregate indicators.

- A number of sectors consist of a heterogeneous set of firms, which have structurally different environmental profile because they produce different products and/or use different technologies. Some - but not all - of these differences have been captured through the analysis of sub-sectors.
- A significant share of the data has undergone little or no third party validation.
- In some sectors, the sample of firms is assumed to over-represent large companies and good performers, since we expect that these would have a higher propensity to publish data and reports.

In the remainder of the section, we report three ways in which the link between EMS and environmental performance was analysed. Throughout the analysis, the 'presence of an EMS' was operationalised as the presence of a management system that is certified to an internationally-recognised standard (ISO 14001 or EMAS). A company was counted as being EMAS certified if *all* its sites had adopted this standard. The link between EMS and environmental performance was investigated through examination of three hypotheses:

Hypothesis 1: Firms with an EMS have a better environmental performance than those without

In a first step, we aimed to establish whether companies with a certified EMS performed better than those without. Analysing every sector individually, we established significant differences between individual normalised performance levels achieved by EMS firms and those displayed by non-EMS firms based on non-parametric analysis. The analysis used those indicators that were identified as being most suitable during the PCA. Non-parametric tests were chosen since they do not assume a normal distribution of the variable analysed. Given that some environmental performance indicators had very skewed distributions, it would have been inappropriate to utilise parametric methods, since this may have introduced distortions in the results (e.g. parametric tests may distort significance levels). Missing values for any of the indicators are treated on a case-by-case basis (pairwise exclusion), i.e. if for a case data were missing on a specific indicator, this firm was then excluded in the testing for only this variable, but was included in the testing for other indicators where data were available for this case/firm. Due to the large number of missing variables, the analysis did not control for any firm characteristics other than industrial sector. The results of examining Hypothesis 1 can be summarised as follows:

Fertilisers

Non-parametric Mann-Whitney tests for significant differences between companies that were ISO 14001 or EMAS certified and companies that were neither were applied to the six relevant indicators identified in the PCA (NO_x, VOC emissions, Hazardous and municipal waste arisings, total water and energy use). The results reveal three significant links to environmental performance:

- ISO 14001 and EMAS certified companies tended to have *lower* NO_x emissions per total sales than non-ISO 14001/EMAS firms (U=2, W=5, Z=1.78, 0.10 level (2-tailed), df=14 for EMAS and ISO, since the same firms are concerned).
- ISO 14001 and EMAS certified companies have significantly *higher* hazardous waste levels per total sales (U=0, W=21, Z=-2.0, 0.05 level (2-tailed), df=9, again firms for EMAS and ISO are identical) and VOC emissions per total sales (U=0, W=21, Z=-2.0, 0.05 level (2-tailed), df=9) than non-ISO/EMAS firms.

Electricity

Using the Mann-Whitney test, none of the thirteen environmental performance indicators tested (solid waste, municipal waste, recycled waste, CO_2, NO_x, SO_2, dust, coal input, gas input, oil input, renewable fuel input, total fuel input) showed significant differences for the EMAS units (no ISO14001 certified units were available at the firm level).

Pulp and paper

Two of the nine performance indicators (water input, energy input, solid waste, hazardous waste, CO_2 emissions, chemical oxygen demand, SO_2 emissions, nitrogen and phosphorous) identified in the PCAs showed significant differences depending on whether a firm was verified according to EMAS / certified to ISO14001 or not. In particular, it was found that:

- EMAS certified companies tended to have lower COD emissions per tonne of paper than non-EMAS firms (U=127, W=155, Z=-2.463, 0.05 level (2-tailed), df=91), as did ISO 14001 certified companies (U=266, W=344, Z=-2.481, 0.05 level (2-tailed), df=93) compared to non-ISO firms.
- EMAS certified firms were found to have significantly *higher* total energy inputs per tonne of paper (U=1, W=596, Z=-4.754, 0.01 level (2-tailed), df=37) than non-EMAS firms and the same was found for ISO 14001 certified companies which also had significantly *higher* energy inputs per tonne of paper (U=18, W=579, Z=-3.761, 0.01 level (2-tailed), df=37) than non-ISO firms.

The major reason for the coincidence of EMAS and ISO findings is (as was for the fertilizer sector) that there is a strong correlation between EMAS verification and ISO certification, i.e. most firms certified to ISO are also verified under EMAS.

For the paper sector therefore, the link between EMS and performance is also ambivalent, with the majority of indicators not showing any significant differences.

Textile finishing

For this sector, only data on EMAS could be analysed, since no ISO-certified firms were in the data set. For EMAS, no significant differences were found for any of the 11 different environmental performance variables identified in the PCAs.

Printing

Only three of the 9 performance indicators tested showed a significant association with EMAS and ISO14001 in the non-parametric tests applied to the data:

- EMAS/ISO-certified firms (being in this case identical for both EMSs) have significantly *lower* sulphur dioxide emissions per employee (U=10, W=25, Z=1.839, 0.10 level (2-tailed), df=16).
- ISO/EMAS firms tended to have *lower* total water input per employee than non-certified firms (ISO: U=96, W=162, Z=-2,131, 0.05 level (2-tailed), df=43; EMAS (at slightly lower levels of significance): U=102, W=147, Z=-1.425, 0.10 level (1-tailed, 2-tailed test statistically not significant, 2 firms which are ISO-certified are not verified according to EMAS), df=43).
- ISO-certified firms tended to have *higher* total energy input per employee than non-certified firms (U=71, W=116, Z=2.043, 0.05 level (2-tailed), df=39). A similar finding, though not at such high significance was made for EMAS (U=73, W=101, Z=-1.337, 0.10 level (1-tailed, 2-tailed test not significant), df=39).

Table 3 summarises the results of testing Hypothesis 1.

Table 3: Overview of results at the firm level

Industry sector	Variable	Performance level for firms with certified EMS	Significance level
Fertilisers	NO_x per unit of sales Hazardous waste per unit of sales	lower (with ISO/EMAS) higher (with ISO/EMAS)	0.10 0.05
Pulp/Paper	COD per tonne of paper Energy input per tonne of paper	lower (with ISO/EMAS) higher (with ISO/EMAS)	0.05 0.01
Printing	SO_2 per employee Energy input per tonne of paper	lower (with EMAS/ISO) higher (with EMAS/ISO)	0.10 (EMAS), 0.05 (ISO) 0.10 (EMAS), 0.05 (ISO)
Textile finishing	No significant differences identified		
Electricity	No significant differences identified		

Overall, three conclusions can be drawn. First, the tests show that, in the large majority of cases, companies with an EMS did not perform significantly better than those without. In particular, significant differences could be identified for the environmental performance variables analysed in only three of the five sectors analysed.

Second, in those sectors where significant differences were found, there were as many instances in which EMS firms were significantly more eco-efficient as non-EMS firms. In each sector where significant differences existed, results were found pointing in both directions i.e. *pro* and *contra* EMS firms. Thirdly, no real differences could be identified between companies with EMAS or ISO systems. This is mainly because largely the same firms were verified under EMAS and certified to ISO 14001.

Overall, the few and, to some extent ambiguous, differences suggest that EMS are not the only powerful driver of corporate environmental performance. However, alternative explanations are also possible:

- The methods adopted to operationalise both the presence of an EMS and environmental performance may not be sufficiently precise and nuanced to capture an EMS-effect.
- An EMS-effect may have been disguised by the stronger influence of other explanatory variables some of which have been captured in the data (e.g. country, subsector, company size), while others have not (e.g. technologies, market conditions, management culture).
- It may be argued that poorly-performing firms tend to adopt EMS because they feel the need to address the issue or to signal commitment. In this case, the lack of significant differences could be due to a lower performance baseline, rather than the ineffectiveness of EMS.
- Conversely, it may be that the majority of companies without registered/certified EMS, have some form of internal EMS and that what is being measured in this analysis is the increment of performance change achieved through involvement of a standard management system and third-party verification.

While these and other explanations cannot be dismissed, it should be noted that the lack of significant links between EMS and performance contrasts with other hypotheses tested where significant associations were found more consistently (for example between EMS and company size, EMS and profitability).

Hypothesis 2: Sites with an EMS have a better environmental performance than those without

In a second step, we aimed to establish whether production sites with a certified EMS performed better than those without. Again, we analysed every sector individually and focused on core indicators identified through the PCA. Compared to the firm-level tests, the analysis was refined in two ways. First, different years were analysed individually. Second, the analysis was largely based on rankings derived from an aggregation of indicators based on the model of Jaggi and Freedman (1992). Three different Jaggi/Freedman ranking methods were tested and compared. Because this approach required a more comprehensive data set, the sub-set of the data with the most consistent coverage was used (i.e. electricity and paper sectors, 1995 to 1997 data). Rankings were constructed on the basis of CO_2, SO_2, and NO_x (electricity) and NO_x, water use and Chemical Oxygen Demand discharge (paper).

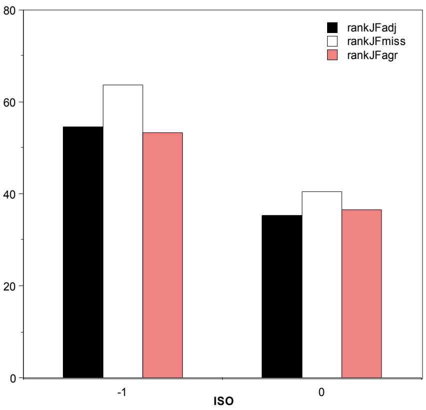
As with the firm-level analysis, some correlations between EMS and performance were found, but in general correlations were weak, sometimes ambiguous and usually not statistically significant. The results can be summarised as follows:

Electricity

In both 1996 (see figure 1) and 1997 (similar result), sites with ISO 14001 performed worse across the basket of indicators than those without. Sites with EMAS performed slightly better than non-EMAS sites in 1997, but for 1996 data no effect could be detected. None of the results was statistically significant.

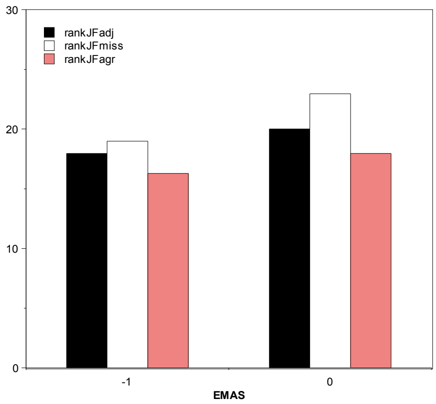
Figure 1: EMS effect on the site-level (electricity)

ISO14001 (electricity, 1996)



Relationship between ISO14001 and JF ranking ("-1" = site ISO certified, "0" = site not ISO certified)

EMAS (electricity, 1997)



Relationship EMAS and JF ranking ("-1" = site EMAS certified, "0" = site not EMAS certified)

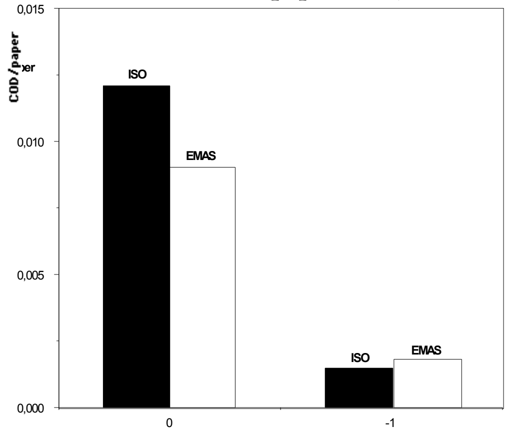
Paper

The analysis in the paper sector produced only one significant result: sites with both ISO and EMAS had lower COD emissions (1996 and 1997) than those without (see figure 2).

Overall, only a few tentative correlations between EMS adoption and environmental performance were found at the site-level. This gives additional weight to the firm-level results, particularly because the object of analysis is defined more precisely.

Figure 2: EMS effect on the site-level (paper)

ISO and EMAS Effect (paper, 1996)



Influence of ISO and EMAS certification on COD ("0" = site not certified, "-1" = site certified)

Hypothesis 3: Sites improve their environmental performance trend after adopting an EMS

In the final test, the performance of production sites over time was assessed to test the hypothesis that the adoption of an EMS had a positive impact on performance trends. The analysis was based on all performance time series of three or more years where a certified EMS was introduced during that period (but not in the first or last year of the series). We then established the trend before and after the adoption of the EMS over all available years[3] using a 'least square' method and calculated the *difference* between both trends (figure 3). The data-base contained 165 of these performance time series related to 24 different production sites in four sectors (that is, each site was represented by an average of seven performance indicators).

It should be noted that this analysis does not explore whether sites improved their performance during the observed period, but whether EMS adoption resulted in a relative change of trend in performance. In this sense, an EMS is also seen to be effective if it lowers the rate at which the performance worsens. If the adoption of an EMS did not contribute to an improvement of the performance trend, we would expect an equal distribution between improving and worsening trends.

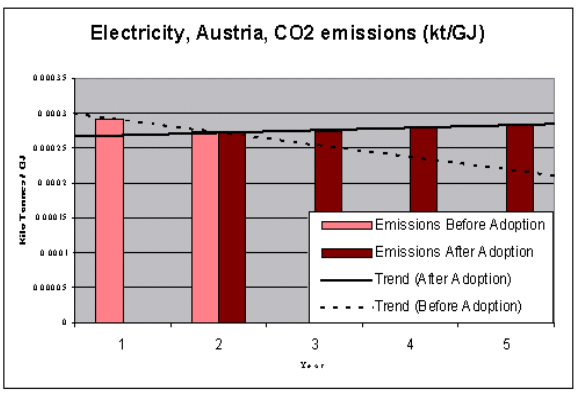


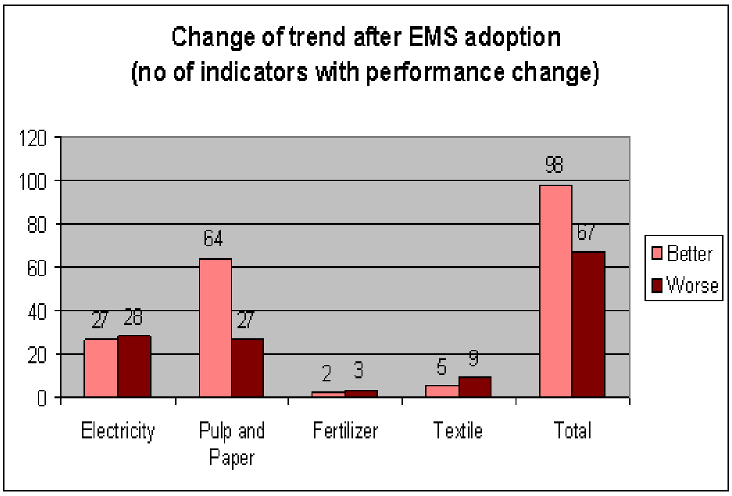
Figure 3: Example of performance trend series (EMS adopted in year 2)

[3] The year of EMS adoption is included as endpoint in the trend 'before adoption' and as starting point in the 'trend after adoption'.

When analysing the trend of all indicators individually, we found that in 98 cases (59%) the performance trend improved after EMS adoption, while in 67 cases (41%) the trend worsened (figure 4). This means that on average the adoption of an EMS appears to have had an impact on a minority of all performance measures. Further analysis generated several other findings:

- There was a high variability between sectors, with only the paper sector showing a strong EMS effect.
- There was no clear difference between the effects of EMAS and ISO14001.
- There was no strong difference between environmental indicators where the level of performance is directly related to economic costs (e.g. hazardous waste, energy use) and those where cost was not a factor (noise, most air and water emissions).

Figure 4: Change of performance trend after EMS adoption (by sector)



When the data was aggregated by production site, a similar picture emerged (table 4). Out of 24 sites, 10 (42%) saw a trend improvement on most indicators in the years after EMS adoption, while 7 (29%) saw more declining than improving indicators. Another 7 (29%) production sites displayed an equal number of improving and declining trends (see table 4).

Table 4: Results of performance trend analysis aggregated by site

Result of performance trend analysis aggregated by production site		
Production sites where:	No of sites	Share of sites
- the trend of most indicators improved after EMS adoption	10	42%
- the trend of most indicators declined after EMS adoption	7	29%
- there was a balance between improving and declining trends	7	29%
Total	24	100%

Overall, the analysis confirms the previous finding that the link between EMS and performance is weak as was also found by Wagner (2002) for energy efficiency as one component of environmental performance. That the third test has not identified a stronger effect is surprising. The longitudinal approach is a more targeted method of evaluating the 'EMS hypothesis' because it reduces the potential impact of intervening variables and should make actual performance effects visible.

5. Conclusions: The EMS / performance link

The results of the analysis presented here can be summarized as follows:

1. There is little evidence to suggest that companies or production sites that have adopted a certified EMS perform significantly and consistently better than those without. This finding can, however, be explained by different substantial and methodological factors and does not in itself disprove the EMS hypothesis. Possible explanations for this finding are
   - EMS are not a strong driver of environmental performance improvement.
   - EMS are a driver of environmental improvement, but this effect is concealed by other stronger determinants of environmental performance.
   - The limits of data availability do not allow an analysis sufficiently precise and nuanced to distinguish the effect of EMS on environmental performance.
2. There is certain evidence that the adoption of EMS has a positive impact on the *performance trend* across a minority of indicators. This finding appears to have special significance because performance time-series capture large-scale emissions, waste and resource use trends of industrial installations which are important in their own right. However, there are again more than one possible explanation for this finding:
   - EMS are not a consistently strong driver of environmental performance improvement.
   - EMS are a driver of environmental performance improvement, but the areas of improvement lie outside the performance dimensions captured by MEPI eco-efficiency indicators (e.g. logistics, product performance, business travel).
   - EMS are a driver of environmental performance improvement, but the effect is not sufficiently large to outweigh other factors which determine year-on-year variations (e.g. plant utilisation, product specification, investment cycle).

In our view it is unlikely that the analysis presented here has failed to detect a strong EMS / performance link merely because environmental improvements occurred in areas other than the environmental efficiency of production. Qualitative research reported in section 3 found that EMS have not usually broadened the scope of environmental management to include impacts outside the factory gate. This suggests that if an EMS / performance link exists, it would be found in the functions examined in the MEPI study. A more plausible interpretation is that EMS have proven only a relatively weak driver of environmental performance. In particular, the result of the longitudinal analysis that the trend in performance frequently worsened after the adoption of an EMS can only reasonably be explained through the presence of other influencing factors.

What could be the reasons for the limited environmental effectiveness of EMS? Our analysis does not provide a positive explanation of these findings. Interpreting the results in the light of previous research into EMS, we would like to propose a number of possible explanations. First, the results could be seen to confirm the view of other evaluation studies that EMS are a tool for performance improvement, rather than being a driver of change. Put differently, EMS may in fact be a necessary, rather than a sufficient condition for successful efforts to reduce resource use and emissions. Taken together with Hamschmidt's (2000) result that environmental performance is not usually the main motive for companies to adopt an EMS, a weak EMS / performance link becomes a plausible result.

Second, the modest effectiveness of EMS could also be due to shortcomings in the implementation and enforcement of current procedures rather than implying a fundamental criticism of EMS. A number of studies have shown that the outcome of EMS depends strongly on the way in which they are put into practice. Current environmental management standards are believed to encourage companies to implement EMS in a formalistic and procedural way (Dyllick and Hamschmidt 1999). Third, it is also possible that there is a time lag between EMS adoption and performance improvement because companies need time to adjust to newly-introduced routines and procedures. The effect of a 'learning lag' is well known in the literature on the relationship between innovation and productivity, which finds that companies suffer productivity losses during the period immediately after the introduction of an innovation (Conceição et al 2003). The MEPI performance time-series are not sufficiently long to test this hypothesis. It is also possible that improvements are made only under certain circumstances, for example in sectors with short investment cycles, or in countries with less stringent regulations and enforcement. The MEPI analysis did not collect data that would allow identification of those conditions under which EMS tend to have an impact on performance.

Fourth, procedural improvements made through the introduction of an EMS may not lead to environmental improvement because of cost barriers. Although EMS have been found to help companies to identify cost-effective environmental measures (Steger 2000), the results from this study suggest that the effect of these measures could be small when compared to the overall environmental impact of the company. It remains an open question, whether this is due to shortcomings of the EMS tool (e.g. focus on ability to manage current processes rather than improving the innovative capacity), or whether it implies a more sober view with regard to the overall potential for win-win solutions.

Given the uncertainty about how the results can be explained, policy recommendations need to be made with care. We do not believe it would be appropriate on the basis of this analysis to conclude either that EMS are ineffective, or that that policy support for EMS should be withdrawn. Any conclusion about the link between EMS and environmental performance is necessarily preliminary, because more comprehensive data are needed and long-term effects have not yet been studied. Moreover, EMS may have benefits other than environmental performance - for example in terms of regulatory certainty, internal and external communication or awareness raising - that may justify policies encouraging their diffusion.

The weak link between EMS and performance is, however, a matter of concern if EMS are envisaged as serving as a substitute for other policy instruments. Scaling-back regulation or environmental taxes for firms with EMS (often referred to as 'regulatory relief') is practiced or under consideration in many European countries, for example in the form of fewer inspections by regulators, reduced rates for plant licences, or exemptions from environmental charges (Wätzold et al 2001; Dahlström et al 2003). On the basis of the research presented, we would argue that there is currently no evidence to suggest that EMS have a *consistent* and *significant* positive impact on environmental performance. Any substantial regulatory relief based on the simple assumption that companies with an EMS perform better than those without would therefore be inappropriate.

More broadly, the findings of this study contribute to the broader debate about the effectiveness of soft policy instruments. We would share the view that there is a strong cognitive element in environmental decision-making in firms. The question is, however, whether procedural and information-based instruments with a very low degree of intervention will be able to change interpretive frames and provide the knowledge required to bring about innovation in organisations that leads to observable environmental outcomes.

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Table A.1: Test Statistics for EMS effects in the Electricity & Fertiliser Sectors (Exact Tests; ISO & EMAS firms identical; FU: Functional Unit, here: MWh)

Variable (Electricity, EMAS only)	Mann-WhitneyU	Wilcoxon W	Z	Exact significance (2-tailed)	Exact significance (1-tailed)	Variable (Fertilisers, EMAS/ISO)	Mann-WhitneyU	Wilcoxon W	Z	Exact significance (2-tailed)	Exact significance (1-tailed)
CO_2 emissions per FU	39.00	42.00	-0.887	0.417	0.208						
NO_x emissions per FU	30.00	33.00	-1.307	0.225	0.112	NO_x per total sales	2.00	5.00	-1.776	0.103	0.051
SO_2 emissions per FU	39.00	42.00	-1.022	0.347	0.173	VOC per total sales	0.00	21.00	-2.000	0.071	0.036
Dust emissions per FU	18.00	21.00	-0.120	0.943	0.471						
Total solid waste per FU	24.00	27.00	-1.188	0.276	0.138	Hazardous waste per total sales	0.00	21.00	-2.000	0.071	0.036
Municipal waste per FU	21.00	1149.00	-0.180	0.917	0.458	Municipal waste per total sales	0.00	10.00	-1.852	0.133	0.067
Recycled waste per FU	21.00	924.00	0.000	1.000	0.512	Total water per total sales	20.00	23.00	-0.301	0.807	0.403
Coal input per FU	21.00	1452.00	-0.367	0.833	0.407						
Total fuel input per FU	1.00	2.00	-0.878	0.667	0.333						
Gas input per FU	20.00	21.00	-0.464	0.750	0.375						
Total oil input per FU	24.00	25.00	-0.160	0.926	0.463						
Renewables input per FU	0.00	1.00	-1.464	0.333	0.167						
Total energy input per FU	0.00	1.00	-1.342	0.500	0.250	Total energy per total sales	9.000	12.000	-1.256	0.260	0.130

Table A.2: Test Statistics for EMS effects in the Paper Sector (Exact Tests; ISO & EMAS separate; FU: Functional Unit, here: tonne of paper produced)

Variable (Paper, EMAS only)	Mann-Whitney U	Wilcoxon W	Z	Exact significance (2-tailed)	Exact significance (1-tailed)	Variable (Paper, ISO only)	Mann-Whitney U	Wilcoxon W	Z	Exact significance (2-tailed)	Exact significance (1-tailed)
CO_2 per FU	132.00	1167.00	-0.088	0.943	0.472	CO2 per FU	175.00	211.00	-0.124	0.913	0.456
SO_2 per FU	37.00	47.00	-0.822	0.444	0.222	SO2 per FU	27.00	37.00	-1.455	0.160	0.080
Total solid waste per FU	63.00	1009.00	-0.067	0.967	0.483	Total solid waste per FU	120.00	148.00	-0.505	0.632	0.316
Recycled waste per FU	97.00	107.00	-0.808	0.441	0.220	Recycled waste per FU	150.00	178.00	-1.282	0.208	0.104
COD per FU	127.00	155.00	-2.463	0.012	0.006	COD per FU	266.00	344.00	-2.481	0.012	0.006
Nitrogen per FU	44.00	47.00	-0.954	0.381	0.191	Nitrogen per FU	189.00	217.00	-0.992	0.332	0.166
Phosphorus per FU	22.00	25.00	-1.185	0.278	0.139	Phosphorus per FU	60.00	70.00	-1.044	0.318	0.159
Total energy input per FU	1.00	596.00	-4.754	0.003	0.003	Total energy input per FU	18.00	579.00	-3.761	0.009	0.009
Total water input per FU	443.00	498.00	-0.136	0.898	0.449	Total water input per FU	579.00	684.00	-0.486	0.634	0.317

Table A.3: Test Statistics for EMS effects in the Textile Sector (Exact Tests; ISO & EMAS separate; FU: Functional Unit, here: unit of textiles produced)

Variable (Textiles, EMAS only)	Mann-Whitney U	Wilcoxon W	Z	Exact significance (2-tailed)	Exact significance (1-tailed)	Variable (Textiles, ISO only)	Mann-Whitney U	Wilcoxon W	Z	Exact significance (2-tailed)	Exact significance (1-tailed)
CO_2 per FU	35.00	56.00	-1.121	0.280	0.139	COD per FU	76.00	427.00	-0.097	0.944	0.472
NO_x per FU	79.00	100.00	-0.093	0.940	0.470	Phosphorus per FU	6.00	97.00	-1.189	0.305	0.152
VOC per FU	5.00	6.00	-0.543	0.750	0.375						
Recycled waste per FU	71.00	477.00	-0.587	0.577	0.289	Total solid waste per FU	20.00	686.00	-1.046	0.344	0.172

Table A.4: Test Statistics for EMS effects in Printing sector Sector (Exact Tests; ISO & EMAS separate)

Variable (Printing, EMAS only)	Mann-Whitney U	Wilcoxon W	Z	Exact significance (2-tailed)	Exact significance (1-tailed)	Variable (Printing, ISO only)	Mann-Whitney U	Wilcoxon W	Z	Exact significance (2-tailed)	Exact significance (1-tailed)
Carbon dioxide per employee	4.00	7.00	-1.461	0.198	0.099	Carbon dioxide per employee	5.00	6.00	-0.372	0.857	0.429
Sulphur dioxide per employee	10.00	25.00	-1.839	0.071	0.034	Sulphur dioxide per employee	10.00	25.00	-1.839	0.071	0.034
Total waste per employee	73.00	508.00	-1.139	0.267	0.133	Total waste per employee	63.00	498.00	-1.539	0.129	0.064
Hazardous waste per employee	42.00	252.00	-0.543	0.621	0.311	Hazardous waste per employee	55.00	245.00	-0.127	0.926	0.463
Total ink input per employee	186.00	252.00	-0.779	0.445	0.223	Total ink input per employee	179.00	245.00	-0.939	0.356	0.178
Isopropyl alcohol input per employee	11.00	336.00	-0.200	0.923	0.462	Isopropyl alcohol input per employee	33.00	39.00	-0.121	0.928	0.464
Total fuel input per employee	105.00	633.00	-0.256	0.812	0.406	Total fuel input per employee	121.00	166.00	-0.467	0.654	0.327
Total energy input per employee	73.00	101.00	-1.337	0.190	0.096	Total energy input per employee	71.00	116.00	-2.043	0.041	0.021
Total water input per employee	102.00	147.00	-1.425	0.161	0.081	Total water input per employee	96.00	162.00	-2.131	0.033	0.016

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Coherence in Industrial Transformation

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Introduction

The most recent element on the South East Asian environmental agenda is the ISO series of international environmental management standards, i.e. the ISO 14000 series. These have recently been appropriated to use in a.o. the newly industrialized Thailand, but it is still an open question wither these will be able to function in a comparative way to the European situation. In the European context the ISO 14000 series standards have to some extent promoted a situation of industrial self governance by functioning as a platform for integrating enforcement control and environmental housekeeping concerns, as well as being a tool that brings environmental concerns to the level of the top management as it provides a framework for integrating environmental considerations into the business activities of the company as a permanent concern of the company management. In this manner the environmental management systems have worked to align the elements that constitute the context of the systems, thus promoting the coherence among these. It is evident that ISO 14000 can function as a catalyst of environmental change, but like with a chemical catalyst the necessary preconditions must be present in order for the desired reaction to take place.

The most radical objective of the ISO 14000 standard is its attempt to initiate and sustain continuous improvements of the environment related to the organization where it is implemented. By introducing an objective of continuous improvements a proper implementation of the standard requires more than just setting up a system of management procedures, but also for the establishment of a description of the environment, that can be used to prioritize the environmental activities of the company. Environmental management systems (EMS) develop different environmental objectives and acquire different regulatory meanings in changing contexts. The importance of the context which the EMS are implemented in, is described through elements, that have previously been identified in the literature as individually significant domains in relation to function of environmental management: regulatory regimes and available technology (Jørgensen 2001), the competence of the networks of environmental professionals that work in the environmental organisation, in consulting and regulatory enforcement (Simmons & Wynne 1993) and dominating business cultures. Our argument is, that the ability of the standard to achieve an impact is dependant on the constitution of 'coherent' environmental issues in the context, where the management system is applied. This is exemplified with comparative discussions on the function of environmental management systems in the different contexts of Denmark and Thailand.

The Thai context of a combination of a recent industrialization and a young democracy draws attention to the preconditions that in a western context often are taken for granted, when discussing the function of environmental management standards: Management culture, enforcement practices, regulatory structures, personal networks and last but not least the existence of a network of environmental professionals. Many of these elements have not undergone the mutual alignment processes which we commonly refer to as 'modernization'.

Based on findings from a research program on the comparative use of EMS[1], we argue that EMS have become a 'voluntary supplements and extensions to existing legislation' in the European setting, while EMS in the setting of recently industrialised countries like Thailand and Malaysia appear to function very differently as 'awareness creators and legislation enforcement'. As a result of this, EMS may over time due to other mechanisms create more homogeneous and standardized environmental performance between countries.

Reflections on recent theoretical development

In general the introduction of EMS like ISO14000 is expected to build and sustain trust in companies' environmental efforts and performance (Deegan, 2002). However, in specific cases the performance of environmental management has been shown to be dependant on a number of individually significant domains in relation to: regulatory regimes and available technology (Jørgensen 2001), the competence of the networks of environmental professionals that work in the environmental organisation, in consulting and regulatory enforcement (Simmons & Wynne 1993) and dominating business cultures.

The standard as such, although, is just a management standard, prescribing certain procedures to be followed by the certified company, which leaves a quite open agenda for the choice of environmental objectives and performance criteria. Previously a number of issues in the ISO14000 standard have been identified where the standard contains interpretative flexibility (Behrndt 2002). This has been followed up in more detail by identifying the implicit assumptions and contextual expectations of the standard (Jørgensen 2003). The standards leave open a number of 'hot spots' to be defined throughout the implementation process: the delimitation of the organisation and territory, the identification of significant environmental aspects (objectives), the extent to which design, planning and product chain management is included, the interpretation of what counts as legal requirements and the interpretation of continued improvements. The importance of the embedding of EMS becomes evident as this interpretative flexibility leads to the definition of different priorities concerning environmental objectives, even though the concept of environment may be shaped in similar ways.

Furthermore does the acceptance and influence of EMS in the business community rely on how they perform and contribute to develop environmental issues and to translate them into concrete problems in specific settings. It is EMS' ability to support the enactment of the environment which is crucial. This follows the argument that making environmental problems concrete requires that they are enacted and thereby given meaning in local settings (Georg & Füssel 2000). But also the more

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1 The chapter is based on studies of EMS in the context of the EMP project organised in LUCED. In this project EMS are seen as travelling concepts that pursue certain objectives and results, and as concepts that need to be identified, used and thereby constituted in the specific contexts, where they are implemented. E.g. ISO 14000 is as such a management prescription for taking up environmental issues. As this standard does not specify the specific conceptual understanding of the environment, the business and regulatory context become very important for the meaning and working of the system.

general understanding that these enactment processes involves the construction and attachment of social meaning and representations for negotiation and mediation (Latour 1999). The environmental objectives are shaped by the concrete activities which they are embedded in. This identification of the role ISO14000 underlines previous understandings of environmental management systems as human constructs (Roome 1991). EMS' are human constructs that are developed in relation to and intertwined with other human constructs like science and politics. And more important and consequential is that what we understand as nature and environment is shaped in these interactions (Braun & Castree 1998).

When EMS' travel to be used in new settings it is not only a management technology which is transferred. As the management technology is implemented it becomes a key element of the embedding of the environment and as such also a central contribution to the local constitution of the environment. How the performance of the EMS is sensitive to the context where it is implemented, may be less evident in many European cases where EMS operate under relatively comparable and homogenous regulatory conditions. But when EMS are implemented in new settings as e.g. recently industrialised Asian countries, greater variations in the agenda setting role and performance of the systems can be identified as results of the varying conditions. New conceptions of the environment piggy-back (Sørensen 2000) onto a number of the different initiatives that are introduced in order to facilitate the development of local environmental strategies; legislative norms, the Cleaner Production promotion programs and EMS. Thus travelling EMS is a case of both technology transfer and the appropriation of key conceptions of the environment.

The context of new regulatory elements in Thailand

EMS' are spreading relatively quickly in the recently industrialised countries in South East Asia. Outside Europe and Japan these countries have the third largest concentration of ISO 14000 certified systems (ISO 2002). The EMS' are commonly introduced either based on demands from trans-national corporations' headquarters or as a response to demands from major customers - also often involving trans-national corporations in the product and distribution chain. A third important reason for implementing EMS is as a preparation for export to European countries in competition on the international market. Some characteristics of the companies introducing ISO14000 systems in Europe and South East Asia are similar. It is typically the larger companies that first introduce EMS (Hansen 1999), but while the European companies see their EMS as a way to integrate environmental management in the overall management of the company and demonstrate that they are environmentally reliable to a large number of stakeholders, companies introducing EMS in South East Asia are oriented towards exports for the international i.e. European market and see EMS as a way to gain acceptance by their major industrial customers on these markets.

The present promotion of EMS is not the first attempt to make the Thai industry more environmentally friendly. The issue has most notably addressed through the concept of Cleaner Production, which has been attempted disseminated to the Thai industry through a number of programs[2]. But CP has in general only been taken up by

[2] CP projects in Thailand include a.o.:
- The Industrial Environmental Management Project 1990-1995 (Federation of Thai Industries, FTI/ Institute of Environmental Management, IEM - supported by USAID).
- The CDG project on Industrial Pollution Control for SME's in Thailand 1992-1994 (AIT/CU/CMU/DIW).
- Promotion of Cleaner Technology in Thai Industries 1996-1998 (FTI/Thai Environment Institute, TEI - supported by DANCED).
- The Cleaner Technology Unit at TEI.

the single companies approached by the various programs. The programs have often been designed to provide knowledge of new technological alternatives, and in many instances these alternatives have been implemented in the production. However, the implementation of CP has not spread to other similar companies, nor has it spread into subsequent CP initiatives in the original company. There is only very limited uptake of the CP idea in industry. "Technology is not a problem or a barrier, but the lack of knowledge on how to practice CP is." (Zatz 2003). The CP development has always stopped once the consultants leave, as the companies don't develop new initiatives directed at their specific context by themselves.

An evident question is thus, whether EMS can overcome the problems that have appeared in the attempts to promote the use of Cleaner Production in Thailand? Will the implementation of EMS in Thai industry lead the companies to begin to develop their own significant environmental issues?

The general experiences from the European context on this issue are not clear. Certainly new environmental priorities are established in relation to the numerous operating EMS's, but as of present these environmental priorities are hardly ever tested, i.e. they are seldom used for real discussions on the environmental behavior of companies. Therefore it is hard to tell whether they are the right issues to take up. EMS have in their original European context avoided ending up in discussions on whether they are dealing with the right problems because they have been directed at dealing with problems that were already well-established as coherent issues in relation to an accepted environmental legislation and a network of professionals. However, this does not imply that the general establishment of priorities is unproblematic. Experiences show, that this is only the case as long as it can be kept as an implicit decision among professionals. Public disputes have demonstrated that these questions are very difficult to handle when they are stated explicitly. Examples of these kinds of discussions range from attempts to evaluate a single event (the Brent Spar incidence) to technological systems (the GMO debate) to the overall state of the environment (the Lomborg debate).

The local context of implementation with regards to the general conditions for economic and environmental development hold significant differences as the regulatory situation and enforcement, the production processes and equipment, the available competences of local professionals and the predominant management culture in general show important differences. These contrasting points are detailed in the following:

The regulatory situation

While a number of European countries have been through a crisis and strengthening of the enforcement of environmental legislation in the late 1980s, most Asian countries have a strong regulation as expressed in words and legislation, but still very weak and uneven enforcement. A change in this situation would include improving the competencies of regulatory officials, but there is resistance from industry towards empowering officials with improved environmental knowledge, as this may function as one more instance for corruption and becoming critical counterparts to the companies. At the same time a number of different programs on

- First Asia Pacific Roundtable on Cleaner Production 1997 (Pollution Control Department, PCD).
- CP in municipalities 2000-2001 (PCD/TEI).
- Cleaner Production for Industrial Efficiency, CPIE (PCD/Environment of the Royal Thai Government).
- Cleaner Technology Capacity Building at DIW 1998-2003 (Department of Industrial Works - supported by DANCED).

cleaner technology, efficient production and environmental management have been promoted. But while these programs have been part of actions trying to make companies go beyond regulatory requirements, government agencies and foreign donor organisations promote other separate programs that introduce cleaner technology as technology transfer options in order to initiate companies' environmental activities on a business opportunity basis. These programs also typically operate with only brief knowledge of the existence of other similar initiatives. Different from the situation in e.g. Europe these programs have primarily been promoted as technology transfer actions while in the European context typically had a strong element of technological innovation and process improvements.

Often the implementation of an ISO 14000 system will be the fist time the environmental legislation is applied to a company's activities - at least in a systematic way. The norms of the Thai environmental legislation are rather strict and quite comparable to European standards. But these norms are not fully enforced. Rigorous enforcement of the legislation would probably be a major problem to industry, and it might even be economically critical for some part of the production seen in relation to the dominant business culture and investments. Case studies in the EMP project revealed, that many big and respectable companies have obvious problems in complying with the legislative standards[3]. This does not appear to be a large problem in relation to the relevant authorities[4]. Several of these companies are ISO 14001 certified even without actually complying with existing legislative demands. Interviews with environmental auditors and consultants revealed that this is due to a widespread practice among auditors of accepting strategies to achieve regulatory compliance rather than demanding this as a prerequisite of acquiring a certificate: "We got our certificate for having good intentions"[5]. There appears to be and obvious parallel between these auditors lack of pursuing the norms of the ISO 14001 standard and the authorities weak enforcement of the norms of the environmental legislation.

In some ways the strict but not enforced legislation perform very well. The strict norms produce legitimacy for the formal environmental regulation created by government. From the governments perspective it is thus better to have a strict legislation, which lacks enforcement, than a less strict but enforced legislation which reflects the actual conditions of industry. The strict norms may also function as a basis for bringing up environmental problems as scandals in the press or as issues of NGO's and thereby shaping a ground for public environmental enquiries without the need of government and state authorities to secure and enforce the policies in detail.

In some incidences, where government offices have been too eager to pursue the enforcement of the legislation, these offices have even been closed. As a result of this subjugation of enforcement, even the Pollution Control Department, PCD of MOSTE[6] will not necessarily include private industry in their initiatives. A program established by the Pollution Control Department of to support the implementation of CP program in municipalities is e.g. directed only at the internal activities of the municipalities. The program involves schools, hospitals and markets run by the municipality, but no initiatives towards private companies, that contribute to a much larger extent to the local environmental problems (In-na 2003).

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3 A big car manufacturer had e.g. evident problems with VOC vapours from gluing and painting. A metal rack producer was also producing deaf employees. A battery company had to much dispensed solids in its waste water.

4 Thai companies are regulated by a number of different authorities according to their location, size and production.

5 Environmental manager at the car manufacturing company.

6 Ministry Of Science Technology and Environment

The industrial processes and technology

In most Thai companies the production technology has been imported or transferred and not developed locally. This leaves the Thai companies like many other companies in South East Asia with a lack of basic knowledge of the technical principles of the production and too little capacity for product development and improvements. Product requirements and standards are typically defined in the industrialised countries leaving only little space for local improvements and local competence building in the supplying company.

This lack of local knowledge on specific details in the production also makes it difficult to establish specific environmental initiatives that are closely related to the actual production. Thus concrete initiatives as e.g. waste management may be implemented in a manner where it is hardly related to the actual production. Given the current problems of the institutional waste handling in Thailand this appears to be a very relevant issue. However in the brochure presenting the company's ISO14000 system to the public, the waste separation process is not presented as an issue which is related to the main activity of the company, i.e. the manufacturing of automobiles and parts for automobiles. On the tour of the shop floor, the guide likewise does not point to any waste separation activities in the production[7]. Rather the waste management appears to be a concern related to the offices of the administration[8], where they use paper, cardboard boxes and printer cartridges. Colored bins for sorting office waste at the car factory show a kind of visible beauty and also superficial understanding of the environmental agenda for voluntary actions at the same time as it shows a visible and for company management easy example of environmental response.

This is also the case for the car manufacturing company's focus on heavily regulated waste water outlets that can be rather easily monitored and controlled. The focus on waste water discharge conditions is in general showing the role of EMS in bringing the legislative requirements onto the companies' agenda. Again the car manufacturing company is illustrative for their focus on BOD-related discharges from the employee's canteen instead of factory based outlets from production.

The examples demonstrate that there is only a weak relation between the actual environmental performance of the production and the concrete environmental monitoring and relief activities that are established in relation to the implementation of ISO 14001 on the factory. There appears to be a lack of knowledge on both environment and production issues which could unite these elements and put them into a broader framework of prioritisation and negotiations of environmental importance, which seem to be crucial to the vision of continued improvements.

Similar patterns of environmental initiatives that were hardly related to the content of the actual production were observed at other factories. In one place brooms were decorated with ribbons in honor of H.M. the Kings birthday: The workers would

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7 This is in contrast to the tour of the Danish company, where several waste management initiatives were pointed out even though waste management was not a priority. Waste management is normally a very visible feature of the company's environmental initiatives compare to e.g. the substitution of solvents.

8 In the car manufacturing company this was shown in the introduction of waste bins, with an obvious visual impact, but questionable in their environmental overall impact besides their contribution to employees knowledge.

"Waste management:

1. Yellow bins are for common waste as food, fruit peels, dust, paper scrap and used diskettes.

2. Green binds are for reusable waste as plastic bottles, cardboard boxes, steel wire scrap, soda cans and newspapers.

3. Red bins are for hazardous waste as all kinds of batteries, printer ink, chemical markers, correction markers and glue."

sweep the floors of the factory to show their commitment to protect the environment. Another company would use treated waste water to sprinkle their greens on the factory site, thus both maintaining literally 'green' surroundings while also reducing the amount of waste water produced and discharged.

The focus seem to be on separating waste, reduce energy consumption and treating waste water, which already are in the focus of environmental legislation – and this is not specific for car factories alone. Other environmental aspects typically relevant for a car manufacturing company such as e.g. substituting specific organic solvents by alternate processes to reduce air pollution and improve health and safety conditions include change of processes and use of other materials, were typically recognized by the employees working with environmental topics in the company but at the same time seen as very complicated, at a change of practices would demand very specific, new production knowledge.

The competences of environmental professionals

Consultants are not widely used in Thailand as they are conceived by business management to be too expensive. This leaves the certifying companies with a rather difficult task, as they often become involved as part time consultants for the companies they certify. The often strict division between consultants and certifying companies found in Europe is therefore less obvious in Thailand.

Also, the overall purpose of implementing e.g. ISO 14001 is not to improve the environmental capacity and competence of the organisation, but rather to achieve certification[9]. The process of ISO 14001 implementation, is a process which then has to very specific and specialised in-house knowledge and routines of production with rather abstract descriptions of what is the environment[10]. Here it appears that many companies lack the necessary competences. To some extent this weak competence can be seen as a side effect of the weak legislative enforcement. The lack of a proper practice of enforcement in the every day activities of the environmental authorities has been counterproductive to building competencies on the environmental problems of industry among the staff of the authorities. This tendency is further supported by the lack of use of environmental consultants as a way of distributing a common interpretation and practice concerning the criteria for enforcing the general requirements in the legislation.

When EMS' are implemented it is therefore often done by in-house technicians or more frequently quality assurance managers that only have general knowledge of current environmental issues and discussions. This gives the certifying companies an opportunity to focus their advice on management issues and to limit their demands to the companies' environmental competence or to their use of environmental consultants. Many of the certifying companies offer a range of different management certificates, especially different varieties of quality management, and health and safety management systems. Therefore their knowledge of the specific environmental issues needed to control the environmental performance of their clients may be limited.

The competence of the professionals in industry have been developed by previous promotion programs of cleaner technology, cleaner production and other programs in relation to the environmental agendas of industry, and through the distribution of

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9 Whereas uncertified EMS are not unusual in Danish companies, no examples of such practice have been encountered in the EMP project, nor in the litterature in general. As a part of a focus group interview in the EMP project it was even stated directly by 8 Thai car manufacturing companies as the common reason for engaging in EMS activities.

10 The ISO 14001 standard does provide suggestions for where to identify the environment as general lists as "emissions to air, ground and water".

EMS through business and management networks But these projects are reported to have had virtually no lasting effect (Zatz 2003). Specific technologies are implemented at specific factories during the project period, and in some instances these technologies are also spread in similar companies. But it is only the specific technologies that are spread. The cleaner technology thinking itself is not anchored in the companies, and no new activities on further cleaner technological development are seen afterwards. The experience of the cleaner technology projects is to a lesser extent than in the Danish context spread through discussions in networks of related professionals. For knowledge on environmental issues it appears to be personal networks - the extended group of friends and family that serves as the dependable source of good advice.

Business culture

The business culture in South East Asia often reflects a traditional paternal family structure of ownership and control. While managerial professionalism is part of the promotion of EMS in Europe supporting the involvement of employees and the spreading of knowledge in the organisation, the paternal structure of management is very dependent of centralised decision making and may not in the same way support the spreading and development of knowledge in companies. Knowledge on diverse matters as economy, organisation, technical equipment and environment is the privilege of central management. At the same time poor knowledge on environmental issues in general and viewing the environment issue as a 'luxury' problem that is predominantly taken up by the 'rich' countries and that should only be dealt with when more basic necessities have been taken care of does still play a major role both in the rhetoric and practices of companies in developing countries.

The implementation of management systems as ISO 14001, but also more dominantly ISO 9001 can be seen as a sign of emerging change in the paternal management strategy. Following the economic crisis of 1997 where the personal networks of the paternal business culture showed to be insufficient, there has been a need for building new mechanisms of trust. The management standards including ISO 14001 can be seen as such trust devices that are introduced in order to demonstrate reliability. Thus the focus on the certificate rather than the certification processes. But it also supports an implicit understanding of the environment as a distinct and separate problem for companies, being of at type that can be handled and 'solved'. As such the environment is seen as objective and as a problem that can be addressed in ways that give companies the opportunity to manage their own processes in a sustainable way.

The environmental policy of the Car manufacturing company states: "The company shall see to that every single production process is not harmful to the environment". This phrasing establishes the environment as something, which is only an issue if something goes wrong. Whereas, in a European context the environment is considered as a continuous concern, like the ISO 14001 standard mentions continuous improvements. The similar objective would her talk of "minimizing the environmental impact" instead of avoiding environmental harm as this recognizes the inevitable impact of production on environment and maintains this as a permanent issue of the company.

Discussion

Perspectives from science- and technology studies provide us with a framework to conceive the regulatory elements that have appropriated from their western origins as artefacts which are constituted and used in a specific context (Latour 1999; Sørensen 2000). The intentions and impacts delegated to the working of these artefacts are complex and not based on consensus among all involved actors, although certain impacts on industrial behaviour and impacts on environmental performance are supposed to be the outcome. Understanding these artefacts, e.g. EMS as an integrated part of and in continuous exchange with their surroundings, stresses how they will identify and pursue different objective depending on the context in which they function. In the description above the conditions of EMS are described as 4 domains. A description such as this provides an analytical background for understanding how the practitioners manage the earlier mentioned interpretative flexibility of the 'hot spots' of the written ISO 14001 standard. The domains provide the 'social' setting which provides a number of taken for granted issue that serve to limit the interpretative flexibility of the standard in the specific case, which is a prerequisite for making it operational. The four domains can as such function as a model of the embedding of EMS which will show the specific differences in the components and the path of change to be expected and to promote.

The local conditions are thus more than just a backdrop onto which the environmental regulation is performed. Rather the environmental activities are embedded in this setting. Both the conditions created by the historical past and the present context of implementation play an important part in the working and impact of the regulatory elements. The historical context of implementation is crucial for what has to be taken into consideration and which roles have been delegated to the different elements and aspects of the system. This supports the idea that environmental regulation consists of historic and setting specific roles to be delegated to different elements. With regards to EMS, it is a predominant model to conceive environmental management systems as a response to independently existing environmental problems and knowledge of these.

In this manner the EMS exposes a common implicit assumption of environmental regulation, i.e. the underlying existence of a number of underlying facts about nature and the environment. The four previously described domains each contribute in a different manner to the production of this pre-existing environment. Thus, the environmental outcome of EMS can be understood as the interaction of previously existing environments. The separate domains produce environment with distinctly different cognitive and practical features:

- The environment as object of legislation (e.g. norms)
- Environment as specific technical measures (e.g. machinery and equipment)
- Environment as management objective (e.g. statements and policies)
- Environment as knowledge and experience of professionals (e.g. exemplary references)

These in turn exist on the background of a dominating public environmental discourse which however only in a few cases gives an expression of its own, typically through the press or local action groups.

In order to understand the performance of the individual regulatory artefacts as EMS in the newly industrialised countries of South East Asia, the interaction of these four domains must be analysed. Apparently the environmental agenda is transformed in the newly industrialised countries. The most noticeable effect of this transformation is an increasing focus on legislative compliance as a result of the poor existing enforcement activities. In some instances this is followed by low priority on the more advanced continuous cleaner technology development.

When EMS promotes a focus on abiding to the legislations demands, the necessary investments in cleaning technology in order to live up to these demands takes resources from continued development. Also they may function as sunk costs in relation to the existing production technology, e.g. in the shape of an expensive waste water treatment facility. In some instances it even appears as these sunk costs function as a barrier to the further implementation of cleaner production elements. This is the case when heavy investments in filtering technologies provide a continued technological dependency on more dirty production processes and thus blocks an up-dating of production facilities. In the EMP project this appeared to be the case for the Battery manufacturing company that would invest heavily in reducing emissions from a production of second grade batteries that can no longer be exported.

The importance of coherence

It is not evident hot to evaluate the success of EMS implementation in new settings such as the recently industrialised countries of South East Asia. Counting the number of implemented systems is not in itself representative to environmental achievements. But also more qualitative assessments of i.e. the environmental priorities of the implemented systems can be misleading without relating these to the rest of the context.

The implementation of EMS in these countries is often supported by various promotion programs. These are financed by foreign donor organisations. The transfer of new technology as EMS is based on the idea of supporting 'progress'. Development is seen as the linear path of history, and development aid as attempts to boost the progress in order to move more quickly through the earlier stages of this line. This concept of linearity is also prevailing in the field of environmental regulation. Newly industrialised countries in Southeast Asia are considered to be 'lagging' behind on environmental protection and should be brought up to common western standards. To the promotion programs EMS is such a technology which is expected to be transferred to work in similar ways that it did in e.g. Europe.

However, the development of an environmental agenda depends not only on any of the single features above, but also on the combination of these. A well performing environmental effort requires for these features to be interrelated, for the involved actors to be able to transfer knowledge elements and have some common references for good performance, and to share visions of environmental improvements and the routines and everyday practice of engineering and management. The individual elements of environmental governance/regulation may all be present, but they will not manage to work together to accomplish a self sustaining basis for continuous improvements. As a manner of providing an analytical understanding and evaluation of the success of EMS in new settings we suggest to include a discussion of the matter bringing the different elements together, i.e. the coherence of the context into which the environmental agenda is embedded. Coherence is a possibility of investigating and even evaluating the success of EMS in new settings. The description of the embedding of EMS suggests that the potential of EMS lies in achieving better relations and as such more coherence among the different domains. The potential for industrial transformation through improved environmental management is limited by the lack of relatedness, i.e. coherence

The question of coherence is not only a question of bringing different environmental issues together, but also a way of analyzing whether different interested parties are committed to maintain a discussion of environmental problems in relation to specific issues. The concept of coherence draws on the actor-network theory understanding of 'alignment' processes (Latour 1999). Alignment is the element of bringing actants together to establish a new network. As different actants are engaged, enrolled and committed the network gradually gains strength and undergoes a process of translation. Heterogeneous elements as legislative norms, regulatory practice (e.g. enforced legislation, corruption practices), 'natures' response, production facilities, workers practice, individual concerns, management practice, environmental management standards, customer demands, supplier capacity, competence of consultant and sector structure are combined to contribute to new entities of environment - well performing environmental problems. Coherent environmental issues are 'good', i.e. manageable environmental problems that are recognized by a wide group of actors and associated with commonly accepted practices of representation. The concept of coherence adds a normative element to the description of alignment processes by referring to environmental issues, which are embedded in well-aligned actor-networks.

Coherence is an attempt at conceptualizing the combination of different aspects and perspectives, and thus as source of further development. Coherence also addresses, that there may appear as a high level of awareness of individual environmental problems, while these are still not interconnected in a manner that would accommodate a future development of the problems. In a situation with coherent environmental problems these will function as a frame for the discussions. This does not imply that the different interested parties necessarily agree about the state of the environment, but that there is a limit to how far the conflict may spread as the different actors are engaged to keep these representations at the centre of their discussions. The coherent environment functions as a boundary ordering devices (Sluijs et al. 1999) that keep actors obliged to discuss the environment within the same frame, thus avoiding conflicts to 'spill over' and develop into situations that are difficult to control and without democratic mechanisms of solution. These unhappy situations can be recognized by their combination of physical violence, corruption and prolonged conflict resulting in a general waste of resources[11].

The lack of coherence between the different domains of the South East Asian context reflects how the different elements in some instances have been developed in parallel as separate entities that are otherwise not related. The coherence that may have existed between the separate elements in their western origins seems to be lacking after the individual implementation and transformation to the South East Asian context. Rather than developing and improving individual elements as legislative norms or management programs, it seems to be the mutual connections that need to be developed and strengthened. The EMS in the European context does function by using these relations. However, the transformation to newly industrialised countries demonstrates that these relations and the coherence they constitute is not necessarily present in countries that have different histories. As a result of this development, the predominant picture of EMS is presently a situation where EMS is left to function as procurement of enforcement. It does not look as if the EMS will in themselves support a development towards continuous improvements beyond the definitions of the existing legislation.

11 A well known example of this kind of situation is the current state of the Klong Dang waste water treatment plant in Samut Prakarn. This mega project based on investments from the Thai government, ADB (and Danish development aid) is now physically 95% finished, but cannot be connected to the appropriate pipelines because of local protests. Meanwhile a former vice-minister is connected to a corruption scam in relation to the land, where the facility has been constructed. But even without the corruption element, the incoherent environment is a cost.

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Australian Experience with Greenhouse NEPIs

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The Spread of New Environmental Policy Instruments (NEPIs) to Australia

Much of the theoretical and empirical discussion of 'new' environmental policy instruments (NEPIs) focuses on European experience and relates to *ecological modernisation* or *industrial transformation* (Anderson and Massa 2000; Christoff 1996; Gibbs 2000; Jordan *et al.* 2000, 2002, 2003a, 2003b; Knill and Lenschow 2002; Wurzel 2001). These perspectives concentrate on the contemporary evolution of interactions between environment, economy, society and public policy. Government imposed command and control measures to manage polluters are seen to be 'old' instruments that will be phased out with a shift to self regulation and incentives for industry. An intermediary phase of coexistence of 'new' and 'old' policy instruments together with 'new' and 'old' institutional structures to facilitate the implementation of agreements is expected. The theoretical assumption regarding NEPIs is that they have greater effectiveness and efficiency. The concept that such a change in the role of government would have positive environmental outcomes was initially academic but has been embraced by politicians in several European nations (Weale 1992). Micro-scale (voluntary agreements, eco-labelling, environmental and carbon taxes, and emissions trading) and meso-scale initiatives (national environmental plans and strategies for sustainable development) have been instituted. Jordan *et al.* (2003a) identify eight driving forces for the implementation of NEPIs:

1. dissatisfaction with environmental regulation
2. perceived superiority of NEPIs
3. neo-liberal ideas about deregulation
4. influence of the European Union in forcing adoption of NEPIs by some member states
5. growing international competition and economic recession driving a search for more cost-effective policy instruments
6. growing domestic support from elected politicians
7. interaction between different types of NEPI (e.g. the threat of environmental taxes has popularised voluntary agreements and emissions trading)
8. climate change has pushed governments to actively explore emissions trading and voluntary agreements.

In particular, implementation of the 1992 Framework Convention on Climate Change (FCCC) has been characterised by adoption of NEPIs and notably voluntary agreements. Governments including those in the EU, the US, Canada and Australia have taken steps to reduce greenhouse gas emissions via NEPIs. This has been in anticipation of the Kyoto Protocol coming into force. Article 4.2 of the FCCC states that each developed country party shall:

'…adopt national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs. These policies and measures will demonstrate that developed countries are taking the lead in modify long-term trends in anthropogenic emissions consistent with the objective of the Convention.'

Also Article 2.1 of the Kyoto Protocol states:

'Each Party…shall…Implement and/or further elaborate policies and measures in accordance with its national circumstances, such as…encouragement of appropriate reforms in relevant sectors aimed at promoting policies and measures which limit or reduce emissions of greenhouse gases…'

Both of these Articles point towards development of new policies and measures.

Policy formulation and implementation in relation to NEPIs in Europe has been underway for nearly two decades. However, according to Jordan *et al.* (2003a):

'Attempts made in the late 1980s and early 1990s to replace regulation with NEPIs did not amount to much. In fact, there is now a widespread recognition that regulation is a necessary aspect of NEPI design and use.' (Jordan *et al.* 2003a)

They report that barriers to NEPI introduction in Europe have included:

1. lack of expertise and familiarity
2. opposition from environmental pressure groups
3. opposition from vested interests (e.g. energy intensive industry opposition to carbon taxes and emissions trading)
4. fears about competitiveness
5. public protests related to distributional impacts of environmental taxes (i.e. related to rising fuel prices)
6. EU requirements (e.g. voluntary agreements taking the form of legal contracts)

(Jordan *et al.* 2003a)

From the early 1990s onwards, NEPI adoption moved beyond Europe along with greater internationalisation of environmental policy via environmental regimes. The report of the World Commission on Environment and Developoment (Brundlandt 1998), the UN conferences in Rio in 1992 and Johannesburg in 2002, and the influence of international organisations such as UNEP, the OECD and the Global Ecolabelling Network all have strongly shaped and influenced the direction of environmental policy both locally and globally. Tews *et al.* (2001) observe that:

'The recent shift in the prevailing policy pattern from a sectorially fragmented and largely legal regulatory mode to an integrated environmental policy approach relying increasingly on 'softer' and/or more flexible instruments such as voluntary instruments, ecolabels, or ecological tax reforms is equally proceeding on a global scale. … in addition to the national demand for adequate environmental policy instruments, the spread of policy innovations is influenced by

- the presence or absence of international platforms or promoting agencies, which have placed the advancement of certain NEPIs on their agenda; and
- the specific characteristics of the policy innovation itself.'

Jänicke and Jörgens (1998) also reflect that environmental policymaking at the domestic level has come under considerable international scrutiny and the influence of epistemic communities. As Hass (1992) describes, these groups are knowledge based networks of environmental bureaucrats, diplomats and scientists who influence environmental policy innovation on the international environmental agenda and develop shared perceptions of innovations that should be adopted at the national level.

Australian officials and scientists have been active participants in these international environmental fora and processes from the early 1990s. After the Rio conference, Australia adopted several meso-scale 'new' environmental policy instruments including a *National Greenhouse Response Strategy,* a *National Strategy for Conservation of Australia's Biodiversity*, and a *National Strategy for Ecologically Sustainable Development* (Commonwealth of Australia 1992a, 1992b, 1992c).[1] All of these initiatives arose from international agreements or commitments and arguably from a desire to maintain Australia's image as with a good environmental citizen. However, Australia has a very different economic base to the European nations such as Germany, the Netherlands, Denmark, and the United Kingdom which have also been proactive epistemic community participants. As Walker (1994) has said:

'Australia's dependence on exports of primary or minimally processed products, the dominance of foreign capital in manufacturing investment, and the large size of the service sector…all create strong pressures on governments, state and federal, for economic growth mythologised as 'development'…the interlocking of Australian business, government and bureaucracy is pronounced reflecting a convergence of government and private interests in 'development.'

Regulatory policy in Australia is responsibility of the states and has been characterised as 'haphazard, ad hoc and piecemeal' (Walker 1999a) and 'generally reactive' (Walker 1999b). It has been over the last two decades been accommodative towards industry. In many cases environmental regulations that are put in place are not well implemented or monitored due to lack of resources available to regulatory agencies. Also stringent regulatory standards are not set when it is perceived industry is not able to comply with them.

At the same time the precautionary principle, measures directed towards ecologically sustainable development and public participation in the policymaking process have come to underpin regulatory, legislative and institutional undertakings at federal, state and local government levels in Australia over the last decade. Crowley observes that:

'There is no doubt that policy rhetoric has become more eco-friendly recently, with the adoption of notions such as ecological integrity, sustainability, diversity, precaution, synergism, whole-of-life-cycle planning and best practice environmental management.' (Crowley 1999)

In particular, development, implementation and review of environmental policies and programs at the micro level have focussed on the goal of international best practice. The now standard directive given to consultants by federal and state environmental agencies as a component of policy reviews is to research and make recommendations taking into account best practice. This aspiration for international best practice policies to be adopted and especially NEPIs would appear to conflict with developmentalist goals of enhancing an economy largely dependent on resource extractive and energy intensive industries. However, NEPIs are not seen in Australia as a constraint on development (Papadakis and Grant 2003).

1 The *National Greenhouse Response Strategy* was subsequently revised and reissued as the *National Greenhouse Strategy* (Commonwealth of Australia 1998) (Bulkeley 2000; Taplin 1994; Taplin and Yu 2000).

Environmental micro-policy critique has been seen as being potentially fruitless in the current Australian situation with the argument being that '…many Australian theorists fail to focus upon micro detail…when politics is so clearly driving environmental policy performance…' (Crowley 1999). By contrast the remainder of this chapter does address the micro level of Australian NEPI implementation so as to derive some case study understanding of what the political status and role of NEPIs is in Australia.

Australian Greenhouse NEPIs

Aspects of Australian experience with NEPIs have been discussed by Papadakis and Grant (2003). Also Jordan *et al.* (2003a) have compared Australian adoption of NEPIs with the uptake in European nations. Papadakis and Grant (2003) comment that Australian NEPIs are predominantly controlled by the state which has '…genuine interest in and experimentation with new tools…' and that the regulatory situation with respect to command and control regulation versus adoption of NEPIs is characterised by:

'…continuity in traditional regulatory approaches, with several qualifications: growing emphasis in voluntary agreements, targeting of resources to encourage the creation of competitive eco-efficient industries, the importance of strategic (rather than operational) interventions by the Commonwealth and other agencies and research on economic or market-based systems (such as emissions trading).' (Papadakis and Grant 2003)

Australia is not seen internationally as a leader in the adoption of NEPIs (Jordan *et al.* 2003a) in comparison to the Netherlands, Germany and Finland but has undertaken a range of NEPI initiatives and, in particular, in relation to climate change. Experience with two particular NEPIs administered by the Australian Greenhouse Office, the Greenhouse Challenge and Greenhouse Friendly programs, is discussed here. These policy instruments have been implemented, together with numerous other greenhouse policy initiatives, notwithstanding the Howard Liberal-National Coalition Government's negative position regarding the Kyoto Protocol (Yu and Taplin 2000). This standpoint was stated openly by the Prime Minister in a speech in November 2002:

'Currently it is not in the national interest to ratify the Kyoto Protocol because, under the terms of this arrangement, many of our competitors do not face the obligations we would face. Australia would lose investment to these countries and the greenhouse gases would simply change location. Indeed many countries have less stringent environmental standards than Australia…For example, under the Kyoto Protocol, a company wishing to establish a new aluminium plant in Australia may face a greenhouse-reduction cost penalty that they would not face in countries like China or India. In a competitive global market, this cost burden may be enough to see the plant is built elsewhere, leaving Australia the poorer without any global gain.' (Howard 2002)

The Greenhouse Challenge and Greenhouse Friendly Programs

A fundamental underpinning of the Greenhouse Challenge and Greenhouse Friendly programs is that they were formulated in line with the 'no regrets' framework set out in the *National Greenhouse Strategy* (Commonwealth of Australia 1992a; 1998) and accordingly are not intended to compromise business objectives of profitability and growth. Aspects of the operation of these programs are given below.

The Greenhouse Challenge Program

The Greenhouse Challenge program was initiated in 1995 in response to a request from major Australian industry players (many having transnational affiliations) for a voluntary agreement on greenhouse between government and industry. At the time there had been considerable public debate in Australia about the potential introduction of a carbon tax although little serious interest had been expressed by the federal or state governments or elected politicians. Major industry actors approached the Keating Labor Government to institute a voluntary greenhouse program with a view to avoiding a carbon tax (Commonwealth of Australia 1999). The business impacts of carbon taxes that were being reported from other countries undoubtedly drove this request for a greenhouse NEPI in Australia.

Voluntary agreements on greenhouse abatement have been taken up in several countries (Commonwealth of Australia 1999; WBCSD and WRI 2001). Such agreements were instituted from 1992 onwards and include:

- Netherlands: Long Term Energy Efficiency Agreements (1992)
- Canada: Climate Challenge Voluntary Challenge and Registry (1994)
- New Zealand: Industry Challenge (1994)
- USA: Climate Challenge Program (1994); EPA Climate Leaders Initiative; Voluntary Reporting on Greenhouse Gas Emissions (1605b Program)
- Germany: Joint Declaration of the German Industry on Global Warming Prevention (SVE) (1995)
- Japan: Keidanten Voluntary Greenhouse Action Plan for the Environment (1997)
- UK: Greenhouse Reporting Program (1999)[2]

Accordingly, it can be seen that voluntary agreements on greenhouse were already underway in the Netherlands, Canada, New Zealand and the US when the Australian Greenhouse Challenge program was initiated.

The Greenhouse Challenge Office (GCO) was set up in Canberra in 1995 as a federal interdepartmental effort and was overseen by three agencies: the Department of Primary Industries and Energy (DPIE), the Department of Environment, Sport and Territories and the Department of Industry, Science and Tourism. The GCO was located in DPIE offices. When the Howard Coalition Government gained power in 1996, the program was allowed to continue notwithstanding cuts to other areas of funding for climate change. In 1998, the GCO was transferred to the status of a program administered by the Australian Greenhouse Office (AGO) with the inception of the agency.

The Greenhouse Challenge program facilitates the establishment and monitoring of cooperative agreements between members of industry and government. Idutry members undertake to abate their greenhouse gas emissions through energy and process efficiency and by enhancing greenhouse sinks. As indicated above, the program is administered by the Commonwealth but does not have legislative backing. In May 2003, there were 820 participants in the Greenhouse Challenge program.

Organisations that volunteer to join the Greenhouse Challenge program enter into a cooperative agreement that is non-binding and is not a legal contract. Cooperative agreements can be individual, facilitative or aggregate:

- 'Individual cooperative agreements are agreed with a company to reduce emissions for the company
- Facilitative agreements are made with a representative body such as industry association which actively encourages its members to join the Greenhouse Challenge

[2] Also interestingly the World Wildlife Fund instituted a voluntary Climate Savers Program for industry (WBCSD and WRI 2001).

- An aggregate agreement is made an industry sector, or part thereof, with an industry association entering into agreement to reduce emissions on behalf of named member companies (e.g. Cement Industry Federation).' (Commonwealth of Australia 1999)

Greenhouse Challenge members are required to prepare an action plan for greenhouse emissions abatement and under their agreements to report annually on their progress with emissions reductions. Actual details of member reports are confidential but summative information is publicly reported. Also aggregate agreement reports from industry associations do not identify abatement by individual corporate entities but only for the sector as a whole (e.g. cement and aluminium industries). As such, there is a considerable lack of transparency in aspects of handling of information by the program.

The *Greenhouse Challenge Factors and Methods Workbooks* (AGO 2003a) are the key supporting documents of the program. The workbooks outline the process of how a business organisation can calculate the greenhouse gas emissions associated with its operations. Data inputs required by the workbooks include quantities of solid fuels, gas and electricity consumed. Confidence in greenhouse gas calculations directly corresponds to the accuracy of these measured amounts. The success of the Greenhouse Challenge Program in turn relies on the accuracy of greenhouse reporting. The focus on accurate emissions reporting has ramifications for potential involvement of Australia in carbon trading (domestically or internationally under the Kyoto Protocol) and environmental reporting.

The issue of the quality of reported greenhouse emissions data under the Greenhouse Challenge Program first arose during the 1999 review of the Greenhouse Challenge program and subsequently with the 2002 independent verification. Reporting varies from 'comprehensive and detailed documents' to inconsistent (i.e. not annually) reporting of variable quality. The *Greenhouse Challenge Evaluation Report* stated:

'Because reporting requirements were not defined at the beginning of the program there has been a blurring over time of what is required, and this has resulted in inconsistent reporting across participants and uncertainty among some participants…Much of this has been because, in an attempt to keep the program flexible to encourage broad participation, no standard format for agreements was originally developed.' (Commonwealth of Australia 1999)

Commentary from participants in the Greenhouse Challenge program included:

'We used the workbook to put together the first progress report. There was no consistency and we didn't know what they were looking for. We did a brief report, while others did huge reports.' (Commonwealth of Australia 1999)

Some standardisation of the annual report format has occurred since these comments were made with the implementation of an electronic proforma report format. However, consistency in reporting is still proving a challenge due to the variations in types of members and industry sectors involved and the capacity of companies to fulfil reporting requirements.

Verification by independent environmental auditors is seen to be a mainstay of the Greenhouse Challenge program as it '…continues to play an important role in improving the quality of reporting…as well as enhancing the level of program transparency and public accountability.' (AGO 2003b). The 2002 Independent Verification of the Greenhouse Challenge was the third independent verification organised by the AGO[3] and arguably more comprehensive than previous rounds. Twenty-three members' reports and reporting procedures were verified under commercial-in-

3 A pilot independent verification was run for four members in 1998. In 2000, 31 Greenhouse Challenge members were independently verified.

confidence requirements regarding company data. The independent verification found that:

- 'I6 Members were verified as having reporting that was comprehensive, comparable and free from material discrepancies;
- 1 Member had a material discrepancy in relation to their greenhouse gas inventory;
- 3 Members has material discrepancies in abatement estimates (2 of these Members also could not be fully verified due to a lack of supporting documentation); and
- 3 other Members could not be verified due to a lack of some supporting documentation.' (AGO 2003b)

These results would be unacceptable for a financial audit as would the generous materiality threshold of 10% that was adopted for the verification (AGO 2003b). Any discrepancy of greater than, or equal to, 10% of abatement reported was considered material or significant. This is quite a liberal materiality threshold as voluntary greenhouse programs implemented in European nations use 5%. Lack of systematic emissions and sink data archiving by companies proved to significant problem that arose during the verification with several of the members revealing that they were not able to retrieve their records (AGO 2003b). Also some verifications for companies were delayed due to overdue annual reports and/or delays in report approval by the AGO (AGO 2003b).

A final and important aspect of the operation of the Greenhouse Challenge program is the role of the Joint Consultative Committee (JCC) which was first established in1998. The JCC provides a decision-making forum for government and industry representatives on key program and implementation issues for the Greenhouse Challenge program. All members of the JCC need to reach consensus for decisions on issues such as materiality, the requirements for reporting, and content of documents and guidelines that are prepared in relation to the program. This means that industry via the JCC has considerable influence on the program's implementation and may block any decisions that are considered detrimental to industry's economic viability.

Several recommendations for improvement of the Greenhouse Challenge reporting procedures and the independent verification process were made by the AGO in 2003. These included moving to a 5% materially threshold for the next round. The AGO report on the 2003 independent verification stated:

'…a general conclusion that can be drawn from this verification round is that ongoing refinement of verification procedures and more explicit guidance to both verifiers and Greenhouse Challenge members is required to ensure that reporting and verification standards continue to move towards world's best practice.' (AGO 2003b)

The goal of international best practice for the program has several barriers due to the implementation of the program to date. These include:

- right of veto by industry to any modifications or new initiatives associated with the program
- lack of reporting stringency
- non-binding nature of the cooperative agreements
- lack of data transparency due to commercial-in-confidence considerations particularly with industry association aggregate reporting
- uneven implementation by members

Some Greenhouse Challenge members take their obligations seriously and report regularly and accurately but the quality of reporting of some members is not of an acceptable standard.

Greenhouse Friendly Product Labelling Program

The Greenhouse Friendly program was launched in 2001 and involves promotion and certification of ecolabelling for climate change abatement. Consumer goods and services that have all *cradle to grave* greenhouse gas emissions offset by corresponding emissions abatement can be certified. Independent environmental auditors verify the life cycle assessments of products that companies submit to the AGO.

Unfortunately the Greenhouse Friendly program has not been embraced by industry or the consumer. By the end of 2003, the only products certified, somewhat incongruously, were petroleum and electricity products: 'Ultimate' premium unleaded fuel, and Global Choice commercial fuels marketed by BP; and electricity by AGL. BP has provided sink abatement to offset their emissions associated with their products. The greenhouse emissions associated with AGL electricity are offset through landfill gas flaring projects.

Although this program is directed towards consumers, it is questionable whether the Australian public is even aware of the Greenhouse Friendly ecolabel and whether AGO resources directed towards the program have resulted in effective greenhouse abatement action.

Ecolabels have been very successful in Europe and particularly in the Netherlands and Germany where they are widely supported by industry, the public ad NGOs. Part of the reason for industry's support in these nations appears to be that ecolabels often have been the precursor for tax benefits. However, Australian experience with ecolabels has been less satisfactory (Johnson and Lundie 2002). This has been due to environmental NGO and consumer association concerns about *greenwash* together with industry critique of ecolabels. In particular, the Australian Government initiated 'Environment Choice Australia' label was withdrawn after two years of operation in 1994 due to lack of industry support. Recently in 2002, a new NGO environmental labelling body has been established as a further attempt to promote ecolabelling in Australia. This new program has not had significant impact as yet. Given this background, the Greenhouse Friendly ecolabel was probably doomed from the very start.

Concluding Discussion

NEPIs in the form of voluntary agreements have been used extensively in the Netherlands, Germany and the United Kingdom. As mentioned earlier in the chapter, Jordan *et al.* (2003a) have noted that European Union as a whole has been reluctant to adopt voluntary agreements entirely free of a legislative superstructure because of:

- the suspicions or mistrust of environmentalists
- perceived transparency problems with VAs
- officials' concerns about long-term enforceability and effectiveness
- industry's preference for tradition regulation because of its *level playing field* nature.

These transparency, enforceability and level playing field concerns parallel the shortcomings of the Greenhouse Challenge program in Australia and call into question the effectiveness of voluntary agreements as currently adopted in Australia in comparison to the traditional regulatory approach.

Examination of aspects of the Greenhouse Challenge program reveal that it is currently a weak NEPI. Capacity building has been undoubtedly the most significant achievement of the program to date. Training has been provided for consultants in greenhouse gas reporting and the program has provided information to professionals in numerous business and industry sectors related to greenhouse emission assessment. This capacity building for could have long-term benefits if Australia eventually becomes involved in domestic or international emissions trading. In addition, the program has assisted in facilitating the uptake of energy efficiency upgrades and the reporting of these by small and medium enterprises (SMEs); arguably energy improvements by major industry players may have been implemented for financial reasons regardless of the program.

If the Greenhouse Challenge NEPI is to become more effective, improvement with regard to quality of reporting, adherence to data archiving, the materiality threshold and provision of a level playing field for all members is essential. Also public accountability issues such as transparency of industry association agreements and industry control of the JCC are significant concerns.

Examination of the Greenhouse Friendly ecolabel reveals that it is a failing NEPI although ample resources have been allocated to it. This has been due to lack of industry interest and participation. It is difficult to appreciate why the Greenhouse Friendly program was initiated given previous lack of business support for ecolabelling programs in Australia.

The limited effectiveness of the Greenhouse Challenge and Greenhouse Friendly NEPIs can be attributed to several factors:

- lack of industry incentives for participation. Industry involvement has been patchy; in some cases participation has been exemplary but in others the response has been unmotivated;
- the AGO's implementation procedures;
- the AGO's capacity to put into effect compliance with agreements; and
- the design of the process for collaboration and information sharing between the AGO and industry.

As mentioned earlier, the political backing of the Greenhouse Challenge program moved from the Keating Labor Government to the Howard Coalition Government. Both Governments were supportive of *light handed* regulation or deregulation and were accommodative towards industry's desire for the establishment and continuation of voluntary greenhouse mitigation and reporting. Although considerable Australian Government and industry resources have been directed towards the Greenhouse Challenge NEPI, its impact has been inconsistent. If the program is not carefully supported, monitored and reviewed with legislative and legally binding contractual improvements made to enhance effectiveness, it has the potential to move to the status of symbolic policy (Edelman 1964). Whether this happens is dependent on political support. Crowley (1999) has observed about the current Australian Government that unfortunately:

'Today notions of federal environmental responsibility have sunk to previous unknown depths under the conservative Howard Coalition Government, even as it claims to be staking out new policy terrain…'

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The European Relief Potential of Green Public Procurement: Methodology and Results

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1. Introduction

The total expenditures for public procurement within the EU-15 countries for the year 2002 was estimated to amount to 1.5 trillion €, which is about 16 % of the Union's GDP. The Importance of total public procurement by Member State varies significantly: from 11.9 % of GDP in Italy to 21.5 % of GDP in the Netherlands.

The 1990's brought the insight that environmental problems could not be solved through environmental policy alone. As a consequence the concept of sustainable development evolved, which integrates social environmental and economic policy objectives. Thus, the need for an integrative policy became obvious. Environmental, social and economic considerations shall be part of all other policy fields.

Public procurement in the European Union is subject to many legislative rules (92/50/EEC 93/37/EEC, 93/36/EEC, 93/38/EEC, 97/52/EC, 98/4/EC), mainly aiming at increasing transparency of public procurement activities as well as increasing cross border procurement in order to reduce the expenditures for public procurement. Finally also environmental, social and consumer protection aspects are taken into account (2004/17/EC, 2004/18/EC).

Green purchasing - or eco-procurement - encompasses all activities that aim to integrate environmental considerations into the purchasing process, from the identification of the need, through the selection of an alternative, to the provision to the user. Green purchasing tries to avoid unnecessary purchases by reviewing the actual need for the product and seeking other solutions. If this is not possible, it seeks to purchase a greener variant that supplies the same (or better) quality and functionality as the conventional choice (Erdmenger 2003, p.11).

The implementation of eco-procurement into public procurement is of high importance. Public purchasing for a long time has been used as a tool for achieving public policy goals. Historically, national industrialisation has been supported by public purchasing from domestic heavy industry. In the same way the supply of environmentally friendly products could be fostered, because the public authorities act as a market participant and the magnitude of their procurement has the ability to influence the market. The thorough introduction of eco-procurement into public procurement practice has the capability to serve as a general model for private procurement too.

Green public procurement can promote "green markets" and thus act as a stimulus for environment oriented innovation in companies.

Technological change is always connected with social change and rooted in social systems and organisational networks (Mulder et al. 1999). It is guided by engineering ideas and very much driven by economics and policies, procurement policy; especially public procurement policy can play a mayor role in this concern.

Most policy documents on sustainable development mention eco-procurement as a complementary tool to environmental policy. In fact the potential environmental impacts of green purchasing have not even been calculated (Erdmenger 2003, p. 11).

2. The RELIEF project

To close this gap, the project named: 'Environmental Relief Potential of Urban Action on Avoidance and Detoxification of Waste Streams through Green Public Procurement' (RELIEF), funded under the key action programme "City of Tomorrow and Cultural Heritage" within the 5th Framework Programme of the European Commission, was designed. The RELIEF project was divided into a research and an implementation phase. Within the research phase methods for assessment and calculation were developed and applied. The present paper refers to one of the principal items in this phase, namely the calculation of the European relief potential. In order to enable the calculation of relief potentials, an intense co-operation between economists, natural scientists and public authorities, was essential. The RELIEF project started in February 2001 and was finalised in November 2003.

3. Basics for quantification of environmental benefits within the procurement of products

The quantification of the environmental benefits of green purchasing has to be based on the comparison of the purchased products and their alternatives causing different environmental burdens. However, this will be only reasonable if the considered products have the same purpose or in other words, if the product alternatives possess the same service function.

The **service function** of a product specifies the service provided by the use of a product. For instance the service function of a heavy goods vehicle consists in transporting goods. Thus, a heavy goods vehicle and a freight train provide the same service function. The dimension of the service function should be a commensurable physical value named **functional unit** e. g. for the transport of goods the physical value: transportation work (transportation work = mass ´ distance [ton-km]) can be used as functional unit.

The **relief potential** concerning procurement represents the magnitude of the reduction of potential environmental impacts, expressed by means of suitable indicators, which can be achieved by purchasing a specific quantity of a particular 'green' product instead of a 'non-green' product. In other words, it is the difference between potential environmental impacts of a particular combination of a 'green' product and a 'non-green' product in terms of avoided environmental impacts for a given number of functional units.

The determination of the relief potential consequently requires the knowledge of the potential environmental impacts per functional unit of a 'non-green' product as well as those of that 'green' product which substitutes the 'non-green' one. Additionally, the number of functional units relevant on the European level or the European public sector is a mandatory input.

In order to determine the environmental burdens of products in their entirety, it is necessary to consider the whole *lifecycle* of the products. In a simplified view the lifecycle of a product can be divided in four stages: raw materials extraction, manufacturing, use and disposal. In general different products have potential environmental impacts of different magnitude during the specific lifecycle phases. For a given product also each lifecycle stage may have different types of potential environmental impacts.

The best approach to identifying and quantifying the environmental impacts from cradle to grave for one or more products is called lifecycle assessment. A lifecycle assessment addresses the whole lifecycle and includes a broad range of environmental impacts (Schmidt 2003, p. 135).

A general framework how a lifecycle assessment has to be carried out has been described in a series of ISO (International Organisation for Standardisation) standards published in the period of 1997 to the present. Generally, a lifecycle assessment is divided into four stages. The first stage consists in the definition of the **goal and scope of the study**. The second stage comprises the collection of information on the interactions with the environment for all activities in the lifecycle of a product is called **inventory analysis**. The third stage called **impact analysis** aimes at the evaluation of the significance of potential environmental impacts, by using the results of the inventory analysis. In general, this involves the combination of inventory data with specific environmental impacts. In this stage of the lifecycle assessment the inventory data are assigned to impact categories like global warming ozone depletion, nutrification, etc. This allows the aggregation of different contributions to the same impact category and to express them with a single indicator value, like CO_2-equivalents in the case of global warming, CFC-11-equivalents in the case of ozone depletion and NO_2^-- or PO_4^{4-}-equivalents in the case of nutrification (see Table 1). The final stage of a lifecycle assessment is called **interpretation**. Therein the findings of the inventory assessment and the impact assessment are combined.

4. The scientific approach for determination of the relief potential per functional unit

The determination of a relief potential, as already mentioned, is based on the comparison of products having the same service function, but different environmental impacts. Generally a relief potential can be calculated using one of the following procedures:

1. Determination of the difference in environmental impacts resulting from the comparison of two existing products considering their respective entire lifecycles, e. g. two buses are compared by comparing every single component of the two vehicles over their respective entire lifecycle. The precondition for this procedure is the availability of lifecycle assessments of the same quality (basically using identical system boundaries as well as impact categories) for each and every component of both products, a request which in most cases proves to be impracticable.
2. Determination of the difference in environmental impacts resulting from the comparison of two existing products considering only those components of the products which primarily determine the products' service function over the entire lifecycle, e. g. not every component of two buses is considered, but only those components mainly responsible for the service function, namely the engines. For products comprising a high number of components, this procedure is easier operable since the requirements regarding the number and the scope of the underlying lifecycle assessments is not that demanding.

The structural complexity of many products and the unavailability of comprehensive lifecycle assessments for many products make simplifications unavoidable.

In the RELIEF project a procedure for setting up a lifecycle assessment-based environmental calculation was developed (Schmidt 2003, p. 140).

As a result of this methodology a relief potential is obtained, which describes the difference between environmental impacts of a 'green' product and the ones of a respective 'non-green' product. It is expressed as the value of the specific category indicator per functional unit for each environmental impact category common in lifecycle assessment.

The most important environmental impact categories considered by lifecycle assessment as well as their respective category indicators are shown in Table 1.

Table 1 - Environmental impact categories common in lifecycle assessment

Environmental impact category	Category indicator
Global warming	t CO_2-equivalent
Stratospheric ozone depletion	g CFC11-equivalent
Photochemical oxidant formation	kg C_2H_4-equivalent
Acidification	kg SO_2-equivalent
Nutrification	kg NO_3^--equivalent
Human toxicity via air	m^3 air
Resource Consumption	GWh
Waste Formation	tonnes

CO_2 Carbon dioxide CFC-11 Chlorofluorocarbon C_2H_4 Ethylene SO_2 Sulphur dioxide NO_3^- Nitrate m^3 air Refers to the amount of air necessary to dilute an emitted amount of toxic substances up to a concentration which turns out to be no longer toxic for humans

Source: Author's version based on Schmidt 2003, table 8.2, p 145

The relief potential per functional unit thus is not a single figure, but a vector of the magnitude of avoided environmental impacts in the respective environmental impact categories. The calculation is performed according to the following Formula 1:

Formula 1 - Calculation of the relief potential per functional unit

$$\begin{pmatrix} rp_{IC_1} \\ rp_{IC_2} \\ \vdots \\ rp_{IC_m} \end{pmatrix} = \begin{pmatrix} ei^{g}_{IC_1} - ei^{n}_{IC_1} \\ ei^{g}_{IC_2} - ei^{n}_{IC_2} \\ \vdots \\ ei^{g}_{IC_m} - ei^{n}_{IC_m} \end{pmatrix}$$

Source: Author's version based on Schmidt 2003

with:	rp	Relief potential per functional unit
	IC	Environmental impact category
	ei	Environmental impacts in terms of category indicator value per functional unit
	g	'Green' product
	n	'Non-Green' product
	m	Number of considered environmental impact categories m=1, 2, …, m

According to Formula 1 a negative value within a specific environmental impact category will denote an abatement of environmental burdens, if the 'green' product is purchased instead of the 'non-green' one. On the contrary a positive value within a specific environmental impact category will denote a rise of environmental burdens, if the 'green' product is purchased instead of the 'non-green' one.

In order to get a clear impression about the relative importance of the relief potential per functional unit a supplementary approach was chosen in the RELIEF project: the results are normalised so that the results may be expressed in **person equivalents**. *A person equivalent is the potential contribution from an average person in a year to a given environmental impact.*(Schmidt 2003, p. 143) For impacts of global relevance, like global warming or the depletion of the stratospheric ozone layer, the person equivalents relate to an average global citizen. For impacts having regional relevance, like acidification, nutrification etc. an average European citizen is assumed.

Taking global warming, this is an environmental impact of global relevance. The total world wide contributions to this impact in 1994 were 43.3 billon tonnes of CO_2-equivalents from all anthropogenic sources. With about 5.61 billion world citizens in 1994 this equals an annual contribution of 7.7 tonnes of CO_2-equivalents per person. In other words, one person equivalent for the environmental impact category global warming, equals 7.7 tonnes of CO_2-equivalents (Schmidt 2003, p. 143).

Table 2 - Person equivalents

Environmental impact category	Person equivalents based on statistical data from 1994		
Global warming	1 PE_G	Ù	7.7 t CO_2-equivalents
Stratospheric ozone depletion	1 PE_G	Ù	81 g CFC11-equivalents
Photochemical oxidant formation	1 PE_{EU}	Ù	25 kg C_2H_4-equivalents
Acidification	1 PE_{EU}	Ù	74 kg SO_2-equivalents
Nutrification	1 PE_{EU}	Ù	24 kg NO_3^--equivalents
Human toxicity via air	1 PE_{EU}	Ù	$3.6x10^9$ m^3 air
PE_G Global person equivalent PE_{EU} European person equivalent			

Source: Author's version based on Schmidt 2003, table 8.2, p. 145

5. Products under investigation

Unfortunately, there are no detailed statistics available on public sector-consumption for different product groups. Therefore, the first step to be taken was to determine the products of high importance regarding public sector purchases.

For this reason six European cities (Stuttgart, Malmö, Zürich, Kolding, Miskolc, Hamburg) joined the RELIEF project and provided data for the analysis of the importance of products for investigation in the project. One approach in this context was to look at the actual spending of the respective administrations.

Regrettably, only few products are in detail recorded in the cities' budgets and often, no procurement monitoring system is in place to assemble the respective data. Therefore, much of this data had to be collected from the individual departments and their book-keeping on certain purchases.

Table 3 indicates the spending of the six local authorities involved in the RELIEF project. It is obvious that this data is not comparable. The cities have very different sizes and the administrations have different tasks. Also, product categories can be defined differently. Still this data provides indications about relevant and less relevant product groups (Erdmenger 2003, pp. 117-120).

Table 3 - Spending on selected product groups in six European cities in 1000 €

Product group	Stuttgart Germany	Malmö Sweden	Zürich Switzerland	Kolding Denmark	Miskolc Hungary	Hamburg Germany
Cleaning products	155	n. a.	563	242	7	614
Energy	29,875	9,000	8,777	2,382	34	72,644
Food for canteens	307	12,000	12,850	1,910	0	n. a.
Furniture	2,390	4,000	6,461	336	3	5,215
IT equipment	8,104	675	19,799	957	67	15,364
Paper	464	1,400	573	146	17	409
Office equipment	1,699	100	721	282	14	256
Person Transport	1,164	5,979	n. a.	2,294	31	2,122
Renovation of buildings	44,686	n. a.	107,734	3,934	1,064	52,425
Road construction	n. a.	n. a.	n. a.	n. a.	2,198	64,985

n. a. not available

Source: Erdmenger 2003, pp. 118

The key findings of this investigation may be summarised as follows:

- Construction, energy, furniture and IT equipment are financially very important product groups for all six local authorities.
- The importance of food for canteens and public transport varies with the responsibility of the city.
- Product groups such as cleaning products (not the services!), office material and paper are of only minor financial importance.

Whether or not a specific product became subject of investigation was however, also dependant from the availability of environmental data (lifecycle assessments) and statistical market data. The products finally considered in the RELIEF project were:

- Electricity
- Personal Computers
- Copiers
- Buses
- Food products (Wheat, Meat and Milk)

The relief potential of procurement - The theory

The relief potential per functional unit for a given combination of a 'green' and a 'non-green' product is a specific value related to this particular product combination. It therefore possess only a limited significance to answer the question what the potential environmental consequences on the European level caused by a change in procurement practice towards environmentally friendlier products might be.

Thus, a main issue in the RELIEF project consisted in up-scaling the relief potential per functional unit to the European level and to figure out the importance of public procurement in this concern.

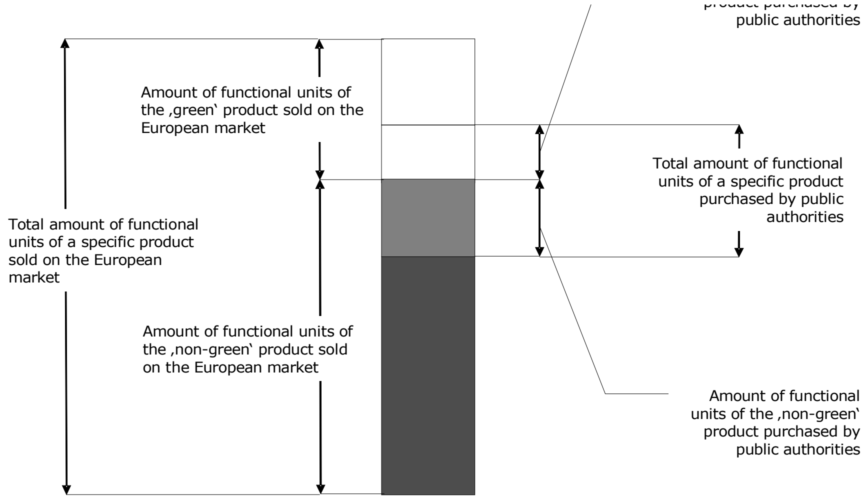
The order of magnitude of the relief potential within the area of procurement depends on the amount of functional units, which at a particular time:

- are requested from the market and
- actually substitutable by an environmentally friendlier product.

Generally, the European market for a specific product may be subdivided in a share for the ‘green’ products and one for the ‘non-green’ products. Furthermore, a share of a product mainly purchased by public authorities can be defined. This may then be again subdivided in one part for which public authorities already purchase the ‘green’ alternative and in an other part for which they don't.

Figure 1 - Structure of the European market for a specific product

Source: Author’s version based on Pierrard 2003



The calculational approach to determine the **Theoretical European Market Relief Potential**’ which focuses on the total functional units of a given product on the European market, as well as the ‘**Theoretical European public procurement relief potential**’, referring to the respective amount of functional units influenced by European public purchasers is shown in the following Formula 2 and Formula 3.Both relief potentials are based on the assumption that the ‘non-green’ amount of functional units for a specific product which is either available on the European market or purchased by public purchasers, is completely substituted by the respective ‘green’ product.

Formula 2 - Calculation of the theoretical European market relief potential

$$\begin{pmatrix} RP^{EM}_{IC_1} \\ RP^{EM}_{IC_2} \\ \vdots \\ RP^{EM}_{IC_m} \end{pmatrix} = \begin{pmatrix} rp_{IC_1} \times \left(nfu^{tm} - nfu^{tg}\right) \\ rp_{IC_2} \times \left(nfu^{tm} - nfu^{tg}\right) \\ \vdots \\ rp_{IC_m} \times \left(nfu^{tm} - nfu^{tg}\right) \end{pmatrix}$$

Source: Author's version based on Pierrard 2003

with:

with:	RP^{EM}	Theoretical relief potential for the European market for a specific product combination
	rp	Relief potential per functional unit for a specific product combination
	IC	Environmental impact category
	m	Number of considered environmental impact categories m=1, 2, …, m
	nfu	Number of functional units for a specific product
	tg	Total 'green'
	tm	Total market

Formula 3 - Calculation of the theoretical European public procurement relief potential

$$\begin{pmatrix} RP^{EP}_{IC_1} \\ RP^{EP}_{IC_2} \\ \vdots \\ RP^{EP}_{IC_m} \end{pmatrix} = \begin{pmatrix} rp_{IC_1} \times \left(nfu^{tp} - nfu^{pg}\right) \\ rp_{IC_2} \times \left(nfu^{tp} - nfu^{pg}\right) \\ \vdots \\ rp_{IC_m} \times \left(nfu^{tp} - nfu^{pg}\right) \end{pmatrix}$$

Source: Author's version based on Pierrard 2003

with:	RP^{EP}	Relief potential related to European public purchasing for a specific product combination
	rp	Relief potential per functional unit for a specific product combination
	IC	Environmental impact category
	m	Number of considered environmental impact categories m=1, 2, …, m
	nfu	Number of functional units
	pg	'Green' related to public purchasing
	tp	Total related to public purchasing

7. The relief potential of procurement - Coming down to earth

For most of the products analysed, it was impossible to determine the European share of the 'green' product. Also investigations of the share of the 'green' product already purchased by public authorities on the European level proved to be a very time consuming task, which would have exceeded the framework of the RELIEF project by far.

Thus, the actual share of the 'green' product available on the European market on the one hand and purchased by public purchasers on the other hand was unknown. However, that share was not neglected, but implicitly included in the definition of an average product, which finally was used as the 'non-green' alternative in the calculations.

Taking electricity as an example, the share that 'green' electricity already has on the market contributes to slightly lower environmental impacts of average electricity, which is then considered as the 'non-green' product (see Section 8.1).

In analogy for personal computer systems the assumption was made that the average personal computer is one which complies at least with minimum Energy Star requirements. This assumption is justified by a market survey showing that almost no personal computers lacking an Energy Star label are available on the market anymore (see Section 8.2).

The same applies to the product line-buses. The average bus is considered to comply already with the actual Euro III specification (see Section 8.4).

Sometimes though, the implicit consideration of the amount of functional units of the 'green' product already available on the market was not possible e. g. for food products (see Section 8.5). Thus, the calculated theoretical relief potentials might more or less exceed the actual figures.

The availability of market data on the number of functional units influenced by the decisions of public purchasers or traded on the European level also is a major constraint in calculating the European relief potential of products. As a result of the RELIEF project it became clear that nearly every product needed a different approach to determine the relevant amount of functional units.

Nevertheless, the general approach for the calculation of the relief potential remained to be the determination of the amount of total functional units of the specific product traded on the European market, as well as the determination of the corresponding amount of functional units influenced by the public sector.

The results of these investigations then were multiplied with the relief potential per functional unit. The relief potential per functional unit is always calculated by subtracting the environmental impacts (related to one functional unit) of the 'green' product from those of the average product being the object of investigation. Among the variety of products the 'green' product was by definition the one which showed the least environmental impacts for most of the considered environmental impact categories.

Finally, the calculated relief potentials were expressed in person equivalents to enable the comparison of the relief potentials within the same environmental impact category for the different products. Nevertheless, the relief potential for each environmental impact category is expressed in the same unit namely 'person equivalents' it is impermissible to compare or calculate a trade-off between the figures of different environmental impact categories.

Furthermore, the calculated relief potentials for the respective products were calculated on an annual basis. The relief potential over the whole lifetime of the product then may be easily calculated by linear extrapolation.

For reasons of feasibility and transparency for the purchaser, it was necessary to reduce the number of impact categories, as they are predefined in the lifecycle assessment procedure, to the 4 or 5 most important ones. Thus, the calculated relief potentials do not represent the whole range of environmental impacts but concentrate on the politically most important, or the most momentous ones.

8. Selected results (Pierrard 2003)

Because of its dependence on local circumstances, the local information (see Section 5) could not easily be extrapolated to the European level; therefore other information sources had to be tapped into. These had to be individually identified for every product being under investigation.

8.1. Electricity

The functional unit for electricity is one GWh of consumed electricity. The main environmental impacts occur during the production stage.

'Green' electricity was assumed to be electricity generated from renewable energy sources in accordance with the European directive 2001/77/EG. The European average electricity mix was considered as the 'non-green' product.

The main data source for the determination of the total amount of functional units on the European market is the International Energy Agency databases (IEA 2002). The observed consumption of electricity in Europe (EU-15) for the year 1999 amounted to 2,232,669 GWh.

The amount of functional units related to the consumption of public authorities in 1999 was determined, using various national electricity reports, to be about 6.2% or 148,460 Gwh.

8.2. Personal Computers

For personal computers the functional unit is one PC consisting of a central processing unit and a computer screen. The main environmental impacts occur during the use stage as a result of the use of electrical power. A likely use pattern for an average office PC was assumed.

The 'green' PC was identified as being one with low energy consumption according to a good Energy Star standard, equipped with a thin film transistor (TFT) display. As the average product a PC complying with minimum Energy Star requirements, equipped with a cathode ray tube display (CRT) was assumed.

The amount of functional units sold on the European market for the year 2000 was 27,431,912 units (EITO 2001). Statistical data on the number of purchased units by public authorities were not available. Therefore, the calculation of the amount of functional units related to the public sector was based on population statistics. The number of public employees in EU(15) was retrieved from OECD-statistics (OECD 2001), it was multiplied with the share of white collar workers obtained from an EUROBAROMETER survey (EUROBAROMETER 1994) and with the number of business PC's per white collar worker (EITO 2001). Finally it was divided by the annual replacement rate of PC's in the public sector. The replacement rate was assumed to be 5, i. e. every PC is replaced after 5 years. Thus, a number of annual purchased PC's by public authorities of 2,836,512 units or a share of 10.3 % results.

8.3. Copiers

For copiers the functional unit is one copier. From lifecycle assessments the use stage was identified as the one causing the most environmental impacts as a result of the use of electricity. A likely use pattern assuming 1,500 copies a day or 2,250,000 copies a year was assumed.

As the 'green' copier an appliance with enhanced energy saving capabilities complying with good Energy Star requirements was identified. The average copier is one possessing no energy saving capabilities.

The copiers sold on the European market during the year 2000 amount to 1,418,637 units (EITO 2001). The share of 14.75% or 209,184 units purchased by the public sector was derived from European Input-Output statistics (Horbach 2002).

8.4. Line-Buses

The functional unit for line-buses is one bus-km. The main environmental impacts occur during the use stage as a result of fuel consumption.

The 'green' bus is defined to be one complying with EURO IV specification despite the fact that such buses are at present time not yet available on the market. Buses complying with the EURO III specification are considered as the average and therefore 'non-green' product.

The number of newly registered buses and coaches in Europe in the year 1999 was 30,957 (ACEA 2002). A survey among producers showed that approx. 50% of these vehicles are line buses, the remaining are coaches. The assumption that one bus drives 100,000 km during one year was made. This equals an annual number of functional units of 1,547,850,000 bus-km. The producer survey also showed that approx. 48% of the line-buses are purchased by public authorities. Thus, a share of the public sector of 24% or an amount of functional units of 742,968,000 bus-km may be calculated.

8.5. Food products

The functional unit for food products is 1000 tonnes of consumed food. The main environmental impacts occur during the production stage, mainly within the agricultural sector.

The 'green' product is one, which is produced considering the rules of organic farming, as they are stipulated in the 'Council Regulation (EEC) No 2092/91 of 24. June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs'. Food products produced by conventional farming are considered to be the average or 'non-green' products. Within the RELIEF project the relief potential for wheat representing the product group cereals, for meat including beef, poultry and pork as well as for milk was determined.

The number of functional units consumed on the European level for the year 2000 was retrieved from FAO databases (FAO 2002). Wheat amounts to 90,389 units, meat to 31,649 units and milk to 114,757 units. The share of 3.15% or 2,887 units for wheat, 997 units for meat, and 3,615 units for milk, purchased by the public sector was derived from European Input-Output statistics (Horbach 2002).

Considering all this information as well as the scientific approach for the determination of the relief potential per functional unit presented in Section 4 and 7 the relief potentials per functional unit for the considered products were calculated and are shown in Table 4. Negative numbers indicate a decrease of environmental impacts, and positive numbers an increase of environmental impacts in the respective environmental impact category.

Table 4 - Relief potential per functional unit for different products in person equivalents per functional unit

Product group	Electricity [1Gwh]	Personal Computers [1 Unit]	Copiers [1 Unit]	Buses [1 bus-km]	Wheat [1000 tonnes]	Meat [1000 tonnes]	Milk [1000 tonnes]
Global warming	-50.4	$-7.2x10^{-3}$	$-110x10^{-3}$	$2.0x10^{-6}$	-36.6	-479.3	-24.4
Stratospheric ozone depletion	n. a.	n. a.	n. a.	n. a.	0.2	1.0	0.0
Photochemical oxidant formation	0.2	$-0.2x10^{-3}$	$-3x10^{-3}$	$-1.8x10^{-5}$	-5.2	-96.8	-3,2
Acidification	-28.8	$-4.2x10^{-3}$	$-64x10^{-3}$	$-2.0x10^{-5}$	-27.0	-554.1	-40.5
Nutrification	-9.9	$-1.5x10^{-3}$	$-2x10^{-3}$	$-2.3x10^{-5}$	-212.3	-3,264.3	-159.2
Human toxicity via air	n. a.	n. a.	n. a.	$-9.5x10^{-6}$	n. a.	n. a.	n. a.
n. a. not available							

Source: Author's version based on Pierrard 2003

Based on the data shown in Table 4 and Table 5 the 'Theoretical European public procurement relief potential' was calculated. The respective results are presented in Table 6.

Table 5 - Market volumes in the European Union and of European public authorities for selected products

Product	Functional unit	Annual functional units European market	Annual functional units pubic sector	
Electricity	Consumption of 1 GWh	2,232,669	148,460	6.2%
Personal Computers	1 Unit	27,431,912	2,836,512	10.3%
Copiers	1 Unit	1,418,637	209,184	14.8%
Buses	1 bus-km	1,547,850,000	742,968,000	24.0%
Wheat	Consumption of 1000 tonnes	90,389	2,847	3.15%
Meat		31,640	997	
Milk		114,737	3,614	

Source: Author's version based on Pierrard 2003

Summarising these results, the 'Theoretical European public procurement relief potential' for the selected 7 products were calculated and are presented in Table 7.

Table 6 - Relief potentials of selected products for the whole European market under influence of the public sector

Environmental impact category	Electricity	Personal Computers	Copiers	Wheat	Meat	Milk	Buses
Global warming [PE]	-7,481,800	-20,300	-23,100	-104,200	-140,600	-88,200	1,500
Stratospheric ozone depletion [PE]	n. a.	n. a.	n. a.	700	300	0.0	n. a.
Photochemical oxidant formation [PE]	28,200	-600	-700	-77,000	-31,700	-11,600	-13,400
Acidification [PE]	-4,273,800	-11,800	-13,400	-77,000	-146,400	-146,500	-14,400
Nutrification [PE]	-1,462,500	-4,300	-4,900	-604,500	-947,000	-575,500	-16,900
Human toxicity via air [PE]	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	-7,100
Resource Consumption [GWh]	-182,900	-1,000	-300	-1.0	-1.0	-0.4	60
Waste Formation [t]	-6,711,100	-16,900	-19,200	n. a.	n. a.	n. a.	n. a.

Source: Author's version based on Pierrard 2003

9. Conclusions

Considering the results presented in Table 7 it becomes obvious that public purchasing is a key tool for 'greening' the market place. Green public procurement is capable of achieving significant savings in terms of environmental impacts, and therefore is far from being only a complementary policy tool to accompany the 'real' mechanisms presumed of being able to change the environmental situation significantly.

The chosen approach to calculate the relief potential of products seems to be rather academic at the first glance. However, appearances are deceptive. The simplifications made in the RELIEF project, like the focus on the most relevant service functions, the most polluting lifecycle stages as well as the concentration on those environmental impact categories depicting the most urgent environmental problems, on the one hand and an adequate flexibility for the determination of the market volumes of the different products under consideration on the other hand, provide results with a reasonable range of accuracy to serve as an input for the decision making process of purchasers.

Table 7 - Total relief potential of the selected products in selected environmental impact categories achievable by European public procurement

Environmental impact category	Theoretical European public procurement relief potential	As % of the Theoretical European market relief potential
Global warming [PE]	7.86×10^6	6.4%
Photochemical oxidant formation [PE]	0.11×10^6	7.3%
Acidification [PE]	4.68×10^6	6.1%
Nutrification [PE]	3.62×10^6	4.0%
Resource Consumption [GWh]	0.18×10^6	6.4%

Source: Author's version based on Table 6

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