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A Third Industrial Revolution?

Solutions to the crisis of resource-intensive growth

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Abstract

Industrial mass production on the basis of cheap raw material and fossil fuels, which has evolved as the economic Leitbild of the 20th century has reached its critical limits. The environmental impacts of fossil fuels are threatening both the environment and further economic development. Changes in the energy and resource base of the economy have been the drivers of productivity: Coal in the first Industrial Revolution at the end of the 18th century and Oil at the beginning of the 20th century. These shifts in fuel base of industry were linked to mutually enforcing technical, social and political innovations.

There are indications that we are at the advent of another change in the energy base. The recent strong growth of renewable energies and eco-efficient technologies are the most visible manifestations of an upheaval. What are the implications for societies and for the steering of such radical change? Industrial transformations of this kind cause a re-valuation of capital, professional skills and redistribution of wealth among sectors and regions. This is reflected in political resistance against such transformations.

In our essay we analyse the opportunities for a political steering of industrial transformation. The large economic regions of the world are compared regarding their abilities to take a leading role on this. The technological competences, the availability of capital, the abilities to compensate social disruptions, the openness for innovation and the ambitions in environmental policies provide a good position for Europe in shaping the next phase of industrialisation.

1 Introduction

> "I believe we are now standing on the brink of a *Third Industrial Revolution: the Low Carbon Age*. Like the previous industrial revolutions, this will be driven by technology and new forms of energy. It will also transform our societies". (José Barroso, President of the European Commission in his speech held on October 1st, 2007).
>
> What we need is a "New Deal" of economic-, environmental- and employment policy. Innovations are its core, a "Third Industrial Revolution". (Sigmar Gabriel, 2006, German Environment Minister).

Industrial mass production based on cheap raw materials, which became the dominant economic and societal model in the 20th century and fundamentally changed the face of the world, has indeed reached its critical limits. Fossil fuels played a specific role in changes, lending an immense productivity to labor in both the First (coal) and Second Industrial Revolution (oil), as well as profoundly changing the technological and economic conditions for transport, production and consumption. However, the impact of fossil fuels on the environment and climate has proven to be destructive, and the practice of replacing labor with cheap energy can no longer be continued. Critical disturbances in the markets become more and more visible, e.g., the skyrocketing price of oil. At the same time, knowledge of new technological breakthroughs regarding the utilization of renewable energies is also expanding. The unexpectedly strong growth of renewable energies and eco-efficient technologies are the most visible manifestations of an upheaval. As a result, resource-intensive mass production in general is subject to massive pressure towards innovation.

This situation can be compared with the big industrial transitions of the last two centuries: The transformation from an agricultural-based society to an industrial society, which began in England at the end of the 18th Century, was initially inseparable from the development of coal as an energy source. In the 1920s this revolution continued with the use of oil and electricity. These former industrial

revolutions also had preceding phases in which new technologies and basic innovations (e.g. Mensch 1975; e.g. Olson 1982; Huber 1985; Greenwood 1999) were developed and prepared for the market. Through the competition between old and new technologies and in the conflict between old and new paradigms of industrial production a new growth pattern and balance was found. The historical examples show that in each case of major industrial transformations, new technology and industry clusters emerged, which served as drivers for economic development and employment (see 4.1). Furthermore, technological transformations of this scale have always been linked with far-reaching social change and new conceptions of state and society. The current transformation is about the development and the efficient use of renewable energy sources.

A broad upheaval, which does not only affect the energy- and raw material base but also important sectors of industry, can therefore be understood as an industrial revolution. However, despite the similarities to previous industrial revolutions, the current revolution has a new urgency. Climate change, the critical development of energy, raw material and food prices create a comprehensive and immediate global need for change - one that is without precedent. Far reaching governmental and societal steering mechanisms are needed in order to cope with the upheaval.

What are the dimensions of what is referred to by the President of the European Commission, the German Environment Minister and even the Chinese media, as the Third Industrial Revolution? What are the driving forces? What governmental and societal steering is possible? Which institutions can cope with the challenges and which are necessary? Can politics accelerate the change, use the opportunities it offers, and minimize its destructive potential? Can Europe continue to develop its current global leadership in environmental and climate protection towards shaping this global process in a significant way? The authors of this contribution would like to give their input for discussion.

In our paper, we assume that after a long phase of technological innovation towards the substitution of fossil energy and exhaustible raw materials, which started with the first oil crisis (1973), a phase of radically accelerated transformation now lies ahead. We expect that the starting point will be in Europe. In addition to the technological competence and the necessary capital available here, there is also a relatively demanding regulative environment which is simultaneously open to innovation. Those are three conditions necessary for rapid change to occur, but unfortunately they are not sufficient to guarantee success. There is a risk that conventional structures could weaken the dynamic, thereby only al-

lowing for limited or marginal improvements to the status quo. Finally, such a disruptive development has the risk of devaluing investments and related skills in currently dominating sectors and regions. In order to assure that the imminent Third Industrial Revolution will not be accompanied by distortions and social conflicts similar to those experienced during the First Industrial Revolution, there is a need for broad steering and decisive action. The relationship between economic markets and the state, which was for a long time characterized by the withdrawal of the state from the economic process, needs to be reassessed.

2 The concept of "Industrial Revolution"

The term "Third Industrial Revolution" (see also Schellnhuber 2007; Hawken 2008; Rifkin 2008) refers to a comprehensive upheaval, which was already labeled by other authors as a "green industrial revolution", "efficiency revolution" and a fundamental transformation towards "green capitalism" (Schmidheiny 1992; von Weizsäcker, Lovins et al. 1997; Hawken, Lovins et al. 1999). The US president elect Obama postulates a "green energy revolution". And the IEA (2008) refers to a global "energy technology revolution" in a narrow sense. Some authors have used the term "industrial revolution" without addressing the environment as a central theme. (e.g.Greenwood 1999; Freeman und Louca 2001). These different contributions all stress the radical nature of both the necessary and possible technical change. Furthermore, they all share an expectation of phases of abrupt change. In general, two different understandings of the concept of "Industrial Revolution" can be identified. Whereas the narrow understanding only refers to the change of the energy base, the broader assessment includes the comprehensive changes in energy, technological, ecological and social conditions and the necessary governmental leadership.

"Industrial Revolution" should be perceived as a radical and abrupt but also long-lasting ("secular") change at all levels of society. Due to fundamental technical innovations in the energy field, especially in generation and utilization, a new balance between the economy and the institutional framework is developing. Historians and economists coined the term "innovation cluster" to express the extent of this innovation process (Grübler 1998; Mokyr 1999). Reciprocal initiation-, multiplication- and acceleration effects within the cluster lead to economic growth, employment and a broad modernization of national economies. Industrial revolutions have always had a critical preceding phase in which traditional technologies and production methods depleted their potential for further

improvements while new technologies were being developed. In this phase, both radically new technical and social inventions are also made which become apparent in the industrial revolution as a radical "paradigm change" and afterwards enable a stable development over a longer period. Thus, industrial revolutions are also the result of radically innovative answers to development crises in the global economy.

The observation of long cycles of "industrial revolutions," which went hand in hand with the utilization of new sources for energy (coal at the end of the 18th century and oil at the end of the 19th century) has to be differentiated from the "long waves" observed by Kontradieff and Schumpeter. Both refer to the introduction of the steam engine as the initial point of industrialization. "Long waves" refer to comparatively shorter cyclical fluctuations of growth rates, which are linked to a broad spectrum of fundamental innovations, and are not restricted to the energy sector. As early as the 1920s, Kondratieff, using statistical analysis of economic data, identified long-term growth cycles with a length of 40-60 years in industrialized countries. What was remarkable about this finding was that the author was only able to analyze a few countries and could not yet identify three completed 'long waves' since the beginning of industrialization. At the end of the 1930s, Joseph Schumpeter continued the work and after detecting a downturn of the third wave since the early period of industrialization (including he crash of 1929), he began to speak of "Kondratieff cycles." Schumpeter and later Gerhard Mensch (1975) explained the cycles with basic innovations. In the 1980s, the conditions of the socio-political framework were increasingly drawn upon as an additional explanation (overview in Huber 1985). Similarly, another, now fifth, Kondratieff 'wave' is assumed to be behind the positive development of the global economy since the beginning of the 1990s (Freeman und Louca 2001). It is questionable whether this approach can explain different regional and sector specific dynamics. However, the proven statistical regularities of long-term growth fluctuations and the high plausibility of its theoretical explanation offer an important basis for estimating industrial cycles and their need for action.

Numerous suggestions for categorizing and dividing such transitions can be found in the literature. These terms are especially meaningful if they define the relevant differences between the transitions. The new production methods, means of transportation, raw material, energy base, and social changes of the First Industrial Revolution in the 18th century are very different from the mass production, mass communication and mass democracy of the Second Industrial Revolution in the 20th century, with its development of electrification, motoriza-

tion, chemicalization, and use of concrete. Exactly these modes of industrial production have become shaky since the end of the 20th century. The limitations of the fossil energy base, which carried the first two industrial revolutions, has become apparent. The fact that clear alternatives have already been heralded justifies the concept of another, third industrial revolution. Thus emphasizing the growing urgency of this transformation and the dramatic need for political steering.

Table 1: From the First to the Third Industrial Revolution

	1st Industrial Revolution: approx. 1780-	2nd Industrial Revolution: approx. 1890-	3rd Industrial Revolution: approx. 1990-
Dominant technology and raw material	steam engine, power loom, iron processing	electricity, chemistry, combustion engine, assembly line, synthetic materials	ICT, microelectronics, new materials, renewable raw materials, cleaner technology, biotechnology, recycling.
Dominant energy source	coal	coal, oil, nuclear power	renewable energies, energy efficiency
Transport/ communication	railway, telegraphy	car, airplane, radio, TV	high-speed railway systems, internet, mobile telecommunication
Society/ state	"bourgeoisie", freedom of trade, constitutional state	mass production, mass society, parliamentary democracy, welfare state	civil society, globalization, global governance
Core countries	UK, Belgium, Germany, France	USA, Japan, Germany	EU, USA?, China? Japan?

The current crisis of resource intensive growth – irrespective of innovative activity - extends beyond the current capabilities of markets and civil society to manage the crisis. Framework conditions must change radically. This also applied to the first two industrial revolutions. The first one, through its new requirements of free trade, property rights, market development and societal division of labor increased the pressure for the creation of the rule of law and the political participation of citizens and the bourgeoisie ("liberal revolution"). The second – with its transition to mass production – necessitated a minimum of social standards and thus, social redistribution ("social revolution") occurred. With the introduction of social security systems the social costs of industrial labor, which had previously been largely externalized, were internalized or compensated to a certain degree. As a result, purchasing power emerged, which in turn allowed for vast growth.

The emergence of both the liberal state and the welfare state were characterized by serious conflicts, expressed by parties, social groups and ideologies. An important part of these conflicts was a re-evaluation of physical and human capital: Innovations regularly devalue investments, resources, and skills connected to them. Often those who are negatively affected fight against these changes politically.

Similarly, the Third Industrial Revolution is not only a broad wave of innovation potentially accompanied by welfare effects. It is about typical innovation conflicts. Economic sectors, which have defined the exploitation of natural resources as their commercial basis, see their existence threatened. They perceive this threat to be the competitive resource-saving and environmentally friendly technologies currently favored by civil society actors and regulatory measures. At the same time compared to the innovators, the old sectors often have an advantage in terms of political influence, which they were able to gather in the previous boom. That is why "old industries" are often quite powerful. However, with the increasing technical and economic maturity of competing technologies, the political pressure on the affected sectors will increase, and in the end the capital flows reorient themselves in favor of new technologies. Continuing to generate electricity from coal, to promote nuclear power, and to disregard energy-saving and environmental protection in the automobile industry clearly show that there are relentless influential advocates for the conventional model of growth. These advocates are avoiding the pressure of innovation – very often with political support.

All industrial revolutions so far were accompanied by the development of new functions and capacities of the state apparatus. The Second Industrial Revolution e. g. was connected with the extension of national state activity and public finance. This tendency was embodied in "Wagner's law," which was the remarkable long-term forecast of an "increased need for state activity" (Wagner 1893). Social core functions have been added to the economic core functions of the liberal state. Both functions being represented also in the structure of interest groups and the political party spectrum.

Since the 1970s in industrialized countries and the 1990s on a global level, a third basic state function in addition to the core economic and social duties has emerged. This new undertaking is in most cases even anchored in the constitution: the protection of the natural bases of life. In this sense many industrialized countries and the EU have taken important steps towards an "environmental state". This movement again is grounded in the political party spectrum as well

as in the social institutional arrangement – German environmental organizations have nearly as many members as the trade unions (Jänicke 2007). Pioneering states which are leaders in this respect participate more intensively in international political processes and have political systems that tend to be more open towards new interests. Interestingly enough, these states are also more competitive on a global scale (Esty und Porter 2000).

All three industrial revolutions also represent significant gains in importance of the global market. Already in the Communist Manifesto (1948) it was stated that the big industries were the ones that created the global market. Industrialization in its current state was only possible by building infrastructures that could transport energy sources, raw materials and final goods to and from remote areas of the world at low prices unimaginable until then. The emergence of an international (however fragmented) legal system is connected with this globalization, and through standardization, regulation of cash and commodity flows, etc., it represents another functional basis for global markets. These regional and international regimes are increasingly including environmental standards.

At the same time, shifts of dominant countries and regions occur during the long-term cycles of industrial growth, a phenomenon which resulted in the theories of the "rise and decline of nations" (e.g. Olson 1982). The important centers of economic development in the early period of industrial development were England, Germany, France the Netherlands, and later Belgium. The USA took a central role in the technological dynamic with the Second Industrial Revolution. After the Second World War, Japan with its automobile, electrical and electronic industry also became one of the most important countries, shaping mass production and consumption.

There are high expectations for China and India in the third growth cycle. This emphasizes a phenomenon, which was evident in former industrial revolutions: the innovations, which cause the economic boom in a country, do not necessarily have to be developed in that country. Even the pioneers of industrialization in England used innovations that were made in France and Germany but not successfully merchandised there. The Japanese industrial strategy of the 1950s and 1960s of *reverse engineering* is another good example of the successful early adoption and marketing of foreign innovations. These examples show that it is not only the ingenuity of the invention that is relevant for their success, but also the general economic and political framework. A suitable example of this may be China, which seems to be studying technological developments in Western industrialized societies while building its own industries domestically. The re-

search, development, and testing of new technologies are oftentimes left to the industrial centers of Western Europe, North America or Japan.

3 Challenges of a "Third Industrial Revolution"

After a long-term decline since the first oil crisis (1973) the growth rates of the global economy have increased significantly since the the 1990s. This has been expected by advocates of long-term cycles with reference to Kondratieff (Mensch 1975; Prognos AG, Schröder et al. 1982; Wallerstein 1983). The basic innovations for a long-term cycle are also visible – especially in the area of renewable energies, energy autarkic buildings and recycling procedures. As early as the beginning of the 1970s, innovative concepts towards a knowledge-intensive, resource- and environmentally friendly production method were presented (MITI 1974), which are only now starting to be broadly accepted (SRU 2008). But this development is so far nothing more than an opportunity. Unless the innovation process and the economic dynamics are given a direction towards environmentally friendly and resource saving technologies, and the speed of the technical process is accelerated, the economic and ecological problems of resource-intensive mass production will not be overcome. The challenge is much more serious than the previous one. In addition, the required scale of innovation exceeds previous experiences in the area of climate, energy, and resources as well as the existing steering capacities of states and companies.

The serious recessions (1975, 1982, 1993) during the previous decades have demonstrated that the production methods of the 20th century have reached their limits, both economically and ecologically (strinkingly addressed by Meadows, Meadows et al. 1972). Support for this conclusion has dramatically increased due to the alarming climate change and the renewed energy price explosion. This situation can be compared to the challenge facing Western democracies during the Second World War and their tremendous achievements defending themselves against a deadly aggression (*moral equivalent to war*). The increasingly unequal income distribution further strengthens the general demand for change.

However, these challenges are also accompanied by opportunities and an impressive potential for innovation (see section 4). Instead of former anarchic and crisis-ridden, destructive upheavals we are now – for the first time – looking at the possibility of a targeted, politically re-enforced and structured change on a broad social basis and at all levels of the global system.

3.1 Economic challenges: resource scarcity and increasing environmental cost

The limited availability of finite cheap raw materials and, in particular, of fossil energies has reached its natural limit of growth. The present crisis of the car industry is only a symptom. Also, the high economics dynamics of the newly industrialized countries are impacting the development of prices: oil, copper, and steel are spectacular examples. Similar demand and price surges are to be expected for other raw materials. Speculative mark-ups do not have to remain a price component indefinitely, and declines can be expected at least temporarily. Nevertheless, markets react to long-term scarcities of raw materials and fossil energies. Resource efficiency becomes imperative for economic development, and is an indicator of success in the competition for innovations.

Even with renewable raw materials we can see limits of availability: The land-use competition between food and bio-fuels is just one example. The extension of farmland at the expense of unspoiled natural lands another. However, the struggle for land is not limited to competition between food and fuels alone. Renewable raw materials play an ever-greater role in the production of chemicals. Traditional users of biotic raw materials, be it the paper, furniture or building industries, are also interested in growth.

According to the UN Global International Water Assessment (UNEP and GIWA 2006) the availability of water will dramatically shrink due to changes in land use, climate change, pollution, overuse of drinking water, and further increases in industrial and agricultural demand in many parts of the world. Steppe formation and desertification are expected in numerous regions, which further increase the strain on the remaining fertile areas. Already current weather events have repeatedly devastated the food resources of many countries and regions. The scarcity of sinks for environmental pollutants presents the discernible limit to economic growth. According to governmental calculations environmental costs threaten to neutralize economic gains in wealth. Also in countries like Spain, the overuse of natural capital is a perceptible limit to economic development.

3.2 Ecological challenges: climate change and critical loss of natural capital

Global assessments of the state of the environment, be it the report from the IPCC, the Millennium Ecosystem Assessment or the Global Environmental Out-

look, show that the carrying capacity of the Earth in many regions, and the impacts of climate change on a global level have reached critical limits. Yet, it is not a steady development. Instead, there are "tipping points" – at which point limits are exceeded, and developments possessed of an incalculable and volatile self-perpetuating momentum are set in motion. The drying out of the Amazon Basin, the melting of the Antarctic ice, the cease of the Gulf Stream and the melting of the permafrost in Siberia with large scale emissions of embedded methane are all critical areas affected by such self re-enforcing feedback mechanisms.

The United Nations Millennium Ecosystem Assessment in 2005 concluded that most of the ecosystem services are in a state of advanced or continuous degradation (Millennium Ecosystem Assessment 2005). Central functions of nature, essential to both the preservation of life and economic systems, seem to be threatened. We live from the very substance of the planet itself.

All of the current major assessments of the state of the environment, in spite of the regional differences, expect a serious global economic-ecological crisis and are calling for major changes to avoid the economic impacts. The costs of the damage due to climate change, including loss of biodiversity and natural resources, were calculated if climate protection is neglected: global GDP will decrease by 5-20% according to the Stern Report (Stern 2007) and by an additional 6% until 2050 due to global deforestation (European Communities 2008). However, these and other calculations for the cost of damages are methodically judged: there can be no doubt that the resource-intensive growth pattern of the Second Industrial Revolution, particularly when its counterproductive economic effects are taken into account, cannot be sustained.

3.3 Social challenges: supporting the processes of modernization with social-policy

The Second Industrial Revolution in the beginning of the 20th century allowed mass production to be accompanied by mass income, which supported the requisite trend of demand. As a result, a radical change of income distribution, the introduction of union rights and social security were necessary; these often emerged after political upheavals, such as in many European countries in 1918. The worldwide development of mass markets from the 1950s onwards, led to a rapid increase in the use of natural resources and emission releases. The promises of freedom through mobility, home ownership, and other symbols of the "Western" economic miracle have spread worldwide and have now reached the limits of natural resources.

The internalization of social costs of labor with the help of social security systems gave a strong incentive to reduce the labor factor. This was accompanied by a rapid development of labor productivity which caused structural unemployment in the 20th century. Economic crises and their social impacts not only pose a threat to mass purchasing power, but also deter the acceptance of more ambitious efforts to protect the environment and resources. Furthermore, a broad redistribution at the expense of those in lower incomes has been pushed through in the name of globalization. The question of fairness in the distribution of wealth and resources is also relevant to the fact that the increasing consumption of luxury goods (e.g. vehicles) is linked to additional environmental pollution. The age pyramid of developed industrialized countries also creates critical challenges for social security systems. Another challenge of the 21st century is the dramatically increasing knowledge intensity of production in the face of critical deficits in human capital.

At the same time, the necessary change does not come without a price. The transformation collides conventional perspectives of development and growth in traditional economic branches. Traditional business sectors, their investments, their employees, and their skills are in danger of being questioned due to the rise in energy and raw material prices, and more demanding standards. In the long-term renewable energies and renewable raw materials are potential sources of prosperity. Yet, the necessary funds for the development threaten to aggravate current inequality. The costs of environmental pollution and the costs of solutions could easily be dumped on those social classes, which only have a limited opportunity to raise concerns (Weidner 2007). This does not only threaten the acceptance of environmental policy but also the long-term purchasing power of lower socio-economic classes. Thus, the broad acceptance of comprehensive industrial modernization also has to be secured on a socio-political level.

3.4 Excessive demands on the steering mechanisms

The first two industrial revolutions were characterized by a profound change of the concept of statehood. The present industrial revolution again represents fundamental changes in the political system and ways to respond to newly emerged problems and claims. This could already by observed in the multi-level-system of global politics, especially since the 1990s (e. g. the UN summit in Rio). But the extend of the challenges and the resistance of conventional interests show an excessive demand on steering mechanisms. This is demonstrated

by striking contradictions in the area of climate protection. On the one hand, the global public and politicians are terrified by the results of the 4th IPCC report (2007). At the same time many countries invest primarily in coal-power (a capacity growth of 60 percent is expected till 2020) and investments in energy-efficiency and renewable energies are often neglected. Although most states have institutionalized environmental targets, they are clearly in a weaker position compared to the rights of an individual. In general, there is now a broad societal consensus that environmental protection is needed, but in reality, when there is a conflict of interest decisions are often made at the expense of the environment. Thus far environmental policy has rather focused on "win-win" situations in which efficiency gains and environmental benefits can also be obtained from a microeconomic perspective.

The particular difficulties of environmental policy – limited capacity for intervention in the case of private property, spatial and temporal divergence of cause and effect in the case of environmental problems, and the difficulty in coordinating players from different political fields and operational levels - have all created numerous policy innovations that extend the capacity for action. Environmental policy, with its new forms of policy innovation and new instruments, is a prime example (Jacob, Feindt et al. 2007). This includes the significance of calculable target-setting, the internationalization of environmental policy, the inclusion of private players and the development of new market-based and regulative instruments (Jänicke 2007). While the areas of modern environmental policy are broadened even further, the complexity of actor constellation has dramatically increased. Therefore, the question of final responsibility has become critical – if all are responsible, then nobody is. Nation states, both individually and collectively as member states, can assert that they have adopted a responsible role, but their role in the European and global context is not clear so far.

By and large, the challenges of the Third Industrial Revolution prove to be challenges for governmental and societal steering. The radical change requires (1) competent and globally networked governments capable of strategic action, (2) informed voters and consumers open to innovation, (3) a significantly higher degree of readiness for innovation on the part of companies and national economies, and (4) a highly productive system of innovation. These prerequisites first needs to be met.

3.4.1 Competent and strategic governments

The Third Industrial Revolution requires multi-level political systems with an extraordinary capacity to act. It is first and foremost a matter for the states, as

there is no alternative to their legitimate powers and responsibility to pursue long-term public interests. Even though governments have become active in national and international networks, it does not change their importance as legitimate national players. States still possess considerable resources and expertise. In a crisis, the population always holds the state responsible first. Nevertheless, there is a lack of necessary strategic capability. Such capabilities are the ability of states to establish long-term public interest policies in spite of short-term special interests. Short-term special interests are often concerns of traditional industries and social groups which consider the long-term change to be a threat. Such persistent interests often have attained an influential position, which innovative new sectors have not yet been able to achieve. Thus, in many countries providers of fossil fuels are capable of hindering an active climate policy. Innovations are also always ambivalent processes during which innovators face the resistance of the "dinosaurs," or established interests. There is no other explanation for the remarkably slow innovation process in the areas of eco-efficient technologies over the last thirty years (Jänicke 2008). In many states the conditions for action are impaired due to unsolved social problems which dominate public awareness. Also, in many places the role of the commercial media hampers an adequate understanding of the need for intervention measures in energy policy. Long-term policy orientation is a challenge for the traditional policy inclination towards short-term economic and political cycles.

A policy that affects people's lives and interests must be able to legitimize its interventions and distinguish between different protected commodities. Democratic governments often succumb to self-restriction which was created two centuries ago to protect against the absolute state. Another common obstacle effective worldwide is the neo-liberal doctrine of "deregulation," "denationalization," or "tax cuts," which is based on the assumption that a general retreat of state influence would improve economic growth, innovation and welfare. This doctrine - regularly ignoring irrational actions in the business sector (banks, automobile or power industry) – is the wrong answer to the increasing steering demands of expertise, regulatory intelligence and financial budget of states. Although the neo-liberal doctrine has reasonably broached the issue of bureaucracy, it has largely underestimated the function of governmental regulation in the market economy. The general discrediting of government influence is questionable, particularly considering that many studies deem the imminent environmental and energy-technical revolution to be especially policy-driven (European Commission DG Environment und Ernst & Young 2006; IPCC 2007; Jänicke 2007; IEA 2008). Against this background the re-discovery of the regulatory role of the

state as a functional condition ("regulatory capitalism") is hardly astonishing (Majone 1997; Moran 2003; Levi-Faur 2005).

3.4.2 Voters and consumers open to innovation

The basic conditions for a radical shift in awareness are still largely missing. The tendency to redistribute income at the expense of the middle and lower income groups produces an unfavorable condition to begin innovation among voters and consumers. People suffering in poverty have priorities other then climate protection. Together with deficits in education, the risk of social decline is a feeding ground for the populist media which gives up their function as a democratic safeguard – e.g. in fighting corruption – to be reduced to routine witch-hunts of "the politicians." The role of the media as a transport mechanism for relevant knowledge is as important for handling the industrial revolution as for the new production model, which is based more on knowledge than on cheap resources. The media must contribute to the knowledge that is necessary for consumers as well as voters to support innovative products and policies.

If policies fail to address the challenges of climate change and resource scarcity, the mechanisms of democratic decision-making could be called into question. The impending economic and ecological crises could be attributed to the alleged slowness of the democratic decision-making process, and thus encourage authoritative forms of statehood. Such a reaction, however, underestimates the innovative potential contained in political competition and opportunities for civil society to participate. It is no coincidence that authoritative systems failed to protect the environment. The openness of political systems to new interests, despite the difficulties this entails, is a central prerequisite for political innovation and problem solving.

3.4.3 Innovative enterprises with a long-term perspective and good governance

Shortsightedness, the orientation towards shareholder-value, and short-cycles also present an obstacle to innovation in the business sector. But innovation are essential in the present economic crisis. The assumption that rational, informed companies will use their efficiency potential in production out of self-interest, and adapt their energy and resource consumption accordingly, is not generally confirmed by reality. Empirical studies regularly show that economically sensible investments in energy-efficiency are not made because of missing information, prevailing priorities, or dominating attitudes in a company hamper reorientation (e.g. KfW 2005).

It has to be mentioned that influential, large corporations often have the privilege to ignore even obvious innovation needs. Many automobile corporations are reacting to the current development of oil prices and the need for climate protection in the same way as they did already in the 1970s.

Adaptation problems: The pressure within companies to innovate during phases of technological transition has to be understood and implemented in decisions. However, this is oftentimes met with substantial resistance. Contrary to widespread assumptions, corporations often have problems adjusting to obvious future needs. In the automobile industry General Motors may serve as an example. In June 2008 this corporation had to close several factories because the high-horsepower vehicles being produced were no longer selling. The corporation had encountered this problem before in the seventies and should have been aware of it. As a former manager stated in 1980: "When we should have been planning to switch to smaller, more fuel-efficient, lighter cars […], the GM management refused saying 'We make more money on big cars'" (DeLorean 1980).

Another obstacle to innovation occurs when companies with products of high environmental impacts, for example in the electricity industry, do not have effective incentives to help to reduce energy consumption in their field. The normal reaction to energy saving of consumers will be new marketing strategies to generate more energy consumption.

Furthermore, financial markets primarily favor short-term profits. An orientation toward a long-term development of the company is impaired by having to demonstrate profit in very short period. Some countries experimenting with reporting commitments to long-term environmental effects of financial assets (e.g. for pension funds in Great Britain). In any case, stronger additional incentives are necessary to encourage the actual use of these mechanisms. Meanwhile there are many governance mechanisms that are being developed like environmental labels, standards for environmental management systems or report- and information duty. But only in combination with regulatory standards can these mechanisms be effective (Hey et al.2008).

3.4.4 A powerful innovation system

The challenges of a comprehensive technical-economic change require the development of adequate education and science systems to increase our human-capital, knowledge, and qualifications. The PISA study on the education system and numerous evaluations of the science system prove however that many coun-

tries (e. g. Germany) are not taking advantage of this potential. For example, it has been reported that the lack of well-trained skilled workers is an obstacle to further development of environmental technologies. The demographic change will aggravate this problem even further if education and research institutions do not do a better job of orientating themselves towards the new challenges. This applies to both vocational courses and further training.

The importance of educational-, science- and technology policy for the successful development of technologies, sectors and industrial development cannot be stressed enough. There is also a need for increased public spending on R&D and flexibility to advance (i.e. through a broad pre-structuring in funding) relevant future innovations.

Many countries have committed themselves to what is in some cases a remarkable increase in spending on research and development. The best example of this is the ambitious goal of the Lisbon strategy of the European Union to increase spending for research and development to 3% of GDP. However, approaches, which only add further innovation programs for environmental technologies to the existing ones, will fail to meet the challenges. Apart from promoting environmental technologies in the narrower sense, it is also necessary to consider environmental aspects in all technology fields.

3.5 Possibilities of failure

Given the extent of the resource-intensive growth crisis, failure is certainly possible. Markets, societies and states may not react sufficiently and may constrain themselves to the usual level of innovation. By this they will overstep the natural limits, and thus cause irreversible damage. Increasing the amount of electricity generated by coal will lead in that direction (as far as CCS is not technically possible and a legal requirement). It may well raise the belief, that the potential of the existing technologies is sufficient. There is the tendency to leave dominant large scale structures and trajectories untouched or even praise them as the solution to the problem. One example is the discussion about a renaissance of nuclear power or the so called “geo-engineering”. An argument for this is that both can increase the capacity of absorbing climate gases or reduce solar radiation. Such approaches are very risky and comparatively expensive. In addition, this idea postpones solving the urgent crisis and ignores the complexity of resource and environmental problems.

In the end it is about two different types of innovation: incremental innovations and radically new innovations. The former reinforces the successful industries

of the past and emerges from ancient branches and power structures. The latter enables existing structures to adapt to new requirements or to search for countries that are open to new structuring. This difference in the types of innovations will result in the rise and fall of nations and regions. Over the last 200 years, dynamic innovations have occurred due to the fact that old structures were left behind and new, open structures were preferred.

4 Opportunities

In order to avoid undesirable development, the structure of opportunities and its possibilities to enforce the trend should now be outlined. As has been the case in previous growth cycles, the crises of the current resource-intensive growth model, stands face-to-face with the opportunities of a new development model. For the first time there is an opportunity to politically shape this radical industrial change without the destructive forms of past breaks in development.

4.1 Opportunities for economic-technological development

Environmentally-friendly, resource-efficient technologies have the potential to become a lead-industry. This is comparable to the textile and iron industry in the early phase of the industrial revolution or the electrotechnic and automobile industry in later phases. Environmentally-friendly innovations are very important because they are the basic condition of long-term industrial growth. To avoid environmental damage and deadweight loss, a growth process for technological environmental relief is needed more than ever. This goal can be met by accelerating a long-term innovation process, which is comparable to the constant gain of labour productivity. Since environmental efficiency is a condition for long-term growth it offers at the same time the advantage of stable global markets.

From an ecological standpoint, new basic innovations in the area of mobility, energy supply, agriculture, recycling, chemistry and telecommunications, which facilitate or are linked to a radically lower energy and resource consumption, are necessary. A measure of the real opportunities of such a development can be found in the unusually high global growth in this sector.

Table 2: Worldwide growth of eco-efficient technologies

Annual growth 2005-07:	
• PV (on-grid capacity, 2005-07):	51 % (7,8 GW).
• Biodiesel (2005-07):	44 % (8 bn l)
• Investment in renewables (2005-07):	30 % (66 bn $)
• Wind power (capacity, 2005-07):	26 % (93 GW)
Forecast (2020)	
• Solar power:	23 %
• Hybrid vehicles:	22 %
• Bioplastics:	22 %
• Automatic sorting:	15 %

(Based on: Roland Berger/ BMU 2007; REN21 2008)

Industrial transformations have previously taken shape around industry clusters and their related key technologies. The clusters contribute above average to economic growth and as a result, their share in overall economic output increases. At the heart of these innovation and growth processes were “macro-innovations” (Mokyr 1993), which in turn were supplemented or improved by a series of "micro-innovations". A typical diffusion curve includes a long warm-up with low growth rates before the rapid take-off phase occurs. In the initial phase improvement innovations have to be made, the necessary skills have to be taught, if applicable the infrastructures have to be built or adjusted, and the required capital has to be collected. In this phase, providers of new technologies also have to prevail against traditional technologies.

An industrial transformation of this scale is inevitably connected to an economic structural change. Companies, which do not engage in the new dynamics and re-invest their capital stocks as usual, face the risk of losing ground in future markets. Radical innovation processes, too, are always ambivalent. They inevitably trigger oppositions, which have been overcome until now by a process of “creative destruction” (Schumpeter 1942). Another opportunity of the Third Industrial Revolution is that these oppositions can be overcome in more constructive ways, with less destruction of capital, and thus a higher acceptance.

4.2 Opportunities for environmental concerns

Resource conservation is always environmental protection, whether it concerns the consumption of energy, resources, water, soil or "nature". Climate change, in particular, calls for a broad new concept of resource use. Resource conservation also offers profitable solutions to a considerable extent – covering and exceeding the costs of damage prevention.

Renewable energies and an increase in energy efficiency are crucial contributions to climate protection. At the same time, they offer the possibility of substituting expensive energy imports, and providing energy at an affordable price. If renewable energies and energy efficiency are firmly promoted and fossil energies are charged for their external damage, possibly through an emissions trading system, learning effects and economies of scale in favor of new efficient and renewable technologies, these technologies would be developed. These innovations would in turn increase the potential for relative climate relief.

Similarly, an efficient use of raw materials not only assists in increasing productivity but also environmental protection. The environment benefits from the reduction or substitution of material flows in many ways. Not least, because these are related to diverse burdens (transportation, secondary energy consumption, storage, dissipative losses), which are difficult to control without further regulations.

The development of a new energy and raw material base not only affects environmental and energy technologies, but impacts the ecological modernization of the entire industry. However, it is particularly important to modernize the energy-, automotive-, air traffic-, chemical-, and construction sectors, which as measured by their added value and lifespan, especially pollute the environment and diminish resources. In the modernization of the construction sector, Germany can serve as an example. Germany has invested 40 billion euros into energy-saving buildings and government support is expected to increase massively (Jochem, Jaeger et al. 2008). Most remarkably, the investment in climate friendly technologies and products alone amounts to 5 per cent of the German GDP (2005). The share is even rising due to the new climate and energy program (2007). So far a statistically quantifiable area of "environmental technology" of about 4 per cent of the GDP and 1,8 million employees (2006) was "visible" which, however, excluded most of the climate protection activities.

Beyond this there is a broad ecological modernization of the whole industry that cannot be quantified and proceeds usually within the enterprises. Due to the

breadth of the environmental industry an English governmental study called it an "invisible industry" (DTI und DEFRA 2006). Such a mainstreaming of environmental concerns is also not restricted to the technological products of a certain environmental sector. The potentials is considerably higher if efficiency improvements are not only undertaken within technology lines, but also if innovations occur with in basic functions and systems. The needs of habitation, sustentation, energy, and mobility have to be met, but this must not occur through existing dominant technologies. For example, mobility is not limited to the road traffic system and energy provision can be met through technical savings, etc.

4.3 Opportunities for social reforms

It seems that the redistribution of income during former economic recessions at the expense of the lower classes has reached the limit of social acceptance. The price increase of both energy and necessary provisions exacerbates the situation even further. As a result, there is a lack of readiness for innovation, and this is possibly the most serious obstacle to an ambitious innovation strategy. Fortunately, positive experiences with reform concepts in this context already exist. The cutting of subsidies, which contribute to environmental pollution and the over-use of resources, is not just a potential improvement to the public spending structure of states, but can also stimulate innovations. The implementation of such spending improvements to sector specific innovation processes can be a sensible solution.

Moreover, the basic question is whether the future decisive basis for public revenue should be labor income or resource consumption. If labor income is the main basis, the problem of mass unemployment will remain. Therefore, it is in general sensible to direct taxation towards environmental and resource consumption. Environmentally related luxury taxes can be considered a source of revenue, which can assist in income redistribution policies. Such approaches further legitimize environmental policy. In the long run, it will be essential that those in the higher income brackets, who have received favorable treatment for a long time, will have to make a greater contribution to the investment in sustainable development.

The accelerated transfer towards more knowledge-based and value-added productive methods is a challenge for the education sector. The previously mentioned bottlenecks in the educational sector and in the vocational training of human capital also have to be overcome to ensure employment. In this respect

the first steps have already been made. Last but not least, the rapid growth in eco-efficient technologies clearly shows how future technological breakthroughs will be connected with qualification requirements and a broad employment potential.

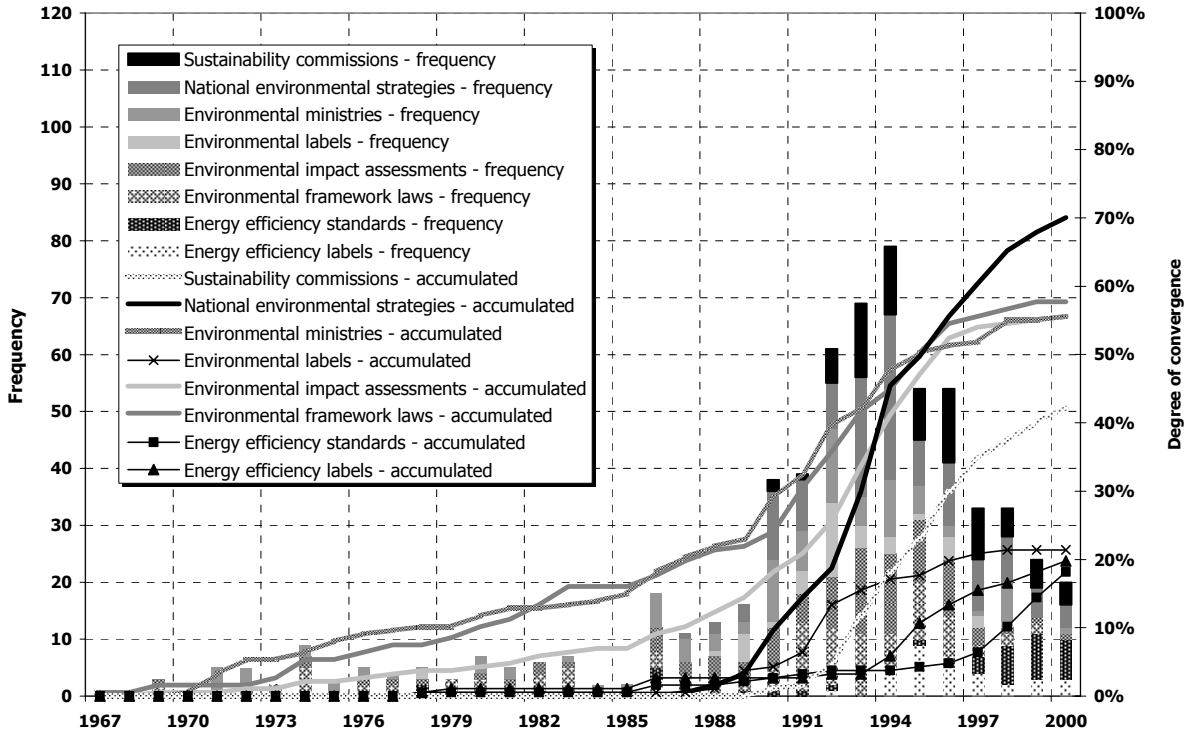
4.4 Opportunities for an improved steering capacity

Political globalization, with its indisputable restrictions on sovereignty, has repeatedly been interpreted as generally limiting steering capacities of nation states. What this interpretation does not consider is that the transfer of sovereignty rights occurs mostly voluntarily in the interest of collective action. Also, nation states have constructed a multi-level-system that has important steering capacities in the areas of technology standardization and the regulation of transport and trade. These steering potentials, as seen in Europe (EU), between industrialized countries (OECD) and also globally (G8, UN), need to be expanded and put to use for ecological modernization. The countries of the world under the auspices of the UN summit in Rio (1992), i.e. at the start of the current industrial cycle, introduced a broad spectrum of new regulations for environmental protection. These regulations apply to international agreements (on climate, biodiversity or Agenda 21) as well as to political innovations within the countries themselves. In the year 2000, for instance, 60 % of all countries had a ministry of the environment and 70 % had a sustainability strategy (see figure 1). These innovations should be the starting point for future strategies.

The need to enhance the *strategy capacity* of governments and intergovernmental organizations benefits from a wide international network of policy actors. Nowadays, ministries of the environment are more connected to international politics and policies than most other departments. Another advantage of this wide network is the increasingly large number of players with potentially long-term perspectives: international institutions, scientific institutions (e.g. climate research), environmental associations, as well as the participating state machineries, are relatively independent of the short-term nature of election or business cycles. Finally, this also applies to jurisprudence. These institutions can meaningfully complement the short-term perspectives of enterprises and democratic systems.

Alongside the international institutions of environmental policy, other international systems and agreements can be used as mechanisms to promote and establish environmental policy (Oberthür und Gehring 2006).

Figure 1: Global diffusion of environmental innovations



(Source: Busch und Jörgens 2005)

Environmental targets are accepted in development collaborations and many times, they form an integral part of corresponding programs. Also the World Bank, despite being rightly criticized for individual projects, has taken important steps towards environmental integration. Other international institutions, such as the WTO, which regulates trade and transport, still have a long way to go. Often the WTO requires ambitious product regulations by international trendsetters to be justified because they supposedly present an obstacle to competition. Because of that, their global expansion and the subsequent diffusion of ecologically advanced technologies still meets obstacles. But the mechanism of policy diffusion also provides a decisive opportunity to overcome this obstacle (Vogel 1995; Oberthür und Gehring 2006; Holzinger, Knill et al. 2007). The European Union, which began as a economic union and has become a central player in environmental policy, serves to a certain extent as an example for the incremental greening of trade regimes and should work to extend this paradigm.

The potential for steering can also lie in a re-evaluation of the concept of statehood. Contrary to the neo-liberal paradigm (which has lead to many miscalculations in particular concerning environmental issues) the role of state administrations, finances and regulations has to be re-determined. The necessary ex-

pansion of statehood does not mean an arbitrary expansion of state budget. But not all options of state regulation have been fully exploited. The quality of governance changes in era of knowledge-intensity. Above all, better regulation (smart regulation) is needed and less deregulation. A singular focus only on the cost estimate of regulation, as is commonly used, should be avoided.

The general suspicion, that future decisions made by the government have a high probability of error, must be rejected. However, what is correct is that a strong governmental role in the Third Industrial Revolution merits precautionary rules. The shortcomings of state action can be reduced through broad networking and evaluations on both the national and international levels. State laws should be made as simple as possible, flexible and restricted to a certain period of time. They should enable learning processes and corrections (Voss 2006). Investment cycles should be respected - overheating of the economy should be avoided. Not deregulation but "intelligent" (smart) regulation is required.

As seen in Germany and other pioneer countries, it is possible to promote eco-efficient innovations and diffusive them into lead-markets (Beise und Rennings 2003; Beise und Rennings 2003; Jacob, Beise et al. 2005). This is the precondition for a global change towards nature- and resource-saving technologies. Paramount is that developed countries and regions develop their internal markets for eco-efficient technologies and products. Various instruments are needed to promote innovation. Experience already demonstrates that a flexible mix of instruments that cover the entire innovation process from invention until diffusion and back to invention is beneficial.

The Japanese Top-Runner Program, in which after a certain amount of time the most efficient products in each category define the standards for all manufacturers, shows that ambitious and innovation-promoting regulation for the development of specific improvements is possible. But it always depends on the general steering through the increasing costs of energy and raw material; the policies should not only favor a broad and efficient search process for better solutions, but also reduce rebound-effects.

Environmental innovations are no subject for dogmatism towards economic instruments or state regulation. Both types of instruments are necessary: regulation to exploit *specific* potentials for innovation – and taxes, charges or emissions trading to stimulate a *general* trend.

Lead-markets for eco-efficient technologies in EU-countries, like Germany, should play a global role. These countries not only demonstrate that it is technologically and economically possible, but also politically. By designing its own

markets in this area, the EU has gained regulative dominance (e.g. the EURO-norms for vehicles, the chemical legislation REACH or the recycling of electronic devices). This has in some cases led to foreign providers adapting these processes and thereby has influenced technological development outside the EU. As a result European environmental norms are adopted by other economic regions. This is the case also with some support programs, such as the German Renewable-Energy-Law, which was copied worldwide, including some US states. The knowledge base, the capital, and the political and institutional environment all contribute to give Europe the opportunity to actively shape the process of a third industrial revolution. That is the special chance within the upcoming challenges.

5 Perspectives: A European model for sustainable development

A European strategy for an ecological, respectively sustainable industrial policy that positively addresses the challenges of the imminent pressure towards innovation in the Third Industrial Revolution, and uses its potential comprehensively, should follow the subsequent four basic goals:

a) Economically it is about a new productivity model that opts for eco-efficient innovations, especially through resource-saving and knowledge-intensive technologies, and the labor factor accordingly. This new productivity model will increase technical progress and human capital while it decreases resource consumption. It should focus on the related acceleration of the technical progress and not on the increase in growth rates. Industrial policy should both allow eco-efficient technologies to be compatible within a competitive market and should design markets with a long-term perspective and an ability to address global challenges.

Such an industrial policy would prevent the effects of long-term ecological damage and their costs.

b) Environmental policies should promote an ambitious innovation process that ensures strong environmental relief. The innovations should produce a broad, absolute decoupling from related growth processes as opposed to only a relative improvement. The importance of these radical innovations is evident when, for example, buildings with incremental augmentation of energy efficiency or coal-fired power plants with normal efficiency improvements, can handicap environmental relief for decades. Furthermore, these technologies need to penetrate

the national as well as global market as much as possible. This assigns a central role to the European lead markets. In the end, the increase of environmental efficiency has to play a role for the innovation process very much like the increase of labor productivity.

c) Socio-politically: Ecological industrial policy should seek additional legitimacy for the ecological structural change by creating significantly fairer incomes, improving the tax system and easing the burden on the labor factor. Poverty and the perceived injustice of living conditions are a bad basis for a radical change. That also applies to the education sector. Massive investments in education and research are indispensable for knowledge-intensive growth. The continuous improvement of eco-efficiency of processes and products is particularly knowledge-intensive.

d) This requires a comprehensive improvement in the steering capabilities and an *enhancement of the strategy capacity of politics*. It is about the capacity to enforce long-term public interests over short-term special interests both politically as well as legally. This requires a qualified state apparatus, which is broadly linked to society and to the multi-level-system. Europeanization and globalization can be used to this end, because both offer public interests a broad arena. Also, both grant importance to actors with long-term goals and outlooks (international organizations, academic institutions or networks of environmental administration of states). A better steering capacity requires a social atmosphere that will accept radical chance. Furthermore, voters and consumers need to be better informed. The frequent failure of government when under pressure from the populist media demonstrates the need for media reform. The drift towards a "Berlusconization" of democracy in some countries needs to be decidedly counteracted (see also Crouch 2008). Simultaneously, if politics intends to play a strong role, mechanisms have to be developed to minimize failures. The extensive networking of decision-makers and the creation of a competent ex-ante assessment are all of great importance.

Among the large global regions the EU leads the way in the upcoming upheaval. The EU has comparatively good preconditions: environment and climate protection is not only a German success story but also one of European industries. In the global market, the EU has a big share in the areas of renewable energies, energy-efficiency, recycling technologies, railway transportation and water supply. As an innovative answer to the crisis of energy- and resource-intensive growth models the EU not only has the technological expertise and the necessary capital but also a regulative environment that is both comparatively ambi-

tious and at the same time open to innovations. The "constitution" of the EU gives the protection of the environment a comparably high priority. As a result the EU is a trendsetter for environmental regulations in many other countries; its environmental standards have even curbed emissions in other regions of the world. Due to generous support for environmentally-efficient technologies like renewable energies, particularly in Germany, lead-markets have emerged in the EU and many of their products are in demand in international markets.

The regulative dominance of the EU in respect to environment and climate protection is a chance to significantly define the global transformation process. Finally, the EU serves as a model because it was founded in the name of free trade and evolved as a powerful institution aiming at a "greening" of markets.

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