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Innovation and Diffusion through Environmental Regulation: The Case of Danish Refrigerators

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Martin Jänicke, Lutz Mez, Pernille Bechsgaard, Børge Klemmensen

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FFU

Ihnestr. 22

14195 Berlin

Tel.: +49-(0)30-838 50 98 / 838 66 87

Fax: +49-(0)30-838 66 85 / 838 22 76

Homepage: http://www.fu-berlin.de/ffu/

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Summary

This study begins by looking at the retail success of class A, B and C energy-saving refrigerators in Denmark between 1994 and 1997, where their market share rose from 42% to around 90%. It also examines analogous innovation by the leading Danish manufacturer of refrigeration units, Gram, which has developed, among other things, equipment whose energy consumption is a further 40% lower. The innovation described here could, over ten years, reduce energy consumption by refrigerators without freezer compartment by a factor of ten.

The hypothesis which immediately suggested itself was that both processes - diffusion and innovation - could be traced back to the rise in energy tax which made itself felt with the comprehensive environmentalist revision of taxation in 1994, and further gradual increases until 1998. The results of this study, however, show that any explanation requires a broader approach.

At the very least, the explanation must include a mix of different instruments. The necessary condition for retail success of the best appliances was certainly the energy tax - which is levied according to CO_2 emissions. Nevertheless, without the further instrument of labelling the energy consumption of appliances (1989, also issued as an EU guideline in 1994, coming into force for refrigerators in 1995), the effect would scarcely have been to be expected. In addition to this came training connected with the labelling for sales staff by the Energy Agency (1994). An instrument which also explains this retail success was the national and regional energy saving campaigns, in which the energy supply companies participated (1994 and 1995). Finally, the campaign also included an upgrade incentive of 200 DK for replacing an old appliance with one of the best models (1994). The Danish public's widespread awareness of environmental and climate change issues must also be considered as a background variable.

For the innovations at the Danish manufacturer Gram, state R&D funding played a considerable part, implying the formation of innovation networks. Here also, the energy/CO_2 tax is a significant background condition, although the company itself did not consider it decisive. The EU's Maximum Consumption Guideline, which will come into effect in Denmark in 1999, making existing energy-saving models standard, is also considered especially important. New markets were thus only accessible through further improvements, and retailers also had to ensure that inefficient appliances were removed early on from their product ranges and warehouses.

The project has also borne methodological fruit. With respect to the broad spectrum of instruments which have come into effect, the significance and configuration of the participating actors and the cooperative, forward-looking policy style of the regulat-

ing authorities, the extended concept of a "regulatory framework" proves to be heuristically useful. The same applies for the bottom-up approach to policy evaluation, which affords the necessary openness for the breadth and dynamics of the influential factors.

In the Danish case studied here, innovation follows diffusion. Both were brought about by an essentially strategic approach to environmental and climate protection policy, notable for its committed, but negotiated, development of aims (CO_2 reduction, energy saving), its good technological policy infrastructure and the close networking between public and private sector actors. Of particular note was the breadth and flexibility in applying instruments, from indicative long-term planning, through energy taxation, subsidies and informal instruments, to efficiency standards.

1 Introduction

What follows deals with the innovation or diffusion effects of Danish energy saving policy with respect to refrigeration units from 1993 onwards. This means the effects of measures springing from the goals set out in the 1990 plan, "Energy 2000", a 20% reduction in CO_2 emissions relative to 1988 by the year 2005. The most important measure - within a mix of further instruments - was the introduction of a combined energy/CO_2 tax from 1992 onwards and the perceptible step-by-step increase in the charge levied from 1994.

This study looks for the impact of these policies on the energy efficiency of domestic refrigeration units. Here, the diffusion effect on retailers is examined. Possible innovation effects were examined in the two leading Danish refrigerator manufacturers, in particular Gram, which has the largest market volume. The study was based above all on surveys - conducted jointly with Roskilde University - and secondary analyses.

The approach selected was evaluation research (BUSSMANN 1996, FISCHER 1995, HOWLETT/RAMESH 1995, ROSSI/FREEMAN 1993) with strong emphasis on a bottom-up approach (SABATIER 1986), which moves backwards from the effects to the causes (JÄNICKE/WEIDNER 1995) and which is more open for the breadth and dynamics of factors promoting innovation than a simple top-down approach from the perspective of the legislator (MAYNTZ/SCHARPF 1995).

2 The regulatory framework of Danish climate protection policy

The following starts with the regulatory framework of Danish climate protection policy, and then traces the unexplained cases of innovation and diffusion back to their causes. Especially in the case of innovation processes, there is always the possibility

that innovation has developed broadly independently of state measures. Thus a two-step analysis appears to have particular methodological advantages.

We define a regulatory framework (based partially on OECD 1997, p. 9) as the sum of all calculable regulations, procedures and contexts for action in an area influenced by the state. We assume here that it is not only the approved measure, but - particularly in the case of innovation processes - the entire process of formulating demands and objectives which is of significance. This is not simply a question of the particular collection of instruments, but also of the policy style which characterises the formulation process and the context of the actions of political institutions, in particular the relationship between regulator and regulated (JÄNICKE 1997). The regulatory framework should be related to the conditions for action by the target groups (top-down). In the second step, these conditions should be related back to the regulatory plan. This can leave an unexplained remainder, which is not, or only indirectly, concerned with state action

2.1 Instruments

In contrast to most OECD countries, Denmark has a long tradition of energy planning. This can be traced back to the two oil crises (1973 and 1979), which hit Denmark very hard at the time, owing to its - at the time extreme - dependence on oil imports. The energy planning institution which grew out of this is notable for the goals it sets, which are negotiated with a broad base of actors and validated by parliament, and its flexibility in applying the instruments arising from this. Financial instruments, networking and an approach based on technology policy are especially important. After the first energy plan, "Danish Energy Policy 1976", came "Energy Plan 81", both strongly oriented towards the goal of using less energy, and in particular oil. The “Energy 2000” plan of action and "Energy 21", agreed in 1996, both relate explicitly to the goal of climate protection and especially the reduction of carbon dioxide emissions (KRAWINKEL/MEZ 1995, KRAWINKEL/MEZ 1996).

For the diffusion and innovation process to be explained here, the "Energy 2000" plan forms the basis of the regulatory framework. Its strategic goal was to reduce global environmental stress caused in the energy sector, in particular emissions of the greenhouse gas CO_2 (but also SO_2 and NO_X). A reduction of 15% in primary energy use relative to 1988 by 2005 was intended to help achieve this. Four main goals were formulated: reducing energy consumption, increasing the efficiency of the supply system, changing over to more environmentally friendly fuels and supporting research and development. A total of 72 single measures were provided to these ends.

For the case under examination here, the following measures based on the "Energy 2000" plan are significant (MINISTRY OF ENVIRONMENT AND ENERGY & DANISH ENERGY AGENCY 1996, S. 39):

- The 1992 "CO_2 package" introduced a CO_2 tax and subsidies as monetary instruments. In 1993, a comprehensive environmental tax reform for 1994-98 was passed, bringing with it new charges on household energy consumption, while simultaneously reducing direct taxation and charges.
- In February 1994, integrated resource planning, with opportunities for energy savings, was introduced.
- In May 1994, the legal basis of introducing efficiency standards for electrical appliances was created.
- In January 1995, the EU introduced energy consumption labelling for, among other things, refrigeration units, based on a scheme which had been operating in Denmark since 1989.

All in all, therefore, the array of instruments is many-dimensioned, and the strategic goals laid out are clearly secondary. Monetary instruments, particularly charges or taxation, play a greater role than in most OECD countries, without policy-makers refraining from laying down obligations.

The measures described here were the response to an evaluation of climate protection measures taken up to that point in time, and which had proved to be inadequate.

2.2 Policy style

Danish environmental policy style can be characterised as cooperative and dialogue-oriented, and the state implements markedly forward-looking policies with great commitment. Formulation of goals with a broad basis is combined with flexibility in the choice of instruments used. This policy style favours innovation, in that it disseminates relevant information at an early date, investment conditions are more calculable and state actors are comparatively strongly oriented towards technology and orientation.

2.3 The context of political and institutional action

In keeping with the neo-corporatist tradition in Scandinavian countries, the tight networks between regulator and regulated are central to the Danish regulatory approach. In the past, this expressed itself in a series of advisory committees and expert committees, where representatives of industry, the administration, science and the environmentalist movement were present. In addition, the environmental and energy ministries were merged after the elections in September 1994, which has simplified policy

integration. Energy saving policy enjoys powerful institutional safeguards - also through the Energy Agency - and the same can be said for environmental policy and the Environmental Agency. In July 1996, under the „Energy 21“ plan, the Environmental Energy Council was set up to promote sustainable development in the energy sector. The new advisory council has 24 members and replaced three other energy councils: the Council for Renewable Energy, the Electricity Savings Council and the Energy Savings Committee. The Environmental Energy Council is made up of independent experts, has its own secretarial staff and advises government and parliament on questions of renewable energy, energy saving, transport policy and energy-related interdepartmental issues. National climate protection policy can also fall back on the political resource offered by a scientifically competent environmentalist movement and a high level of environmental awareness among participating actors.

3 The diffusion of the best models

3.1 Domestic appliances as the subject of climate protection policy

Emissions of CO_2 cannot - as with sulphur dioxide and nitrogen oxides - be reduced by way of additive filters. The only method for limiting CO_2 emissions is to limit the creation of CO_2 in the first place. Opportunities are available chiefly during the transformation of primary to final energy, energy use in production and the use of final energy for energy-related services. During final consumption, CO_2 emissions can only be reduced through using less energy. In households, therefore, the use of energy-saving appliances presents a significant opportunity for reducing electricity demand and with it, CO_2 emissions.

Reducing energy consumption is a declared aim of Danish energy and environmental policy. According to the 1996 electricity consumption figures, households consumed 30.7% of total domestic (national) consumption (32,423 GWh). In 1996, 45,387 GWh were generated in Denmark. With a share of 23% in household energy consumption, refrigeration units form the second most important area of consumption after cooking (DEF 1996, p. 8). In households with an annual consumption of 2,000 to 2,500 kWh, refrigeration units consume around 28% of the total, where consumption is 4,000 to 4,500 kWh, the share falls to 16% (DEF 1997, p. 5). Since a refrigeration unit has a product life of some 13-15 years, and its cumulative energy consumption during this time represents by far the greatest single contribution to household electricity use, its consumption is an important starting point for increasing energy efficiency overall in an eco-balance of appliances. Annual energy consumption by

the average modern refrigeration unit in Denmark is between 255 and 575 kWh, according to the type of model.[1]

The Danish energy authority believes that energy consumption by these appliances can be reduced significantly, if the "best technological developments" with respect to insulation and compressor performance are supported. Energy-saving models of refrigerators without freezer compartment consume over 60% less electricity than average models. For refrigerators with a freezer compartment and fridge-freezers the energy-saving models' lead over average models is 25 and 30% respectively.[2] By 2005 it is expected that technical improvements will be able to reduce consumption by these refrigeration units by two thirds relative to the current best models.[3]

Specific CO_2 emissions by Danish power stations were around 822 g CO_2/kWh in 1996. Total household energy consumption caused the emission of some 8 Mt CO_2, of which about 2 Mt can be attributed to energy use for refrigeration. Relative to Denmark's total CO_2 emissions of 58.2 Mt in 1996, this is a share of just under 4%. The structural change towards energy-saving refrigeration units is therefore making a noticeable contribution to reducing CO_2 emissions.

3.2 The retail boom in energy-saving refrigerators

The market for refrigerators in Danish households is saturated. According to Danish figures, every household contains at least one refrigerator. Production volumes in the 1990s were between 127,000 and 164,000 units per year, while between 91,000 and 123,000 units were imported and between 79,000 and 91,000 were exported. This means that today, up to 70% of the refrigerators purchased in Denmark are imported.

In 1996, 38 refrigerator manufacturers were present on the Danish market. Of these, ten manufacturers can supply class A and B models, the best models of twelve manufacturers are energy class B, eleven can manufacture up to class C models and four only class D (VINDING PETERSEN 1997, App.).

In the 1990s, an average of just under 172,000 refrigerators were sold per year. After a turnover of around 182,000 units (1991) had fallen to 153,000 in 1993, sales in 1994 and 1995 boomed. In 1994, 186,415 refrigerators were sold, a growth in turnover of 22%. In 1995, turnover was still 177,524 (+16% over 1993), while 160,763

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1 Refrigerators without freezer compartment 255 kWh, with freezer compartment 290 kWh, fridge-freezers 575 kWh. DEF 1997, p. 6.

2 Refrigerators without freezer compartment 100 kWh, with freezer compartment 215 kWh, fridge-freezers 400 kWh. Ebd.

3 Refrigerators without freezer compartment 30 kWh, with freezer compartment 100 kWh, fridge-freezers 110 kWh. Energistyrelsen 1996, p. 23.

units were sold in 1996 (cf. Table 1). This trend applies also to refrigeration units as a whole.

Nonetheless, turnover varies greatly from month to month. Every year, about twice as many units are sold in August as in February and April. The sales peak in August is due not only to the summer sales, but also to the heavy demands made on refrigeration units - older appliances break down considerably more often under high temperatures.

Table 1: Sales of refrigeration units in Denmark 1991 - 1996

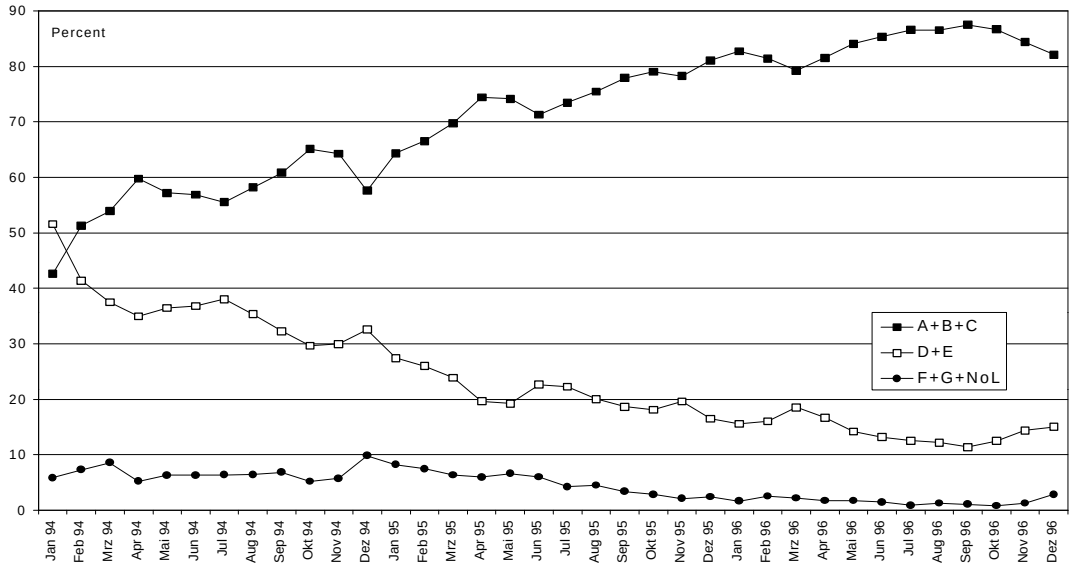
	refrigerators and deep freezes	**of which refrigerators**			
year	**wholesale**	**production**	**imports**	**exports**	**sales in DK**
1991	**290,174**	151,785	113,670	83,662	**181,793**
1992	**295,040**	163,910	90,932	83,689	**171,153**
1993	**274,340**	142,520	90,843	80,364	**152,999**
1994	**339,245**	161,039	110,822	85,446	**186,415**
1995	**329,102**	144,972	123,323	90,771	**177,524**
1996	**289,408**	126,943	112,557	78,737	**160,763**

Sources: Feha; Danmarks Statistik

Crucial to this study is the change in the demand structure for refrigerators: while just four out of ten units sold were more efficient than the average at the start of 1994 (i.e. they corresponded to energy classes A, B or C), by the end of 1996 these appliances made up over 85% of turnover (see Figure 1). In 1997, their share rose to some 90%.[4]. These figures are based on sales figures from the largest Danish distributors, Snehvide & Køkkenland, whose market share is around 20%.

[4] According to figures from Snehvide & Køkkenland (Ken Zillmer).

Fig. 1: Turnover of refrigerators in Denmark by energy class (%).



Turnover of refrigerators should now be looked at more closely. In January 1994, the mid-range group, D-E, had a market share of around 52%, while energy class A-C models together occupied only just over 42%. The market share of class B models has more than doubled, from 20% in January 1994 to some 47% in September 1996. The best (energy class A) models' market share has risen from just over 2% (January 1994) to just under 6% (December 1996), almost by a factor of three. In November 1995, both top energy classes together (A & B) achieved 40% market share, for the first time greater than that of class C models.

While refrigeration units with average energy consumption (energy classes D & E) - which, with over 50% share, occupied the largest market segment at the start of the period under examination - still had a market share of around 33% at the end of 1994, this fell consistently to 20% in 1995 and to half as much, 10%, in 1996. The most dramatic fall can be seen in class E models, whose market share shrank from just under 24% in January 1994 to below 1% in December 1996.

Three significant changes or turnarounds took place in the period 1994-1996, the first as early as February and March 1994: the drastic fall in class D and E models is compensated by strong growth for classes A, B and C. This development cannot be attributed solely to the coming into force of the environmental tax reform on January 1st 1994. It was also supported by retail staff training (at Snehvide & Køkkenland), which also took place at the start of 1994.

The second significant change can be made out in October and November 1994. Here the market share of class A models doubled from 5 to 10%. There was, during this

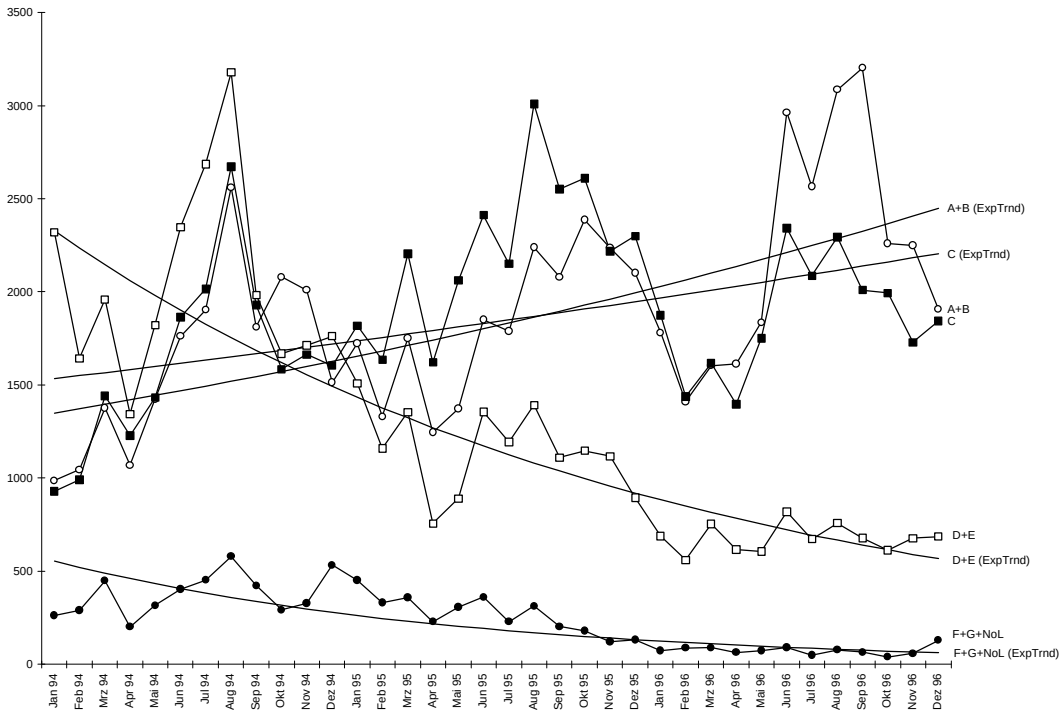
period, a large energy saving campaign, and from 23/9 to 19/11/1994, retailers offered customers purchasing an energy-saving model 200 DK for their old one.

The third turnaround came in the summer of 1996. From may 1996, the market share of class B models rose from 33 to almost 50%, and then fell slightly. On the other hand, the share for class C models - since 1994 the best selling refrigerators - fell from 41% in May 1996 to 33%.

During this period, there were no new measures to promote energy-efficient domestic appliances, but other refrigerator manufacturers (Blomberg, Bauknecht, Indesit and Hoover) expanded their product range to include energy-saving models. A further explanation of the structural change in turnover can be found in the extended range of products available. After consumer's purchasing decisions became more strongly influenced by energy consumption, more and more manufacturers began supplying energy-saving models in Denmark.

The trend analysis shows that the strongest demand was for the best models (energy class A & B), while the upturn in turnover of class C models is less strong (cf. Figure 2).

Fig. 2: Trends in turnover of refrigerators in Denmark by energy class



Long after the pioneer Gram had done so, five other companies (Bosch, Electrolux, Frigor, Husquarna and Vestfrost) put their first class B models on the market. By the end of 1993, seven other manufacturers had done the same. A further nine manufac-

turers presented their first B class model after 1st January 1994, three of them not until the end of 1996.

The first class A model was offered by Gram from July 1987. Four other manufacturers followed suit in 1990, 1991 and 1992. Five offered no class A model until after 1/1/94.

Thus it can be noted that supply of energy-saving refrigerators almost doubled after 1993. However, the two Danish refrigerator manufacturers to supply both class A and class B models have failed to profit from this development. In recent years, their market share in Denmark has even fallen slightly, as some 20% more refrigeration units are being imported as in 1992/93. Nonetheless, they have been able to increase their exports - and have reduced production.

4 Policy Development

A series of energy policy measures present themselves as possible factors influencing this remarkable restructuring of demand for refrigerators. The following table offers a chronological overview of energy policy measures and other initiatives for increasing the energy efficiency of electrical household appliances in the period under examination (see Table 2).

4.1 The CO_2 / energy tax

Denmark was the first EU country to introduce a CO_2 charge in addition to energy taxes (in 1992). At the start of 1993, Schlüter's conservative government was replaced by a centre-left coalition. The winning coalition, as the "green majority" (ANDERSEN 1997) had already forced the previous minority government into action on environmental policy. Correspondingly, the new government announced a markedly environmentally friendly policy: an environmental tax reform passed through parliament in May of that year. Under it, income tax will be reduced within five years, and the share of the "green" tax falling on households will rise from 10 to 15% (cf. MEZ 1995).

Alongside 25% VAT and the CO_2 charge, the price for electricity in Denmark contains two further charges: a special electricity charge levied since 1977 - aimed at reducing oil consumption - and a limited term SO_2 charge (introduced on 1/1/1996). Together with the CO_2 charge, these three electricity-specific charges now make up 47% of the cost of electricity. Following the environmental tax reform, the electricity charge has risen annually from 27 Öre/kWh (1993) to reach 46 Öre/kWh (1998) (see Table 3).

Table 2: Chronology of energy and environmental policy measures in Denmark since 1989

Year	Policy Development
1989	Introduction of the „energy savings arrow“ (el-spare-pilen) on hard white goods.
1990	The long term energy programme „Energy 2000“ defines targets on the reduction of energy consumption and CO_2 emissions.
12/21/91	A CO_2 tax was adopted by Act 888.
05/15/92	CO_2 tax of 0.10 DKK/kWh comes into force
01/01/93	Energy tax on electricity increased to 0,27 DKK/kWh.
1993	EC directive on labelling of refrigerators decided.
05/1993	Parliament adopts the „Ecological tax reform“.
09/1993	Follow-up to „Energy 2000“
01/01/94	Energy tax on electricity increased to 0.30 DKK/kWh.
1994	Training for sales staff on how to sell „energy-friendly“ products.
09/1994	Energy saving campaign on „energy-friendly“ refrigerators. Focus on the élite.
09/1994	Introduction of a part exchange scheme (200 DKK for trading in an old refrigerator).
01/01/95	Energy consumption labelling of refrigerators comes into force.
01/01/95	Energy tax on electricity increased to 0,33 DKK/kWh.
10/1995	Follow-up to the energy savings campaign
01/01/96	Energy tax on electricity increased to 0,36 DKK/kWh
01/01/96	SO_2 tax on electricity of 0.009 DKK/kWh comes into force
04/1996	„Energy 21“ as 4th Danish energy plan is launched, placing strong emphasis on CO_2 emission reduction.
09/03/96	EC directive on norms for refrigerators decided - to come into force in 1999.
01/01/97	Energy tax on electricity increased to 0,40 DKK/kWh.
05/1997	New energy saving campaign on „energy-friendly“ refrigerators.
20/10/97	Environmental Energy Council organises first Energy Day, mounts advertising campaign: „Private Energy Consumption““
1/1998	Electricity charge raised to 0.46 DKK/kWh; new energy charge of 0.006 DKK/kWh (to finance „Energy Savings Fund“)

Table 3: Changes in electricity charges in Denmark since 1992 (Öre/kWh)

year	electricity charge	CO_2 charge	SO_2 charge	energy savings fund	total
1992	25.50	10.00			35.50
1993	27.00	10.00			37.00
1994	30.00	10.00			40.00
1995	33.00	10.00			43.00
1996	36.00	10.00	0.90		46.90
1997	40.00	10.00	0.90		50.90
1998	46.00	10.00	0.90	0.60	57.50

As of 1998, a new charge of 0.6 Öre/kWh will be levied to finance the "energy savings fund" (El-Sparefonden). It aims to support substitution of electric heating systems and promote the development, marketing, purchase and use of electricity-saving appliances.

According to a study conducted by Gallup for the daily Berlingske Tidende (11th May 1997), the charges are accepted by the majority: 44% of those questioned consider the green taxes to be set at the right level, 16% find them too low, 22% find them too high, 10% argue for their abolition and 8% expressed no opinion.

The environmental tax reform triggered a boom in the use of renewable energy. It was the necessary condition for the aforementioned diffusion of the best energy-saving appliances. The tax hike, in association with the lowering of income tax, was highly visible. However, its impact on behaviour came about only in combination with other instruments, and the specific impact of the individual impacts is hard to investigate, precisely because of this interdependence.

4.2 Labelling energy consumption

The purchaser's preference for an efficient appliance can only make itself felt where there is corresponding labelling. There is a certain tradition in this respect in Denmark. As early as 1989, the energy supply companies introduced the "energy savings arrow" for hard white goods. According to the energy consumption of the article, between one (lowest consumption) and fifteen (highest consumption) arrows were awarded.

This initiative influenced the European energy labelling system, which was agreed in an EU directive in 1994 and came into force for refrigeration units on 1st January 1995.[5] The labelling divides refrigeration units into energy classes from A to G, where A represents the most efficient and G the least efficient appliance. At present, there are already class A refrigerators without freezer compartment and deep freezes on the

[5] A directive on energy labelling for washing machines and tumble dryers followed in October 1996.

market. The most efficient refrigerators with freezer compartment and fridge-freezers are class B.

In Denmark it was decided to extend the EU labelling system with the already well-understood energy savings arrows. The arrows offer a more subtle picture of the worst and the three best energy classes, in which A corresponds to 1-4 arrows, B to 5-6 arrows and C to 7-8 arrows, while G corresponds to 12-15 arrows. Energy classes A-G correspond to a energy consumption, [6] relative to class D, of:

A < 55%

B < 65%

C < 90%

D < 100%

100% < E <110%

110% < F <125%

G > 125%

The intention is to revise the energy classes at regular intervals. Appliances in the worst classes should be taken off the market within certain time limits. Thus the development of more energy-efficient models will receive additional incentives.

4.3 Public awareness of energy consumption

Several advertising campaigns targeting consumers were conducted to promote the diffusion of more energy-efficient refrigeration units. It is worth noting that the campaigns were not only initiated by the state, but also by the energy sector and retailers. They offered information about energy consumption labels and the economic and environmental advantages of efficient appliances. In September 1994, a nationwide campaign about energy-saving refrigerators in particular was started by the energy supply companies. This campaign targeted the most efficient models. A list of these models was published to help consumers make an informed purchase, and the new-for-old payment of 200 DKK per refrigerator was a particularly influential factor in the campaign - 7,015 new refrigerators were purchased in part exchange under this scheme. October 1995 saw a follow-up to the 1994 energy saving campaign.

As a guide to consumers, the Association of Danish Electricity Plants has produced a list with the range of refrigerators currently available which is updated ten times a year. The list contains the names of the manufacturers, countries of origin and information on technical data, energy consumption, energy class and the recommended

[6] Relative to the market average in 1992.

retail price (DEF 1996a-e). The information on around 4,600 appliances is collected in an electricity sector data base.

From May to September 1997, a further campaign about energy-saving refrigeration units was conducted, in the form of informative leaflets and a seven minute long TV advertisement, "The Olsen band's savings plan". Consumers were told about the environmental benefits of using efficient appliances and the financial advantages for the user. This energy sector campaign can now be found on the Internet.[7] In October 1997, yet another energy saving campaign was started, this time by the new Environmental Energy Council (see below).

Alongside public consumer information, the electricity supply companies also conducted regional campaigns to encourage households to purchase energy-saving refrigerators and thus to reduce energy consumption. The regional campaigns consisted mostly of information delivered with the electricity bills or soirees, where information was available on energy savings and products, as well as tips on using various electrical appliances more efficiently. The electricity suppliers also used energy advisers, who answered questions on appliances' energy consumption.

There have also been campaigns by retailers or distributors in connection with specific appliances.

4.4 Training for retail staff

To enhance the impact of energy consumption labels, the Energy Agency took the step of training staff in the electrical goods retail sector in 1994, when a pilot project was started for sales personnel at Snehvide A/S. The goal of the course was to familiarise salespeople with energy labelling and with using the label as a selling point in sales pitches. The project was conducted by a group containing, among others, representatives of the Energy Agency, the Association of Danish Electricity Plants, NESA, NESA, Snehvide A/S and DTI Energi. In 1995 the project was conducted nationwide by the Energy Savings Committee and the Energy Agency. Some 20% of sales staff connected with white goods retail took part in the training, approximately one salesperson per outlet.

4.5 Maximum consumption standards

Standards play a not inconsiderable role in Danish environmental policy. There have not as yet been any concerning energy consumption by refrigeration units. In Septem-

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[7] http://www.spareskab.dk

ber 1996, the EU agreed common EU standards for the maximum energy consumption by refrigeration units.[8] These will come into force in Denmark in 1999. At this time, only sales of class A, B, C and the more efficient class D models will be permitted.

In order to meet the requirements of the standard, the energy consumption of refrigerators will have to be reduced, it may only be 15% above the maximum permitted consumption. It is expected that this requirement will lead to a corresponding fall in energy consumption by European refrigerators. A study from 1995 showed that only 120 of 280 models on offer (in November 1994) met the EU requirements (MØLLER 1995, pp. 32f). If the Danish refrigerator market were to be regulated according to this standard today, only five manufacturers would be able to offer one or more of their models for sale, while nine manufacturers would disappear from the Danish market altogether (VINDING PETERSEN 1997, pp. 73f). For this reason, the introduction of this standard is expected to produce a considerable innovation effect with respect to refrigerators.

4.6 Institutional arrangements and innovation networks

Last but by no means least in the mix of factors favouring energy-saving electrical appliances comes state support for the corresponding innovation networks and well-targeted R&D projects. With respect to the development of energy-saving refrigerators, there were two major state-sponsored innovation projects: the UMIP project and support targeted at the development of a new compressor.

The UMIP project ran from 1991 to 1996 and was supervised by the Institute for Product Development (IPU), a charitable institute at the Danish Technical University (DTU).[9] The aim of the project was to evaluate methods of recording the environmental burden produced by complex industrial products, to develop guidelines for constructing environmentally friendly industrial products and to see these processes implemented within companies. Five Danish companies participated in the project, among them the refrigeration appliance manufacturer Gram A/S.

The institutional arrangements include in particular the state-financed “Energy Savings Council” (dissolved in 1996), the “Environmental Energy Council” and the “Energy Savings Fund”. The Energy Savings Council issued a biennial report on energy-saving initiatives. The Environmental Energy Council has been the Danish advisory panel on environmental and energy-related questions since 1996. It has an annual re-

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8 Directive 96/57/EF, 3rd September 1996.

9 The Environmental Agency has published five Danish language documents and an English summary in connection with the UMIP project.

search budget of ca. 5 million DKK. The Energy Savings Fund is a relatively recent initiative, and will, from 1998 onwards, be funded by an energy charge of 0.6 Öre/kWh. Its aim is to support the removal of electric heating systems, and to promote the marketing, purchase and use of energy-saving electrical appliances. It offers no funding for research.

As has already been stressed, the integration of energy and environmental policy is favoured institutionally by the merged "Ministry for the Environment and Energy".

4.7 Determinants of the change in consumer behaviour

So what motivated this change in purchasing behaviour, which led to the significant diffusion of the best energy-saving appliances? Since the question concerns a complex compound of influences, pointing up specific component instruments and their influence is difficult and, in the context of the regulatory framework approach, also unnecessary. Nonetheless, surveys of customers and sales personnel do. offer some answers in this respect.

A study conducted by NESA at the end of 1994 showed that energy consumption was an essential determinant in purchasing decisions for a refrigeration unit: 47% of respondents replaced their old model because of its high energy consumption, 18% for environmental reasons and 34% because the old model had broken down. At the same time, however, the - higher - retail price was unimportant for only 9.5%. From this it can be concluded that - setting the environment aside - the cost of electricity, which rose from 1994 onwards, and thus the CO_2 / energy tax, was an important determinant of purchasing decisions, as it justified the higher retail prices.

Another study was conducted in 1994 in the context of the EU decision to require labelling of energy consumption on electrical appliances, in a related pilot project in Denmark. Among others, the Energy Agency, the Association of Danish Electricity Plants, NESA, Snehvide A/S and DTI Energi took part in the project. The retail staff questioned in the study emphasised that price was the most important factor in purchasing decisions, but almost all (95%) confirmed that energy consumption labels bore some influence. Of the customers themselves, 46% emphasised the primary importance of energy consumption, when asked, 25% that of price (DTI ENERGI 1994, pp. 31-33). A third study found that about half of households questioned considered the energy consumption labelling system introduced nationwide from 1995 onwards to be important or very important, while 29% thought it unimportant (DEFU 1996).

The surveys confirm that the impact of the CO_2 / energy tax grew stronger only in combination with energy consumption labels and information from retail staff. The numerous public information campaigns may have reinforced the effect.

The part exchange scheme certainly did. It is also the decisive factor in the strong growth in sales of class A refrigerators in autumn 1994. At precisely the same time, Siemens and Bosch also brought out their first class A models.

It should nevertheless still be noted that the sales boom in energy-saving refrigerators and the significant fall in sales of appliances in higher consumption classes had already begun in January-March 1994, at a time when the only explanation for a change in consumer behaviour on offer is the anticipation of higher electricity costs. In the light of consumer surveys also, the coming price rise was the core influential variable. The fact that customer preferences, in particular since 1996, have been for more expensive, but more efficient, models should also be emphasised once again.

5 Emerging technologies at the Danish manufacturer Gram A/S

There are two producers of refrigeration units in Denmark, with widely differing company profiles. While Gram A/S produces refrigerators above all for the Scandinavian market, production by A/S Vestfrost comes onto the European and Middle Eastern markets. Gram is seen as the environmental innovator for refrigerators in Europe, but Vestfrost also belongs amongst the front runner companies in its branch (see Table 4).

Table 4: The range of refrigerators in Denmark - dates of introduction for the first class A and B models (Danish companies in boldface)

date	**manufacturer**	**energy class**
11/1984	**Gram**	**class B**
7/1987	**Gram**	**class A**
1/10/1989	Bosch	class B
1/10/1989	Electrolux	class B
1/10/1989	Frigor	class B
1/10/1989	Husquarna	class B
1/10/1989	**Vestfrost**	**class B**
8/8/1990	Atlas	class B
15/8/1990	Vibocold	class A & B
17/6/1991	Candy	class B
27/9/1991	Electrolux	class A
21/10/1991	Frigor	class A
20/8/1992	Miele	class B
20/8/1992	Siemens	class B
31/8/1992	**Vestfrost**	**class A**
1/3/1993	Cylinda	class B
3/3/1993	Gorenje	class B
1/1/1994	AEG	class B
29/6/1994	Whirlpool	class B
1/9/1994	Bosch	class A

1/9/1994	Siemens	class A
12/9/1994	Blomberg	class B
21/3/1995	General Frost	class B
25/4/1995	Atlas	class A
3/5/1995	Husquarna	class A
15/10/1995	Vølund	class B
1/11/1995	Zanussi	class B
1/4/1996	Blomberg	class A
24/10/1996	Bauknecht	class B
18/11/1996	Indesit	class B
28/11/1996	Hoover	class B

Source: Vinding Petersen 1997, Appendix; own research

Even in the early years, Gram was the European pioneer of energy-saving refrigerators. In the period under examination, the firm also occupied itself with a series of additional energy-saving and environmental improvements, the most important of which are included in this study (see below).

Innovations by Gram from 1993

- Development of a new compressor (on sale 1997/98): energy savings of 40%
- Improved electronic control for refrigerator systems: energy savings of 5-10%
- Vaporisers relocated: energy use ca. 10% more efficient
- New construction for condensers and rear cover: material savings of 15% less steel
- Improved cooling and foaming systems, reducing contribution to greenhouse effect by 75%
- Nickel-free hinges

Sources: Ugebrevet Mandag Morgen No. 21 - 3rd June 1996; own research

The firm, founded in 1901, had a turnover of 968.7 million DKK in the 1995 financial year. Production is divided evenly between household refrigeration units, commercial refrigeration or freezing units and specialist equipment for ice-cream production. Gram currently employs 1,800 people in Denmark and 200 elsewhere, of whom 800 are involved on the manufacture of household refrigeration units.

Gram manufacturers refrigerators for its own brand, and primarily (50%) for the Danish market, where it has a market share of 30%. The remaining production is sold in Sweden (20%), Norway and Finland (10% each) and other European countries (Netherlands, Germany).

Its competitive strategy is based on quality, where a low energy consumption, low environmental impact and safeguarding the quality of the refrigerator’s contents are

the key parameters. The first refrigerator which would qualify as energy class B today came onto the market as early as the end of 1984. The LER 200, a low-energy refrigerator, developed jointly with Denmark's Technical University between 1986 and 1988, was the world's first refrigerator with such an extraordinarily low consumption of energy, and was put on sale in summer 1987. Despite the relatively high retail price, however, turnover was not high enough to cover the development costs, and the climate debate also turned its attention to the technically still insoluble environmental problems inherent in refrigerator components towards the end of the 1980s. Nonetheless, the LER 200 provided excellent publicity for Gram. A second generation of refrigerators was subsequently developed, with a somewhat higher energy consumption, but about 1,000 DKK (ca. 260 DM) cheaper. Gram has not used CFCs in its refrigerator production since 1992.

In the context of Denmark's integrated environmental and energy policy, where the goal of energy savings was stressed for the first time in 1990, the company has enjoyed competitive advantages from its ability to supply especially energy-efficient models.

The 1990s saw a second impetus to innovation, this time from state-sponsored R&D projects. Gram was an active participant in the UMIP project (see above) and the development of a new compressor, which received special state funding, as well as taking part in R&D networks with other companies and research institutes interested in reducing the energy consumption and environmental impact of refrigerators. Most of these innovations are already ready for the market.

The UMIP project was conducted in the period 1991-96, supervised by the Institute for Product Development (IPU), and funded with 50 million DKK. At Gram, the UMIP project led, among other things, to the development of a new electronic temperature control for refrigerators, which - along with other improvements in the vaporiser - cuts energy consumption by 10-15%. UMIP placed Gram into the position of technological pioneer. The UMIP system was described as the "best strategic environmental tool" (ANONYMOUS 1996), because industrial companies could investigate precisely to what extent their products burdened the environment, and then include this in strategic company decisions. The IPU won the Nordic Council's nature and Environmental Prize in September 1997 for the UMIP project.

State funding of the compressor project started in 1993, with the aim of developing a compressor able to reduce the energy consumption of refrigerators. Funding took place through the Energy Agency. Danfoss A/S, Gram and Ålborg University jointly developed a compressor which consumes 40% less energy. Refrigeration units with this compressor are, however, not yet on the market. This is also the case with better

insulated refrigeration units, developed by Gram in 1996 (VINDING PETERSEN 1997, p. 58).

Iver Iversen, head of the construction and development department at Gram, believes that obligatory labelling of energy consumption gave a push to the development of energy-saving refrigerators. The product range was extended by energy class A products while, at the same time, production of energy class D-G models was gradually closed down.

Gram's main range currently meets the requirements for energy class B, while class A and C models are also available. Around 80% of turnover is in class B and C models. Because of their high prices, turnover in class A models is limited to "environmentally conscious consumers". In the opinion of the company representative we spoke to, energy consumption labels have promoted environmental awareness over considerations of cost in consumers. He backed this up with a comparison with Sweden, where he claimed there was as much consumer pressure to be found, although electricity prices were significantly lower than in Denmark, and the return on a purchase was therefore considerably lower in Sweden.

The product life of energy-saving refrigerators is estimated to be around 13 years, as with conventional models. Class A models are considerably more expensive, class B models somewhat more so. A sizeable portion of efficiency-related savings therefore goes to the innovator. Nonetheless, a class A model is able to pay off the additional purchasing costs within three to five years, according to Gram.

The motivation for Gram to develop and supply energy-saving and less environmentally harmful refrigeration units was described as follows (in an interview with Iversen):

- The key motive for the company is to remain one step ahead of the legislator, with mature products.
- This has been the case with environmentally motivated innovation since the start of the climate debate. It strengthens the company's image of always being ahead of the game with respect to development - and political environmental requirements. For example, CFC-free refrigerators from Gram were already in the shops before other manufacturers could make a name for themselves in this area.
- Gram favours external support and cooperation, e.g. with universities, the state and other manufacturing companies, when developing components or strategies. This cooperation in R&D networks has brought about two decisive examples of environmental innovation.

- Because Gram is in the market with its own product, its brand name and image (quality, stable production, energy-consciousness, etc.) must be protected. Thus the company considers strategic aspects itself, in order to take on the role of front-runner.

In fact, however, the following reasons will above all have stimulated this innovation:

- Extensive state support of the environmental innovation undertaken and the context of R&D networks parallel to declared goals of the state.
- The altered market conditions for refrigerators after 1994, even if the company itself assigns little importance to the changes in electricity pricing.
- The altered market conditions for refrigerators after 1999, when the current average will become the bare minimum.
- The company's tradition as an innovator in an environmentally and energy-conscious country.

Finally, the environmental innovations which were put onto the market were and are a chance for a relatively small company to survive in Europe.

Vestfrost, the second largest Danish manufacturer of refrigeration units, was founded in 1963 and had a turnover of 1,2 billion DKK in 1995. The company has about 1,000 employees. Its product range covers refrigerators and freezers, above all for the European market. Vestfrost's market share in Denmark is about 5%. Some four fifths of production is of so-called "private labels", i.e. unbranded appliances. These are bought by distributors, mail order companies or other producers of refrigeration units.

Vestfrost's competitive strategy is based on well-designed quality products. Energy-saving refrigeration units were developed as a niche product at the end of the 1980s and sold with great success in Germany. The first class B model in Vestfrost's product range was introduced on 1/10/1989, the first class A model on 31/8/1992. Since then there has been no new development, but sales of these models are stagnating. Vestfrost has no specific image for consumers and therefore no opportunity to carve out a name for itself. The key motivation was to have a product which would sell and satisfy legislation. Thus Vestfrost is influenced by Danish energy and environmental policy to a considerable lesser extent than Gram.

6 Conclusion and analysis

The case of innovation here, a significant increase in the energy-efficiency of refrigeration units above and beyond the high level already achieved, will now be summarised and interpreted in terms of the factors which influenced it. The compound of influences will once again be presented as a regulatory framework (see Section 2)

which includes - alongside the range of instruments - policy style and the political and institutional context of the actors and their actions (see below).

REGULATORY FRAMEWORK FOR ENVIRONMENTAL POLICY:

1. INSTRUMENTS:

* Dominant instruments in the instrument mix
* Extent to which they determined behaviour
* Single-purpose versus strategic approach

2. POLICY STYLE:

* Formulation of goals
* Flexibility in applying instruments
* Timing of measures
* Orientation towards consensus
* Legal requirements, red tape
* Calculability

3. POLITICAL & INSTITUTIONAL CONTEXT FOR ACTION:

* Competence and influence of regulator(s)
* Role of other policies (Policy integration!)
* Relationship between regulator and target group
* Role of non-state representatives of environmental interests

The OECD, in its study of regulatory reform, states that "...the term 'regulation' is used broadly...to include the full range of legal instruments by which governing institutions, at all levels of government, impose obligations or constraints on private sector behaviour. Constitutions, parliamentary laws, subordinate legislation, decrees, orders, norms, licenses, plans, codes and even some forms of administrative guidance can all be considered as regulation" (OECD 1997, S. 9). Our suggested definition above takes account additionally of the heavy emphasis laid on stable networks of actors in recent policy research.

Section 2 mentioned the regulatory framework of climate protection in Denmark. Innovation effects in this sphere of action can be attributed to a combination of the three levels of influence, while the instrument mix - including the dominance of certain instruments - can be considered especially important. The regulatory framework which explains this concrete case of innovation will now be examined in the context of the country’s general climate protection policy.

6.1 The range of instruments determining the innovation process

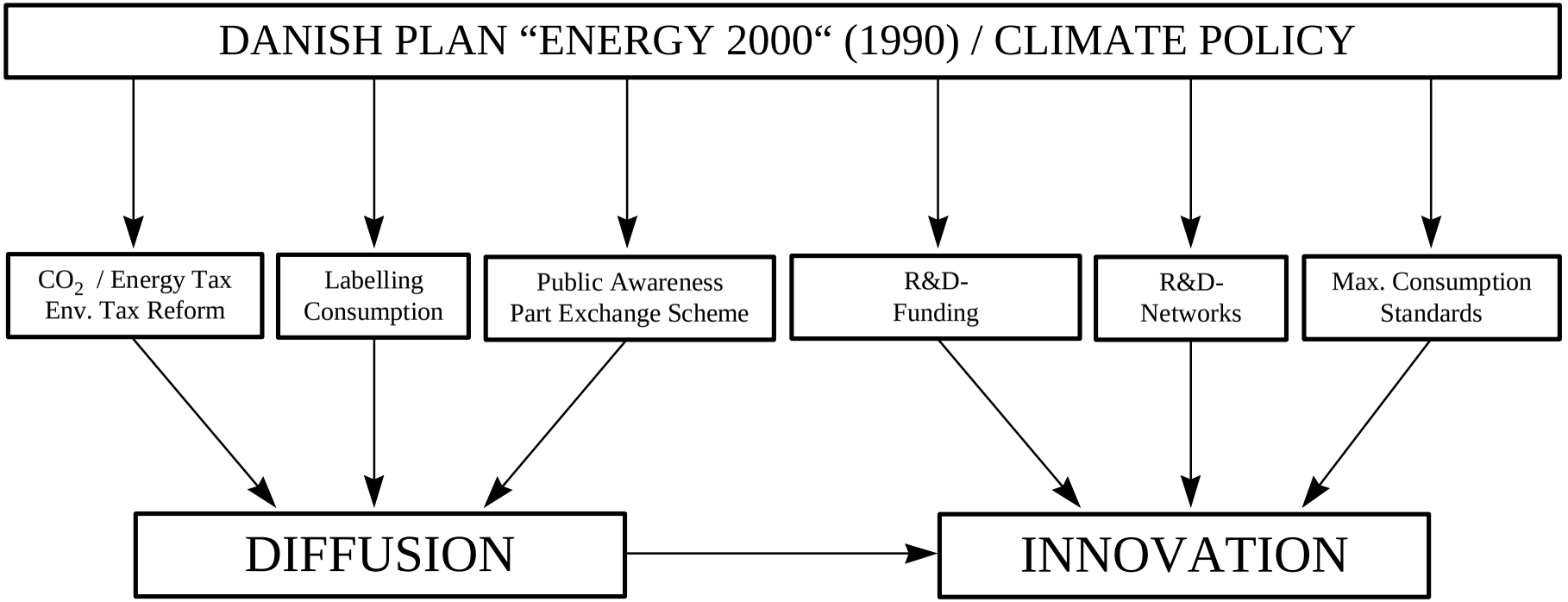
Researchers are increasingly recognising that the intended policy effects are not being achieved by a single optimal instrument, but by a mixture of different instruments (OECD 1997, EEA 1996, JÄNICKE/WEIDNER 1995). Mechanistic depictions of a state governing from the top down more or less by leverage have come in for increasing criticism. The effect of even a small environmental charge can be considerable, if reinforcing effects occur as a result of other measures. This is also the case here.

Without the framework of the proactive Danish climate protection policy, in the form it assumed in the "Energi 2000" plan of action, the entire innovation process cannot be explained. As described above, both the CO_2 / energy tax and the labelling of energy consumption (with the involvement of the EU), as well as the legal framework for introducing efficiency standards (subsequently with analogous EU regulations) grew from this plan. In this specific case, information campaigns by the Energy Agency, retailers and the electricity sector (a kind of integrated resource planning) can also be added. State information campaigns were given additional accentuation through a short-term part exchange scheme. Taxation, labelling energy consumption and information campaigns all contributed decisively to the diffusion of the most energy-efficient appliances.

Running in parallel, research support was targeted towards further increasing the energy-efficiency of refrigerators. It made use of subsidies and organising R&D networks. An additional stimulus for suppliers to increase efficiency further was the 1996 EU Directive 96/57 on efficiency requirements for household appliances, which was strongly supported by Denmark.

Diffusion came before innovation. However, the primary diffusion effect is deceptive if it calls to mind classical environmental policy, which tended rather towards diffusion of advanced technology (CONRAD 1996) than towards innovation or state "technology forcing" (e.g. through exhaust gas standards; KERN 1997). In the case here, the support for diffusion of the best models, in combination with direct support for research, was in itself a stimulus to innovation and, together with the aforementioned 1996 EU directive, increased the predictability of market conditions for further technological development (see Figure 3). The fact that a considerable portion of the efficiency-related savings for the customer went to the supplier via higher purchase prices must also have intensified the stimulating effect.

Figure 3: RANGE OF INSTRUMENTS IN THE INNOVATION PROCESS
(Case: Energy Efficient Refrigerators)



FFU 1997

6.2 Policy style

The fact that policy style or the mode of application of instruments can have a considerable effect on the policy outcome was first emphasised by Richardson (1982). The way in which goals are formulated and the flexibility, timing and prior consultation in respect of a measure have great importance, especially for innovation strategies. Policy style is significant, especially during the preparatory phase of political decisions, which is especially important to innovators: close networks between administration and industry, also information for the target group at an early stage, enable pioneer companies to anticipate the actions of the state. The knowledge about potential for innovation in the target group which is gained from close communication extends in turn the room for manoeuvre by regulators. In the present case, the policy style is characterised by a combination of determined, broad-based formulation of goals and flexible, consensus-oriented implementation. The two domestic companies were not merely offered concessions, opportunities were made available to them by a fundamentally innovation-oriented attitude to policy.

6.3 The political and institutional context

Empirical studies suggest that environmental innovation flows not only from targeted state action, but also from the dynamic interaction of public and private sector actors under complex conditions for action (BRESSERS/KLOK 1991, JÄNICKE/WEIDNER 1995, CONRAD 1996). The central aspects here are the institutional context, the constellation of actors and policy learning in communication networks and negotiating systems (JÄNICKE 1996). In 1983, Renate Mayntz pointed out that the success of a regulation - setting aside the problem itself - depends upon the “programme” formulated and the interaction between regulator and regulated (the “field of intervention”), and that the significance of the instruments used shrinks as the actors reach consensus on their goals (MAYNTZ 1983).

In the case under examination, the political and institutional context involves a highly professional administration with pronounced strategic capabilities, while the institutional simplification of integrating environmental and energy policy and the widely accepted energy plan both have a favourable effect. Network management and “negotiating in the shadow of the hierarchy” (Scharpf) has a tradition in the neo-corporatist politics of Denmark - and of Scandinavia as a whole. In this case, a close network of actors - from the Energy Agency and the research administration, research institutes, the electricity sector and pioneer companies in retail (particularly the distributor Snehvide) and the refrigeration unit industry - made itself felt.

The regulatory framework in this case was targeted overall at both supply and demand, thus combining push and pull with respect to innovation. This well-targeted, innovation-oriented shaping of market conditions fits, in the final analysis, Porter's framework of creating "first mover advantages" (PORTER 1991, PORTER/VAN DER LINDE 1995, WALLACE 1995). However, it is interesting to note that specific support of the market for the best energy-saving models also led foreign suppliers to bring corresponding products onto the Danish market, making it a kind of pilot market for European companies, which instead rather limited the opportunities for Danish manufacturers: Siemens and Bosch introduced a class A model in September 1994, at exactly the right moment to take advantage of the part exchange scheme. In this respect, Danish activities here have also more or less set the pace for other EU countries. Even the first (national) energy consumption labels in 1989 had a noticeable effect on Bosch, Electrolux, Frigor and Husqvarna, all of whom - following in the wake of Gram - introduced a class B model onto the Danish market at this time (see Table 4). The fact that the second manufacturer, Vestfrost, who is not primarily oriented towards the Danish market, showed itself to be less innovative also supports this interpretation.

The ecological effect of energy savings of up to a factor of ten over a decade can still be seen as considerable, even if the total cost in materials of replacing an entire generation of appliances is taken into account.

Remarkably, restrictions are not to be found in this case. Even the electricity sector, whose turnover is significantly affected, was an active participant in public information and other campaigns. To the same extent, retailers and energy policy, both equally good candidates for restrictive factors, also played a proactive role.

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