tip WORKSHOP PROCEEDINGS

REGULATION AND INNOVATIVE ACTIVITIES: ELECTRICITY SUPPLY INDUSTRY

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EINE KOOPERATION DES ÖSTERREICHISCHEN INSTITUTS FÜR WIRTSCHAFTSFORSCHUNG UND DES FORSCHUNGSZENTRUMS SEIBERSDORF

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Preface and acknowledgements

Regulation is one of the key factors shaping both supply of and demand for new technologies and systems. Consequently, the regulatory framework for utilities such as electricity suppliers and public telecom operators can - although primarily focused on the introduction of competition - play an important role for technology and innovation policy. In both industries regulatory reform primarily concentrates on the establishment of a competitive environment for traditional incumbents and new entrants, whereas unintended regulatory (side-)effects on innovation and diffusion of technologies do not achieve the same level of attention.

In 1997 the tip team organized two workshops on „Regulation & Innovative Activities“ in order to improve the understanding of the regulation/innovation interface. The main objective of the workshops was to provide a forum for the exchange of information between academics and policy-makers with specialized practical or theoretical expertise in the fields of technology policy and regulation. Invited papers, the discussion of international experiences and panel discussions with participants from industry allowed for a deeper understanding of the innovation process and regulatory issues which in turn could enable the effective and efficient conception of Austrian policies.

More than 60 participants from administration, industry and science attended the first tip Workshop on Regulation and Innovative Activities held in Vienna on the 25. of February 1997. Speakers from the University of Graz, the International Energy Agency, Oxford Economic Research Associates, the UK Department of Trade and Industry, the Science Policy Research Unit in Brighton and the Technical University of Denmark raised a number of issues concerning the interrelationship between regulation and technology policy in the electricity supply industry.

This book brings together written contributions prepared by speakers before and immediately after the workshop. The book starts with a chapter titled Innovation and Regulation in the Electricity Supply Industry which is intended as an introduction to the topic and as a synthesis of the workshop contributions. The tip team is not only grateful to the authors for having delivered their chapters promptly but to all who participated in the workshop.

I would therefore like to express my particular appreciation to the participants of the panel discussion, Siegmar Gerhartz (Head of Board, Jenbacher Energiesysteme), Manfred Heindler (Director General, Energy Conservation Agency, EVA), Reinhart Kögerler (Director General of Technology and Innovation, BMWA), Stefan Schleicher (Prof. of Economics, University of Graz), Johannes Schmidl (Federal Renewable Association), Maximilian Witzani, (Project Manager, OMV Cogeneration) and Bruno Zluwa (Director General of Energy, BMWA).

Last not least the whole tip programme would not be feasible without the initiative of and financial support from the Austrian Federal Ministry of Economic Affairs and the Austrian Federal Ministry of Science and Transport. The management of the workshop itself - from the correspondence to the electronic files to the budgeting - as well as the editorial work of the proceedings owe a big debt not only to the speakers, but also to the people who helped me in the management of the numerous tasks, especially Andrea Luger, Vera Plass and Kristin Smeral.

Norbert G. Knoll

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Innovation and Regulation in the Electricity Supply Industry[1]

Norbert G. Knoll, Austrian Institute of Economic Research

During the last decade many countries have started to liberalize the electricity market. The introduction of competition in formerly monopolistic markets poses new challenges to the regulators. Beside the introduction of competitive forces, regulatory intervention may sometimes be undertaken to pursue environmental goals; it might also have an impact on the development of technology, as the examples of the United Kingdom and Denmark suggest. Effectiveness and efficiency of new regulatory measures can be improved in a dynamic learning process.

Changes in the market structure and regulatory framework play a decisive role in determining the intensity of competition in markets. Indirectly, these changes are also important for the technological choice of production processes and shape innovative activities, for example in connection with the development of technological knowledge and the diffusion and adoption of new technologies and systems. Consequently, in sectors such as telecommunications and electricity, where far-reaching changes in the competitive environment take place, technology policy makers have to improve their understanding of the interrelationship between competition, regulation, and technological change; adjustments in the use of policy tools to the changed market conditions are required.

International developments

An increasing number of countries seek to liberalize market entry in the electricity supply industry (ESI). Increasing competition will have important implications for technology and innovation policy[2]. Countries such as Chile, Norway, and the United Kingdom were the first to implement structural reforms (commercialisation, corporatisation, introducing price controls, privatization, etc.). Since the beginning of the nineties, the European Commission has also paid more attention to the introduction of competition into the energy markets. In

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[1] It is the main purpose of this article to summarize the contributions in this volume. An earlier, German version of this article has been published in WIFO Monatsberichte 7/1997. The author wishes to thank Kurt Kratena and Maria Haberfellner for valuable suggestions and comments as well as Wolfgang Pollan for his valuable translation work.

[2] See *Lekander* (1997).

December 1996, a directive was passed which aims to create a competitive environment for the internal market in electricity (directive 96/92/EC). The implementation of this directive implies, *inter alia*, a step-wise liberalization of electricity generation, while a monopolistic market structure in transmission and distribution will still require regulatory intervention[3].

The experience in several countries allows us to trace the effects of introducing competition into the ESI.[4] Accounting separation between those activities which are effectively natural monopolies (operation of transmission and distribution networks) from the supply and generation businesses is considered a minimal precondition of the liberalisation of market entry. In order to keep the administrative costs of regulation low and to raise the efficiency of regulation, an organizational separation into independent enterprises for the generation, on the one hand, and for the transmission and distribution of electricity, on the other, may be called for. The introduction of competition into the electricity sector changes the price formation process, particularly in the generation segment, and one of the results may be higher price volatility. As *Lekander* points out, liberalisation and privatization may entail improvements for customers (quality and prices) as well as benefits for tax payers and owners (through higher productivity and profitability). A Swedish electricity utility, e.g., managed to boost sales by 15 percent (despite of a reduction in employment by 30 percent) and profits (before taxes) by some 300 percent within a period of only six years.

As far as technological change is concerned, the new competitive environment has important effects on the choice of technology and on research and development. Competition in generation, for example, has stimulated the use of combined cycle gas turbine systems (CCGT)[5]. Advances in CCGT technology brought about a reduction in system costs by 40 percent and - in the best plants - an increase in energy efficiency from 45 percent to almost 60 percent within just five years. Despite overcapacity in the generating segment and stagnation in electricity demand, CCGT systems now dominate the market for replacement investment and new plants because of their superiority over conventional systems (reduced planning and construction lead times and planning horizons, lower minimum efficient scale and modularity, better cost characteristics, lower emissions, availability of cheap natural gas, etc.). These advances, however, also reduce the prospects for renewable technologies to play a role in the investment decisions of the electricity industry.

Increased competition in the electricity sector will create new incentives for the various actors to reduce overall costs as well as R&D activities and to shed social obligations.

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[3] See, for example, the analysis in *Haberfellner* (1997).

[4] A detailed presentation of the effects of the new competitive regime in the British electricity sector on the various actors (producers, suppliers, consumer, share holders, employees, etc.) is given in *MacKerron - Watson* (1996).

[5] See Buxton (1992) and Watson - Mitchell (1996).

Lekander points out that in most OECD countries publicly financed research and development activities are on the decline and that the effects of competition on R&D spending need to be researched more carefully. Some examples suggest a trend toward a sharp reduction in R&D as part of cost cutting exercises in anticipation of competition. Furthermore, the development of technological solutions to long-term problems such as environmentally friendly power generation seem also in danger of being neglected.

Public support for R&D activities and the regulatory framework for the new competitive environment of the generation of electricity are important issues in technology policy. Regulation may stimulate the development of a market for new renewable energy. Here, traditional regulatory instruments may be used or the regulatory framework may be adjusted to the exigencies of strong price differentiation between conventionally produced power and green electricity from renewable sources. The Swedish Environment Protection Agency, for example, has developed a licensing procedure for environmentally friendly power. As a result, about 3 percent of the electricity is sold as green at a 15 percent price premium. In this model, customers have the choice of making a contribution to environment protection, while the profit margins for green electricity is about twice as high as for normal power and thus affects the utilities' choices of technology (*Lekander*, 1997).

Liberalization, regulation and innovation: Lessons from the UK experience

The example set by the UK clearly demonstrates the effects of liberalization of market entry and of privatization on the electricity sector; it also shows that new regulatory tools can be utilised in order to achieve energy, environment and technology policy goals. The lessons learned since the first liberalisation steps in the United Kingdom in 1990 point to various requirements for intervention, if regulation is to support market access of new entrants under fair conditions, and to achieve goals in connection with securing public service. In a monopoly regime with publicly owned electricity suppliers, companies often conducted their activities in ways which implicitly met certain social and environmental policy objectives. In the future targeted policies and regulatory intervention to foster the environmental aspect, will be required and can be implemented alongside the introduction of competition into the markets.

At the time of the privatization of the electricity supply industry in England and Wales in 1989/90, this sector was reorganized and a new regulatory regime established[6]. In contrast to the privatization of British Gas (BG) in 1986, restructuring involved a far-

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[6] A detailed analysis is given in *Surrey* (1996), *Green - Newberry* (1997) and *Helm* (1996); *DTI* (1996) presents an account of the British energy markets. This presentation is based on *Hartley* (1997).

reaching vertical disintegration and the establishment of independent entities in the various production stages. In 1989/90, National Power and Power Gen, with market shares of 48 percent and 30 percent, dominated the generating segment (i.e., the segment that had been opened to competition), but did not own parts of the 12 regional operators of the distribution nets (the Regional Electricity Companies - RECs). The operation of the national transmission net was turned over to a monopoly, the National Grid Company (NGC). As had been the case for the infrastructure areas telecommunications and gas, that were privatized in the middle of the eighties, an independent regulator, the Office of Electricity Regulation (OFFER), was established for the electricity industry.

In those areas in which there are natural monopolies (transmission and supply) or in which competition has just been introduced, regulatory intervention concerns the structure and level of prices (price controls), the quality of services (e.g., standards of performance), and the provision of community services (obligations imposed under the licensing agreements). In general, the design of the regulatory framework is flexible enough to meet defined social, environmental and technology policy objectives, even though market structures are constantly changing and competition intensifies. In 1994, OFFER established the "Energy Efficiency Standards of Performance" (EESOPs) which set electricity saving targets for each Public Electricity Supplier (PES). The scheme provides for organizational and technical measures to reduce demand for electricity; it is financed by a surcharge, sanctioned in the Supply Price control Review, on customer bills of £1per customer per year. Over the period of five years, this yields a budget of £ 102. It is estimated that the scheme will lead to savings of 6103 GWh. The costs amount to only 66 percent of the costs as originally forecast. According to the Energy Saving Trust, the scheme is very successful, recording a benefit cost ratio of 5:1 (*Hartley*, 1997).

The EESOP are an example of the proposition that regulatory instruments, if used appropriately, can serve to induce even sales-oriented energy suppliers to take account of environmental goals in their decisions. These measures can also be evaluated under the perspective of technology policy: the EESOP projects do not imply the development or introduction of "high technology"; nevertheless, organisational and technological learning with respect to the use of renewable technologies are stimulated. Moreover, this scheme helps to achieve the long-term goals of the electricity regulator (OFFER) to develop a market for new energy efficiency services. At the moment, it is an open question how the EESOP scheme can be developed to fit in with the emerging competitive environment. To continue the present system would put the PESs at a disadvantage relative to their competitors. In principle, the EESOP obligation could be imposed on all suppliers (and not just the PESs) and a levy on the distribution segment could be used to finance the scheme.

The NFFO: Regulation and technology policy

At the time of the privatization of the ESI the prospects for the diffusion of renewables were extremely bad. The gradual intensification of competition in the gas sector at the end of the eighties as well as the technological development made electricity generated in gas-powered facilities relatively cheap. In 1990, gas played a marginal role in the generation of electricity, but in 1993 8.8 percent of electricity was generated on the basis of CCGT systems; in 1995, the share was as high as 16 percent (DTI, 1996). The preparations for the privatization of the industry revealed the extent to which nuclear power stations were unprofitable. The Non-Fossil Fuel Obligation created an instrument for subsidizing nuclear power and renewable energy sources, an instrument that at the same time supports environmental concerns by helping to reduce CO_2 emissions. The NFFO was also intended to foster the development of a market for technologies using renewable energy and to complement the technology policy of supporting research, development, and demonstration.[7]

The NFFO requires the Regional Electricity Companies (RECs) to buy a certain amount of nuclear and renewable electricity. The generators receive a premium price from the RECs for this type of electricity; the difference between the premium price and the regular price is reimbursed to the RECs by the Non-Fossil Purchasing Agency (NFPA) from the Fossil Fuel Levy (FFL) on electricity, which is paid by customers via electricity bills. The FFL raises about £ 1,105 billion per year (1995/96), about 10 percent of total electricity sales. The major part of the funds flows to nuclear energy; the share received by renewable projects is 8.6 percent (£ 95 million). The support for nuclear energy is not compatible with fair competetition in a single European electricity market; the EU exemption, therefore, runs out at the end of 1998. For renewable energy, however, the European Commission agreed to an extension of NFFO and FFL beyond 1998.

The combination of NFFO and FFL achieves a cross subsidization from fossil to non-fossil electricity, a measure that can be viewed as a correction of false market signals. The main arguments in favor of this type of intervention are the diversification of the energy supply (generation mix), the development of a market for technologies in a pre-commercial phase (especially for technologies for renewable resources), as well as the existence of externalities (taxation of emissions from fossil energy). The success of the NFFO, as laid down in the Electricity Act of 1989, depends crucially on its flexibility, which has allowed institutional learning to take place with this regulatory tool and which has facilitated the adjustment of this tool in response to changes in technologies and market conditions.[8] In contrast to similiar measures in many other countries, the NFFO provides for a competitive

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[7] See the detailed analysis by *Mitchell* (1995, 1997).

[8] *Mitchell* (1997) presents a critical analysis of several side-effects of this instrument and points to the changes and improvements undertaken after every round of bidding.

selection of projects that are eligible for the premium price; within each technology band (e.g., wind, small-scale hydro, landfill, sewage gas, biomass), only those projects which require the least amount of subsidies receive support.

The main motivation for renewable energy projects is to support environmental as well as technological goals (e.g., to raise the generating capacity to a certain level, to foster the transfer of technology and the commercial exploitation of results from R&D).[9] While the establishment of capacity targets in a sequence of orders serves to evaluate and limit the volume of projects supported, the modalities of the scheme have the effect of minimizing the volume of subsidies. In the first four orders during the period from 1990 to 1997, a remarkable increase in cost efficiency was achieved, a result mainly due to technological and organizational learning. In a direct comparison of NFFO3 (end of 1994) with NFFO4 (beginning of 1997), generating costs, as measured by the average bid price, fell from 0,0435 £ to 0,0346 £ per KWh.

The experience gained in implementing the NFFO procedure also shows the complexity of the use of regulatory tools in achieving environmental and technology goals[10] (Mitchell, 1997). When the NFFO1 was to be implemented, the know-how for cost appraisals of renewable energy projects was not available. In the NFFO2 (1991), the contract length was too short (with a cut-off initially set at 1998); this proved to be a serious handicap for the development of commercially viable projects. It was not before the NFFO3 order that a contract length of 15 years was established. As experience was gained with the development of projects and system costs fell rapidly in the course of the third and fourth order, the capacity targets were recognized as a problematic design element. In NFFO3, 141 projects representing a capacity of 627 MW were awarded a contract, while 380 projects totaling 1870 MW capacity were refused. In NFFO4, applications totaled more than 8,4 GW capacity, but only 10 percent were awarded contracts. In sum, thanks to its flexibility, the NFFO proved to be a pretty successful regulatory tool stimulating the diffusion of renewables. The NFFO schemes were successful in lowering the volume of subsidies over the years; thus, the burden on the customers were relatively low. At the present time, the subsidies amount to about 1 percent of total electricity sales; an increase to between 1.5 percent and 2 percent is expected for the next few years.

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[9] Current government policy is to increase new renewable capacity towards 1500 MW by the year 2000 through the five NFFO Orders.

[10] See Mitchell (1997).

Innovation, regulation, and Danish policies with respect to alternative energy sources

Over the last 20 years, Danish energy policy has implemented many measures which have an impact on technology.[11] With regard to policy goals, three phases can be distinguished between 1975 and 1997. In the wake of the first oil price shock of 1973/74, security of supply was given the highest priority; the share of oil in the generation of electricity was reduced, that of coal increased to 90 percent. In the second phase, from the beginning of the eighties to 1987, the improvement in the trade balance became the overriding goal; in the course of the nineties, environmental concerns took priority. Sustainability and the reduction of CO_2 emission were established as the main targets of Danish energy policy in the third Danish energy plan ("Energy 2000") as well as in the fourth energy plan ("Energy 21"). In addition to raising energy efficiency, these plans sought to increase the contribution of renewable energy over the medium and long term: the target for renewables as percentages of the total energy supply for the year 2005 is 12 to 14 percent, for the year 2030 even 35 percent.

As *Meyer* points out, a wide range of measures have been implemented to improve the position of technologies based on renewable energy. These measures include taxes and subsidies, regulatory measures, research, development and demonstration programs, as well as public test and certification stations. Energy taxes such as the CO_2 tax on fossil fuels change the structure of prices and thus improve the competitive position of renewable energy sources in the market. There is a special rate for electricity from wind and biomass; this rate, about $ 0,088 per KWh, is calculated as the sum of the production cost of electricity of coal-fired plants, refunding of the CO_2 tax, plus an environmental credit. Investment subsidies are applied to new technologies until they have reached a certain maturity (at the present time, solar collectors and biogas installations receive subsidies of between 15 percent and 30 percent). The regulatory framework also provide for agreements and obligations on the part of electricity suppliers; the utilities are obliged to use 1.2 million tons of straw and 0.2 million tons of wood in central electricity plants; two programs provide for the installment of 100 MW capacity of wind power. Government support for development and demonstration projects totaled some $ 23 million each year. The first test station for wind turbines was opened as early as 1978. Funding also includes test and certification stations for solar heating systems, biomass and heat pumps.

The instruments deployed in Denmark to establish systems of renewable energy sources comprise a whole array of measures, ranging over the whole life cycle of a technology, from the first research activities, tests and standardization of the products to the establishment of a home market. How energy, environment, and technology measures are interlinked can be clearly demonstrated by the example of the Danish wind turbine

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[11] See Meyer (1997).

industry.[12] The government energy program has greatly contributed to the development of technology and the use of wind energy in Denmark. Both, supply-side measures, particularly in support of research and development, and demand-side measures, such as subsidies and regulations, acted as an infant industry incubator. Within a closed-off segment of the energy market, the various agents compete under quasi-market conditions; this strategy of a market-based industrial policy does without "picking the winner" among previously specified technologies or companies (*Jørgensen,* 1997).

An in-depth analysis of the Danish development of the wind industry reveals, however, that this type of technology policy was not based on an ex-ante design; nonetheless, the measures implemented created an environment supportive of the producers. Regulation has always contained a technological aspect; this is true for the development of standardized products (such as by certification) as well as for the creation of a test market for technologies and systems in a pre-commercial phase of product development (investment subsidies and premium prices for renewable energy electricity). Regulation with the goal of establishing a Danish home base has fostered the diffusion of technologies by giving traditional as well as new electricity generators incentives to employ new technologies. The home market also serves as a reference for the export business.

Conclusions and lessons

With the implementation of the Single Market directive 96/92/EC the liberalization of market entry in the electricity sector will begin also in Austria. In the UK, which started liberalization and privatization at the beginning of the nineties, a competitive market was established in generation and supply of electricity. Liberalization required the establishment of an independent electricity regulator, and also changed regulation in a direction that has affected the policy areas of energy, the environment, technology, as well as social and consumer affairs. It became clear that in the transition from a monopolistic market structure to competition the market mechanism has to be corrected in such a way that it serves to increase energy efficiency and to foster the diffusion of technologies and systems based on renewable energy.

In connection with renewable sources of energy, public intervention has a strong technological aspect, if the task of regulation, in addition to supporting research and development, is to foster the diffusion of new technologies. This is the case both in the UK and in Denmark. The experience gained with the Non-Fossil Fuel Obligation (NFFO) on the liberalized British electricity market shows that the dynamic development of market

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[12] See especially *Jørgensen* (1997) but also the analysis of the development of the Danish wind turbine industry by *Karnoe - Garud* (1997) and *Meyer* (1995).

structures and of technologies call for steady improvements in the design of regulatory tools over the course of many years. There are specific and general design requirements. The design of instruments should meet the following general rules:

- avoid imposing unequal burdens on enterprises that will be in competition with each other in the future,
- keep costs for all customers under control and do not discriminate between various groups of customers (such as industrial customers and private households),
- secure and expand the supply of electricity from energy sources with low CO_2 emissions,
- support the further development of technologies using renewable energy sources and establish a home market for technologies and systems that are in a pre-commercial development phase.

Examples of specific requirements are the adjustments that were made in the course of the orders of the NFFO since 1990. The negotiating power of the established electricity producers and the developers of renewable projects needs to be neutralized. Regulatory instruments can be deployed in an economic way if contracts are allocated on the basis of competitive bidding. The experience gained in administering projects and the regular evaluation of the effects of regulation should provide a basis for continuous learning and an improvement of the regulatory tools. In the long run, financial support should be no longer needed.

The design of regulatory tools has to account for specific needs of technologies and projects. The design should guarantee investment security for projects but at the same time avoid the development of "investment ruins" and of deadweight losses. Subsidies that depend on the volume of electricity injected into the supply system are preferable to pure investment subsidies. The guarantee of a fixed price for a certain volume for a period which allows the amortization of the project (e.g., 15 years for the NFFO) would provide investment security for the project developers. Electricity in excess to the guaranteed quantity which can be sold at a premium price should be sold at the current market price. The investment incentives for renewable energy projects should not be restricted to new independent power producers, but should also give the established suppliers, which account for the major part of electricity generation, the opportunity of technological and institutional learning with these new technologies. In setting the price of electricity from renewable energy a distinction should be made between existing and new projects and between the various technologies and the various stages of the technology's maturity.

Of particular importance are instruments that provide incentives to exploit the technological and organizational learning potential and to continually improve the projects' technologies. In this connection, bidding schemes may play an important role and reduce the extent of financial support, as is demonstrated by the NFFO scheme. There remains the question of how to finance these public support schemes. Here again, the NFFO shows that the introduction of competition into the markets is not the primary impediment. Imposition of a levy amounting to 1 to 2 percent of electricity sales in the UK on all electricity suppliers and customers in equal measure does not result in grave market distortions - the costs imposed by subsidizing nuclear power were almost ten times as high. Against this background, a volume of ATS 80 million per year to support renewable energy projects as proposed by the Austrian electricity utilities seems rather low. The industry's net sales are worth about ATS 53 billion[13]; a levy of 1 percent of sales would amount to about ATS 530 million.

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[13] The difference between the sales of electricity (ATS 89,692 billion) and the purchase from outside sources (ATS 36,426) total ATS 53,266 billion for 1994 (*ÖSTAT* 1996).

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Patterns of technological change in a competitive electricity industry: Implications for public policy

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Introduction and summary

The main argument in this paper is that liberalisation forces technology policy makers to rethink their focus and tools for technology policy and that these new tools become intimately integrated with the general regulatory framework. Therefore technology policy in a competitive market demands an understanding of and an influence on the general market reform. The paper is divided into five parts with the following main arguments..

- The number of competitive electricity markets is growing and I think competition will be the usual way to structure electricity markets in future.
- The Early evidence of the impact of competition on the performance of the industry is generally very positive.
- However, the changed behaviour of the industry means that it does not necessarily fulfill public policy expectations, including in the technology field.
- This means that technology policies' responsibilities change. At the same time public policy receives a new tool with high potential; the „rules"of the competitive market.
- Finally, provided it is the right type of competition that is promoted it will change the electricity supply industry into a more diversified and innovative industry.

Competition is spreading across the electricity industry

Three countries have played a special role in electricity restructuring; Chile, UK and Norway.

Already back in 1982 Chile initiated a gradual change starting with an unbundling of the industry and a price reform, followed by introduction of a substantial degree of competition in generation, freedom for the largest customers to choose their supplier and finally, in the mid 80's an almost complete privatization of the industry. The Chilean industry has thus by now operated under competitive conditions for about 10 years.

United Kingdom restructured their industry and then privatized it in 1990. The market has gradually been opened up starting with the large users, then the medium sized and from next year, at least that is the plan, the whole UK market will be competitive.

The from a regulatory standpoint most drastic step was taken by Norway which in a penstroke reform opened up the entire market to competition in 1991. However, that reform was not linked to an ownership reform but the industry still remains mainly in public ownership.

Just over the last couple of years a lot has happened worldwide. Finland, Sweden, Norway and the UK have competitive markets. In Spain, Netherlands and to some extent Ireland there are plans for radical reforms. In Germany the debate is intense and, despite mainly French resistance, an EU-directive for a gradual opening of the market was adopted late last year. The full consequences of this compromise are however yet unclear.

Competition has improved industry performance

Introduction of competition in electricity, which really is a natural monopoly, leads to a separation of the traditionally vertically integrated industry into three parts. Generation becomes competitive. The wires business remains a monopoly but typically receives a much more focused incentive based regulation. The third part is Power services, the competitive sales of electricity in the wholesale and retail markets.

The second change regards the change in price setting regime in generation. The old industry typically had a cost recovery system. The rates where set to guarantee a reasonable return on capital employed in the industry. The new industry will have a pricing system as in any other capital intensive commodity industry. That is, it is the short run marginal cost in the system that is the main determinant for price. This leads to an extremely volatile price behaviour. The characteristics of the volatility will differ a lot between capacity constrained thermal systems, where volatility over the day will dominate and energy constrained hydro based systems, where the volatility will be over and between seasons. However, in both cases it is a more extreme volatility than in any other industry I am aware of. Most of the time prices are down almost at fuel cost but when peaking capacity is needed prices boost. It is at these few hours of the day that the industry players earn their capital cost and profits.

The third change concerns customers. Some or all customers get the opportunity to change supplier and thus to bargain. In England as an example more than 2/3 of the large users changed or re-negotiated their contracts over the first two years after the reform.

A main objective for reform has been to reduce prices to customers. And the experience so far is that this has succeeded, especially in the large customer segments. Small users have received less dramatic price discounts but also these customers have as a group experienced declining or at least stable prices.

At the same time there has been an improvement in service quality. Indices of service quality show generally significant improvements.

The probably largest winners on the reform so far have however been owners and tax payers. Rationalisation has radically improved profits despite the falling prices. As an example, a Swedish utility over a 6 year period increased its sales volume by 15 percent, reduced its staff by 30 percent and increased its pre tax profit by 300 percent. In the UK there has been some even more radical changes. This has meant that investors have received very good returns. Since the public sector usually keeps part ownership in the industry it has benefitted from this. Further, since profits have gone up dramatically the tax payments have increased.

And what is the implications for technology?

The most spectacular technological development in electricity over a long period of time is without doubt the CCGT. A technology which development and deployment is almost entirely linked to competition. It has been adopted either in competitive pockets in franchise markets mainly in the US and Germany for industrial autogeneration and co-generation, and in competitive markets such as the UK and South America. Over a five year period the price of the technology has dropped 40% and the thermal efficiency of the best units have risen from about 45 percent to close to 60 percent, an almost unbelievable figure just a couple of years ago for any combustion system.

There are also signs of a new direction of technological change. Electricity innovation used to be „always larger and more expensive“ but now some of the most important innovations are small scale and have more to do with the service that electricity produces and of the efficient use of existing resources. Some exmaples from the Sedish market.

- Cheap remote metering devices are developed and installed to avoid the costs of manual meter reading.
- With an on-line meter you can increase the price discounts to customers if they are prepared to avoid using a lot of electricity at peak. These meters cost about 1000 dollars a piece just a year ago, thus only available for commercial users, but the first system for households is now under installation at a cost 1/10 of that.
- System optimisation in the Scandinavian model of competition is done through spot trading. An option broker has developed an electronic trading system which allows for automatic instantaneous trading thus improving the system optimisation. The first export order for this significant product was announced last week to California's new competitive market.
- Systems for telephone communication on the electricity lines are near completion and will provide an almost free good when available.

The term innovation also covers things that are not technically new and the slide shown some new concepts which have not been in use in the electricity industry before.

Firms focus on creating shareholder value

Competition implies new roles for firms. Utilities have often had societal responsibilities to do with redistribution of income through cross-subsidised tariffs, to keep people in remote poor areas at work and often specific public R&D responsibilities. All these aspects loose in importance under the new market conditions. Here we just focus on the R&D-aspect of it.

No reliable data exists on the effects on R&D-spendings from competition. The IEA is presently conducting a study on it and within short we should have better information.

However, it is clear that there are examples of drastic utility reductions in R&D as part of the initial cost cutting exercise in anticipation of competition. Some of it has simply been an outsourcing to other companies and some has been genuine reductions. The new innovations I showed before indicate also that there are new R&D-efforts mainly in the equipment manufacturing industry that should be credited to competition..

There are two types of R&D that have suffered from this development, both of significant importance to policy.

(1) Funding of energy R&D of more general scientific interest, which to a certain degree has been a responsibility for state owned utilities.

(2) Due to the relationship between energy and the environment the public sector has an interest to influence the direction of change. Without market forces or incentive programs supporting this R&D it is clearly at stake.

Technology policy's responsibilities and tools must be adjusted accordingly

Policy's responsibilities thus change and increase. The obvious response is of course to ask for more money. However, the trend in most OECD-countries is in the opposite direction and it is probably unlikely that this trend will change in the short run.

The first part of a rethinking of public policy must therefore include a concentration of financial resources and incentive programs to the areas which clearly are out of the scope of the market.

The second part which is my focus has to do with the fact that competition in electricity is very different from in a „normal"market. The way the „game" is set up has a direct effect on how the market operates and what technologies are favoured. I would almost be so bold as to say that every more important aspect of the market framework, such as should there be a mandatory pool, should there be a capacity payment, what customers are eligible, how is cross border export/import regulated, etc, everything is of importance to technology policy.

Considering the short time available I will just give one example of this. My ambition with this example is to show that the competitive wholesale model chosen will influence whether we are likely to get a market which is a „commodity game", that is a market which focus soly on supply at lowest possible cost, or a „differentiation game", where electricity is not solely a matter of price, but also can have a quality aspect valued by customers.

The Swedish environment protection agency has developed a licensing procedure for environmentally friendly („Green") power. It is a new effort but already about 3% of the electricity is sold as Green at a 15 percent price premium. If the cost of producing electricity is the same for the normal and the green alternative, it is great business. The profit margin is more than double the normal. To put it differently, the utility should be prepared to accept up to 30 percent higher generation costs for the power and still enjoy above average profit margin. Of course this has an effect on the utilities' choices of technologies.

However, there exist no „green"electrons. Electricity flows according to Kirchhoff's laws and electricity can only be marketed as green if customers see a tight relationship between their choice and the generation output of the utility. This link will be influenced by regulation.

In Europe there are basically three competitive models that are discussed. In the Single buyer model Generators sell their electricity to a Single buyer at a tariff price and the Single Buyer then sells it to suppliers which in turn sell it to the market in competition. There is thus no direct contractual link between the generators and the end users.

In the mandatory pool model all power is sold through the pool in a competitive bidding process which also determines the dispatch order. Typically suppliers, customers and generators sign financial contracts to hedge themselves against the volatility of the pool price. There is thus a link between generation and use but a relatively week one.

In the bilateral model, which is the one that is used in Sweden, Generators strike direct contracts for supply with suppliers and end users. Generators dispatch as much as they have customers for. The link between generation and use thus becomes more obvious and therefore the possabilities to differentiate between different sources of electricity increases.

The bilateral model therefore seems to, at least from this very minimalistic one dimensional analysis, to be more likely to support a differentiated pricing of electricity than the pool model, which in turn is better than the single buyer model.

Again, this was not a unique example. Almost every decision on the regulatory framework has impact on technology policy. Therefore it is an obligation for all of us who work on technology policy to understand and to take active part in the development of the general competitive framework. So far, at least that is my experience, electricity reform have been focused around other issues and technology has only entered via the development of incentive programs. This is important, but not sufficient.

Provided this happens, technological change will become more appropriate than before

Finally, will competition foster innovation also in the long run? No one knows where the electricity industry and the technologies it uses will develop. However, it is likley that competition together together with other forces at work, mainly the development of small scale efficient technologies and our increasing concerns for the environment, will foster an industry which is very different from the one we are used to.

The old one, with its huge vertically integrated state monopolies, is gradually changing into an industry which is more like others, that is it will be much more diverse, with different types of players and different types of technologies. And most important, it will deliver a service which is of higher quality and more in line with what we as consumers want to have.

Technology Policy and the Regulation of the UK Electricity Industry

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Introduction

This paper looks at the way in which the UK government and UK regulators have developed technological policies to meet the new challenges posed an electricity supply industry (ESI) which is now wholly in the private sector and which is becoming more competitive. In particular it looks at:

- the way in which privatised companies have been encouraged to concern themselves with energy efficiency, and the way in which these obligations have been financed; and
- the UK government's broad approach to technology policy as it applies to the energy industries.

The paper does not deal with the Non-fossil Fuel Obligation, since that is dealt with in other papers presented to the workshop (though the NFFO is, of course, one of the main means by which UK government intervention seeks to influence the direction and pace of technological change).

This paper does not seek to set out all the new structures in the UK ESI. These are explained very clearly in a number of sources.[16] Readers are reminded that, as a result of the privatizations of the early 1990s, all parts of the UK industry (except the old nuclear stations and the company responsible for dealing with nuclear waste) are now privately owned. The process of privatization has been combined with a process of liberalisation, so

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[16] For example, *Guide to the Economic Regulation of the Electricity Industry*, Martin Brough and Seumas Lobban, The OXERA Press, Oxford, September 1995.

that, wherever possible, competition has been introduced in order to substitute market-based decision-making for centralised government decision-making.

The table below shows the current state of play: the reorganization of the industry has served to define two areas of natural monopoly—transmission, via the National Grid Company (NGC) and distribution, via the Regional Electricity Companies (RECs). Elsewhere there either is free entry to the market—as with generation and supply to the over 100 kW market—or will be free entry before then end of the decade. The present government's plans are to liberalise the whole of the supply market, including supplies to domestic customers by the end of 1998. At the time of writing (March 1997) the opposition, the Labour party, is also committed to this target, though it remains to be seen what decisions they take if they win the forthcoming general election.

Table 1: The State of Competition in the UK ESI

	Competition	***Monopoly***
Generation	yes	
Transmission		yes
Distribution		yes
Supply (above 100 kW)	yes	
Supply (below 100 kW)		yes (until 1998)

Just as this paper gives only cursory information about the new structures of the ESI, it similarly cannot do justice to the new regulatory structures which have been established. Some details are, however, necessary in order to understand what follows. The basic approach to regulation is that stricter regulations are needed for those parts of the industry which are natural monopolies and where competition is still in an embryonic stage. Nevertheless all parts of the industry operate under licences granted by the government and none are wholly free from regulatory interference.

A particular innovation in the UK has been the use of price caps to control the prices of private sector companies. At present caps are applied to the RECs and to the NGC, but not to the generators—though there have been times when the regulator has interfered with the prices of the dominant generators, National Power and PowerGen.

The aspect of regulation which is most relevant to this paper is the control which the regulator—the Director General of Electricity Supply and head of the Office of Electricity Regulation (OFFER)—still applies to the prices which the Public Electricity Suppliers (PESs) charge to domestic and other small users (the PESs are, in effect, the supply arm of the RECs). These control are kept in place because, until 1998, this market is a monopoly. A debate is starting in the UK concerning the extent of residual regulation once this market is opened to new entrants. The main issue concerns the speed with which new entry takes place, and the extent to which the existing PESs will still be in a dominant position.

At the moment the PESs, as the suppliers of electricity to the majority of users (by number, but not by volume), are subject to a range of obligations. It has been interesting to note how the process of privatization has served to codify obligations which were previously accepted by the publicly owned companies. Public companies conducted their activities in ways which met social objectives like:

- the provision of support services to elderly users;
- the provision of the same kind of services to the sick and disabled;
- the administration of schemes which protected customers in financial difficulty from being cut-off.

Exactly the same sort of obligations have been laid on the PESs. But the process is now more formal with the establishment of published Codes of Conduct to guarantee these rights, together with various processes of appeal.

The government has also laid other obligations on the RECs which are more economic than social. Thus the privatization compact started with a commitment by the industry to contract with the generators for a given proportion of coal-fired generation—this agreement will run out in 1998. There have also been schemes to, in effect, subsidise both the nuclear industry and the renewables industry.

Energy efficiency

Even before privatization the ESI accepted a responsibility of providing energy efficiency advice to customers. This obligation was continued after privatization—though it must be admitted that this scheme has never been particularly successful in effecting change.

It is important to understand the different motives which have, at various times, lain behind energy efficiency policy. The rationale underlying government intervention has varied. Objectives have included:

- to reduce dependence on imported energy (in the 1970s the focus was on imported oil);
- to improve economic efficiency and international competitiveness of industry;
- to conserve, or decelerate, the depletion of finite fuel resources;
- to meet defined social objectives, namely providing affordable warmth to the less well off and, more recently, exploiting net employment benefits;
- to take advantage of a 'no regrets' approach to the potential impact of climate change.

As elsewhere in the European Community, debate about the importance of securing greater energy efficiency was stepped up in the context of the wider debate about the way in which the UK would meet its obligations under the Climate Change Convention. A result was the establishment of a new government-inspired, but independent, body—the Energy Saving Trust (EST)—whose role was to act as a catalyst in the market and achieve a much faster rate of progress than had been achieved before.

There are two broad theoretical precepts which underpin the case for promoting greater energy efficiency.

- arguments are often based on the barriers created by several well known market failures—e.g. asymmetric information, inability to appropriate benefits, and credit constraints—which seem to explain why individuals do not exploit the *private benefits* of energy efficiency measures, even where the present value of future benefits exceeds the initial investment.
- arguments are often framed in terms of the *public good* characteristics of energy efficiency measures both in terms of improving the living conditions of the poor and elderly, and as a means of displacing emissions, and thereby help meet our climate change, and other environmental objectives. In these circumstances there are general gains to society from investment by particular individuals.

These strands need to be carefully distinguished since the scope and type of intervention depends on the motivation. For instance, if the first rationale is accepted and the individual gains are as hypothesised, then it will be sufficient to get people to act sensibly and, as a costless by-product, there will also be wider social gains. The case for public subsidies is far less compelling under this scenario than in the case of the public good.

The separate identification of private and social benefits has been important to the existing UK energy regulators, who have both expressed their concern about creating mechanisms whereby one set of energy-using consumers benefits at the expense of their fellow consumers.

Given the full liberalisation of domestic electricity and gas markets in 1998 it is important to look, in detail, at scenarios for these markets. Two types of effect may be seen.

- Energy pricing may become more cost-reflective—competition in the upstream and downstream energy sectors may drive down supply costs, reduce overall margins above costs and reduce cross-subsidies resulting from inappropriate tariffs. Tariff rebalancing may change prices to different types of user and change the balance between standing, peak and unit charges.
- Pricing signals may be used more efficiently—competing suppliers may have more incentive to investigate potentially profitable energy saving measures. Customers may also become more aware of energy costs and the savings available from being more energy efficient.

These two factors are not unambiguously demand-reducing. It may be that cost-reflective pricing leads to lower energy costs generally and lower marginal rates in particular, which could increase energy consumption (while perhaps reducing peak demand). On the energy efficiency-side it may be that suppliers and consumers get better at spotting new ways of using cheap energy to provide additional services or replace labour or capital.

UK liberalisation has been associated with a 25% reduction in industrial gas prices. Some of this reduction reflects lower primary energy prices and would have come about in time, irrespective of whether liberalisation had taken place, but the liberalisation of the domestic electricity market will, no doubt, also be associated with some reduction in electricity prices. This reduction will probably be less than 10%. Even so, this change will not serve to improve energy efficiency, which generally flourishes when prices are high.

Energy Efficiency Standards of Performance

The focus of this paper is on the Energy Efficiency Standards of Performance (EESOPs) established by OFFER in 1994. OFFER sets electricity saving target for each PES. These targets can be fulfilled in a variety of ways. There are three types of scheme: 'national' schemes (conducted by the Energy Saving Trust (EST)), 'framework' schemes (administered jointly by the EST and the PESs), and 'regional' schemes (which are the responsibility of the PESs alone).

The measures covered by these schemes are the familiar ones—insulation; draught prevention; low energy light bulbs; better refrigeration, DSM, etc. The innovation is perhaps the way in which these schemes are financed. That is by a surcharge, sanctioned in the quinquennial Supply Price Control Review, on customer bills of £1 per customer per year—giving an overall budget of £102m.

The scheme seems to have been successful to date since it is estimated that it has been responsible for cumulative lifetime savings 6103 Gwh, which equals the electricity consumption of 460,000 domestic consumers over 4 years. Moreover, 83% of targeted total reduction in energy usage had now been achieved by November 1996. Yet the cost of the schemes, in terms of public subsidy had been less than forecast—ie 66% of estimated cost. There is an issue, however, of whether diminishing returns will now set in so that the remaining savings will be more costly to obtain. The EST claim that the scheme has a benefit:cost ratio 5:1—ie £1 PES investment produces £5 of energy savings (also allowing for other financial contributions).

The most interesting issue for the future is how the EESOP scheme can be developed to fit in with the new competitive environment. OFFER's long-term aim is to encourage the growth in energy efficiency services to be provided in a competitive market by suppliers and energy management companies. But the immediate options are: either to impose EESOP obligation on all suppliers (and not just the PESs), financing EESOP obligations from a levy on distribution business (an arrangement of this kind has been proposed, but not implemented in telecoms); or to continue with the present arrangement—which seems unfair on the PESs (who would have obligations which were not imposed on their competitors), but which might work for a period.

OFFER wishes to avoid the imposition of excessive burdens on new entrants to the market. Equally it is opposed to the ideas of a levy on the distribution system, on the grounds that this would be unfair since it would be paid for by all users, and not just those in EESOP schemes. At the moment the Director General seems predisposed to continue with the existing PES obligations for two more years, while looking for ways to provide the PESs with new incentives to get other financial contributions.

Technological choices

The final section of this paper examines the ways in which the technological choices in the ESI have changed with the introduction of privatization and liberalisation. Under public ownership, technological choices had in the main been taken by the Central Electricity Generating Board (CEGB). In part the CEGB acted under political guidance, but its engineers also had a strong culture of their own and firm views about the best ways to secure the efficient deliver of electricity to the nation.

Diversity

One set of decisions concerned the appropriate diversity of the primary fuel mix—a concern which became more urgent first under the pressure of the OPEC price increases and then the miners strike of 1973. A key part of the policy was the decision which the government made about the construction of nuclear power stations—the end result of which has been that in 1997 the UK now gets over a quarter of its electricity from nuclear (though this proportion is now set to decline slowly since old stations will be closed and, as far as can be seen at the moment, no new stations will be built).

In today's world decisions about the generation mix are now entirely the concern of the private sector—under the Conservative government, this even includes decisions about whether or not to build new nuclear stations. It is well known that the main impact of private sector decision-making on the UK primary fuel mix has been the rapid increase in gas-fired generation. This development raises a fundamental question which will be posed in this paper, but not answered: will the free market secure a sufficiently diverse mix of primary fuels—that is will the mix be sufficiently diverse to protect the UK from the risks inherent in dependence on a narrow range of fuels?

These risks are primarily price risks, but could in some circumstances also include the risk of supply interruptions. Those who believe in the general efficiency of private sector decision-making think that the private sector will have a strong interest in avoiding over-exposure to any one fuel or source of supply, and so will seek protection through a range of different contractual arrangements. Others, believing that private-sector decisions will inevitably be biased against long-run policy concerns, are not so certain. Thus it remains to be seen whether some government intervention will be needed to steer the generating sector towards other fuels than gas, or whether the generators will themselves, in due course, wish to broaden their portfolios.

Technical efficiency

One theme which has come through strongly from a study of the UK experience is that private sector disciplines have been very successful in inducing all parts of the industry to produce and distribute electricity more efficiently than before. This may in some cases be the result of significant technological change—but more often not. It has become apparent that a private sector industry, motivated both by the need to satisfy shareholder expectations and the added incentives provided by the price controls imposed by the regular, has a strong incentive to cut costs. The most obvious manifestation of this need has been the substantial fall in employment in the ESI. But other means have also been found of cutting costs, including increases in technical efficiency. A list of some of the ways in which technical efficiency has been increased is as follows:

- transmission losses in the national grid have been reduced induced partly by the commercial incentive which the NGC now has to reduce losses—and further reductions are possible;
- in the generating sector the pressure to produce profits has again served to increase conversion efficiencies and to reduce down-time (a particularly good example has been in the now privately owned nuclear industry);
- more cost-reflective pricing of the transmission and distribution network has acted as an encouragement to more local generation and in particular to auto-generation.

Competition for supply

The paper has already considered the possible impact of supply competition on the EESOP scheme. But there are other ways in which supply competition, and the innovation which is likely to accompany it, may serve to induce technological change. Particular examples are:-

- the possibility that some of the suppliers will sell ‘green supplies’—ie they will back their sales with contracts with generators using new renewables—these supplies may be sold at a premium;
- the possibility that suppliers, or even wholly new middle-men, will offer energy services, in the way that already happens in the industrial sector;

- the use of wholly new metering technologies, both to align use more closely to cost and to offer users with wholly new service options.

The final scale of these developments remains to be seen.

Energy R& D

Nationalised industries, run by engineers, are generally good at research and development (R&D). They have to be, since in a world in which nearly all electricity industries are publicly owned, domestic manufacturers of capital goods inevitably depend on them for all their home sales, and international capital goods markets tend to be undeveloped. In contrast, private sector ESI companies do much less R&D, concentrating on getting the most out of existing facilities.

In this case the key question is whether the full range of generation technologies be procured on the open market? The evidence seems to be that it can. It is inevitable, however, that the generation technologies which are available tend to be more standardised and less tailored to particular national needs. (An example might be clean coal technologies where technologies should ideally be constructed to deal with the particular chemical properties of each nation's supplies of coal.)

A related development in the UK has been the marked reduction in government funded energy R&D. This reduction has mirrored a more general scaling-back of government-financed R&D activity. The present government has evinced general desire to separate out pure research—an activity for universities and research laboratories—from near-market development—an activity which should primarily be for companies. At the moment the signs are that the UK government will increasingly treat energy R&D as no different from any other R&D (this trend is, for example, encouraged by the integration of the old Department of Energy into the Department of Trade and Industry).

These developments should not, of course, be seen in isolation form the parallel development of the NFFO—which has proved to be a particularly good means of encouraging technological development in new energy technologies.

This paper ends on a slightly questioning note regarding the nuclear industry. At present all nuclear research programmes are being run-down quickly (with the exception of research into better ways of decommissioning redundant nuclear plant). But not everybody believes that the debate about the future role of nuclear power is over for all time, particularly if the search for ways of reducing greenhouse gas emissions becomes more urgent.

To conclude: the UK ESI has been changing rapidly under the combined forces of privatization and liberalisation, but it is still in a period of transition—perhaps it always will be!

The Renewable Non-Fossil Fuel Obligation - The diffusion of technology by regulation

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1. Introduction

Renewable electricity generation was supported by a market enablement programme, as compared to research and development funding, for the first time in the United Kingdom (UK) in 1990 as a result of privatization of the Electricity Supply Industry (ESI). Renewable energy projects were able to obtain a premium price per kWh of generation if they were successful in their application for a contract under the Non-Fossil Fuel Obligation (NFFO) in England and Wales; the Scottish Renewable Order (SRO) in Scotland and the Northern Ireland NFFO (NI-NFFO) in Northern Ireland. The NFFO requires the Regional Electricity Companies under the Electricity Act to buy a certain amount of nuclear and renewable electricity. The RECs pay the generators a premium price for the renewable electricity and the difference between the premium price and the average monthly pool selling price is reimbursed to the REC by the Non-Fossil Purchasing Agency (NFPA) from the Fossil Fuel Levy (FFL) on electricity, paid via customer electricity bills.

The electricity companies are obliged to buy the NFFO electricity by law. Neverthless, the Governments goal has been to make the renewable NFFO as competitive and market-like as possible, hence it's unique feature that contracts are awarded as a result of a competitive process. Moreover, the legislation is very flexible (discussed below) and this has allowed several alterations to the application and contractual procedures which has resulted in an NFFO contract which is perceived to reduce risk and be bankable.

Thus, it is the 'copper-bottomed' NFFO contract which is so attractive to developers and investors; which has led to over 2GW of contracts awarded; and which has led to intense competition for projects. For example, over 8GW of applications were received for NFFO4 with around a tenth of the capacity receiving a contract. Nevertheless, while the NFFO has market features it is an entirely separate, very cushioned environment compared to the privatised electricity industry. The key question is how can the momentum of the NFFO continue.

This paper tracks the evolution of the NFFO contract and discusses some options for the future[17].

2. Renewables in the UK - pre privatization

There were almost no commercial renewable energy projects commissioned in the UK at the time of privatization. The UK renewable energy policy was based on research and development (R&D) programmes since the mid 1970's and, latterly, a few demonstration projects. Moreover, when comparing the technologies which received R &D spending to those supported by the NFFO we can see that there is limited overlap. The four NFFOs supported medium size wind turbines (ie turbines of 300-750kW), landfill gas, sewage gas, hydro, agricultural wastes, biomass gasification and waste to energy plants while R&D mainly supported large scale wind turbines (ie 3MW), although latterly changed to smaller-scale turbines, landfill gas, hydro, geothermal, wave and tidal. The main overlap was with landfill gas and hydro and smaller scale wind turbines.

Thus, in practise, renewable energy generation prior to privatization, even including R&D and demonstration projects, was very limited in the UK and therefore the NFFO's task of developing commercial projects was particularly hard.

3. The creation of the renewable NFFO

The renewable NFFO developed out of the need to find a means of supporting nuclear power, once it was realised that the nuclear portion of the ESI could not be privatised. The Competition Directive required that the Government apply for permission from the European Commission (EC) for a levy to pay for nuclear power. This they did, but they asked the Commission to accept a levy to pay for non-fossil generation. The Commission agreed to a levy but only until 1998. Just as the Goverment did not use the term nuclear power, neither did they ask for support of renewable energy but it was accepted at an early stage that the definition of non-fossil would include renewable energy.

From the perspective of the Government, therefore, renewables were supported in the privatization process as a result of, and linked to, the need to support nuclear power.

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[17] For more details please see C Mitchell, 1995, The Renewable NFFO - A Review, Energy Policy, December; C Mitchell, 1996, The UK's Renewable NFFO - Results and Lessons, Economia Delle Fonti Di Energia e Dell'ambiente, Universita L.Bocconi, Milano, Italy, Vol XXX1X, No.1, April.

Furthermore, when the levy was first announced it did not set a capacity of renewable energy to be supported through the renewable NFFO. It was only when the timetable for the privatization process began to slip that renewables and nuclear power were seperated and the Government announced that the renewables NFFO would support 600 Mega Watts Declared Net Capacity (DNC)[18].

4. The Legislation

The NFFO legislation is contained in Section 32 and Section 33 of the 1989 Electricity Act. Section 32 of the Electricity Act states 'the Secretary of State may ... by Order' require the Public Electricity Suppliers (PESs) to purchase a certain amount of electricity. Section 33 is responsible for the Levy by which the PESs are able to recover the monies. However, Section 32 contains no reference to the number of Orders which may take place; no time reference (for example, by 1998 or by 2030); no reference to capacity (for example, 100 MW or 100 GW); and no reference to technology (for example, sewage gas or wavepower). It appears that a Secretary of State could Order the PESs to buy all renewables without any new legislation being required. Furthermore, Section 32 and 33 are not linked therefore it would be possible to scrap Section 33 while retaining Section 32. Thus the Act is extremely open and a potentially powerful and flexible tool in support of renewables.

It is the flexibility of the NFFO legislation which has allowed for the procedural changes which have resulted in the gradual development of a successful, bankable contract.

5. The allocation of the contracts

There have been 4 NFFO Orders and a fifth is expected to be announced following a review of the NFFO4 procedures. The first NFFO was in 1990 (NFFO1); the second in 1991 (NFFO2); the third Order was awarded in December 1994 (NFFO3) and the fourth Order (NFFO4) was announced a couple of weeks ago (see Table 1). Contracts were awarded to NFFO applicants following a bureaucratic vetting process, known as the 'will secure' test, undertaken by OFFER and an economic assessment of each project. In NFFO1, contracts were awarded following a process known as cost-justification and in

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[18] DNC = the equivalent capacity of base load plant that would produce the same average annual energy output see The Non Fossil Fuel Obligation - A background note, DoEn, August, 1991.

NFFO2 onwards contracts were awarded following a process of competitive bidding within technology bands. NFFO1 and NFFO2 contracts are until the end of 1998 and NFFO3 onwards had 15 year contracts with a five year grace period to allow for development work.

Current Government policy is to work towards 1500 MW DNC of new renewable capacity by 2000 through the five NFFO Orders. There is therefore no formal policy of support for renewables in the UK after 1998.

6. Application and Contractual Alterations and their Implications

It can be argued that one of the most successful characteristics of the NFFO process is it's flexibility. This has allowed changes to the application procedures with the intention of overcoming problems encountered in the last Order. The key alterations have been:

1. The move from cost-justification of NFFO1 to competitive bidding within technology bands as the basis of awarding contracts for NFFO2 onwards.
2. Changing NFFO contract lengths from ending in 1998 to 15 years + a grace period.
3. Altering basis of contract premium price from strike price in NFFO2 to bid price in NFFO3 onwards.
4. Removing or adding eligible technologies.
5. Altering government goals for new renewable capacity by 2000.
6. Introducing a review process after each Order.

6.1 NFFO1 and cost-justification

The initial method of awarding NFFO1 contracts was based on an economic assessment known as cost-justification. The NFFO applicants bid a price per kWh from their project and then had to justify it to the regional electricity boards (later known as regional electricity companies) and the Office of Electricity Regulation (OFFER). It can be argued that this method developed because, as was explained above, very little renewable energy deployment had occurred in the UK and none that was commercial except for some large hydro plants. As a result, the Department of Energy (DoEn), responsible for the privatization of the electricity system and the NFFO, was not clear how much renewable electricity should be paid per kWh. Cost-justification meant that each project was assessed seperately and no direct competition occurred between projects or technologies.

A fundamental problem with this allocation procedure was that it had not been clearly established what the basis of the assessment of the cost-justification was to be so that each project would be treated equally in each region. This provoked criticism from the applicants, some of whom felt that their project had been extremely critically vetted while other projects in other area boards appeared to get through the process much more easily.

This was aggravated by the fact that at the same time as vetting the cost-justification proposals, the regional electricity boards were occupied with the transfer to becoming privatised RECs. Amongst many other activities, the regional boards were creating wholly owned Generation subsidiaries for the RECs who could also apply for the NFFO. Renewable developers were unhappy sending their financial and economic details, required for the cost-jutification process, to the regional boards which they saw as potential competitors.

There were a number of other problems with NFFO1, usually to do with problems of the privatization process rather than the NFFO directly, but in general it can be said that the application procedures of NFFO1 were not particularly successful. However, it did illuminate the commercial price of renewables and the new procedures of NFFO2 set the precedent of altering the application and contractual basis of the next Order to overcome the problems of the previous Order.

6.2 The 1998 end-date

The Government had intended to privatise all of the CEGB. However, it became clear that the nuclear portion could not be privatised and a mechanism had to be found to continue to support it in such a way that minimised the costs to the newly privatised companies. The NFFO was the answer and as we have seen this also allowed the inclusion of the support mechanism for renewables, paid for by the levy until the end of 1998.

However, the European Commission let it be known in a number of sources for example a letter to Friends of the Earth[19] and later in Evidence to a Select Committee[20] that they would consider an application for the extension of the NFFO for renewables 'with a generally favourable view' and 'there is little doubt, however, that the commission would

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[19] Friends of the Earth (FoE), 1991, Removing the Wind Brakes, Ref 22.

[20] House of Commons Energy Select Committee, 1992, Vol 2, CEC Memorandum and CEC Appendix.

look favourably on a proposal for the UK to support renewable energy sources beyond 1998'[21]. Nevertheless, an EC exemption for the 1998 end-date for renewable energy was not finally agreed until the summer of 1993, just prior to the announcement of the conditions of NFFO3.

6.3 *Competitive Bidding, 1998 and NFFO2*

The second NFFO in 1991 (NFFO2) and subsequent Orders (NFFO3 and NFFO4) differed from NFFO1 in that the contracts were awarded as a result of competitive bidding in technology bands rather than by cost-justification.

Competition requires the bringing together of a number of projects at one time. This results in 'waves' of development. Furthermore, the cessation of payments at the end of 1998 created a powerful incentive to commision the projects as quickly as possible. Moreover, competitive bidding provided an incentive to develop the best resource sites so that lower bids could be proposed.

This had particularly unfortunate results for wind energy development. Because contracts are awarded at the same time, the projects tend to develop together so that several wind farms began to be commissioned at the same time, mainly in Wales. It was perceived by some that wind energy development was happening too quickly, with too limited a local involvement and that the link between wind turbines and visual intrusion was not being assessed adequately. A serious wind 'backlash' developed which was a direct result of the NFFO procedures and which the wind industry is still having to battle against.

The combination of competitive bidding and the 1998 end-date had a number of other impacts. Small scale projects and independent generators (whether individuals or communities) found it particularly hard to obtain contracts: the smaller scale projects because they were on the whole more expensive than the larger scale projects and independent generators found it hard to obtain finance[22]. In addition, because of the time pressure created by the 1998 end-date and the small manufaturing base for renewable energy technologies in the UK, the equipment used by NFFO2 developers was mainly non-British. While NFFO generators wanted to use British equipment, the few manufacturers did not have the volume ability to meet the Orders quickly enough forcing the NFFO developers to use overseas equipment.

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[21] House of Commons Energy Select Committee, 1992, Renewable Energy, Vol 2, Memo 43, page 151, Q2.

[22] C Mitchell (1994) Financing Small Schemes, Conference Proceedings, AT 2000, 13-14 June 1994, Open University, Milton Keynes.

Furthermore, the waste projects were unable to develop their projects quickly enough and still be economic within the 1998 end-date. This was a blow to the NFFO process because about 250 MW DNC of contracts withdrew, making it appear that the NFFO contractual basis was not working. Moreover, the NFFO was intended to be a central tool in the Government's waste management strategy.

Finally, it became clear that within Government policy that the projects of each subsequent Order would have to raise their bids in order to have their costs paid off by the end of the NFFO contract in 1998. This meant that NFFO2 prices were higher than NFFO1 prices (see Table 2) and to the ordinary person in the street it appeared that renewable electricity was very expensive. The 1998 end-date was clearly not satisfactory.

6.4 Competitive Bidding, NFFO3 and 15 year contracts

As a result of this, NFFO contracts for NFFO3 onwards were extended to be for 15 years. Moreover, they had a five year grace period when the development of the project, for example obtaining planning permission for a waste project, could be undertaken. This meant that the Fossil Fuel Levy could continue for 20 years after the awarding of NFFO3 and NFFO4. This meant that prices would come down for NFFO3 and renewable electricity could move away from the impression that it was very expensive. It mitigated the need for haste in developing projects and should make it easier for projects to use British equipment. Furthermore, NFFO3 contracts were eligible to new projects only (unlike NFFO1 and NFFO2 which allowed existing projects); and it included a sub-band for small scale wind energy projects to provide support for community projects.

The difficulty on the part of the DTI officials in changing these contractual arrangements for NFFO3 should not be under-estimated. Nevertheless, it resulted in the current bankable contract that has proved to be so attractive to developers and investors.

Nevertheless, in a sense the NFFO contract became too successful and a new problem developed: that of over-subscription. In NFFO3, 141 projects were awarded 627 MW DNC of contracts while 380 projects totalling 1870 MW DNC were refused and in NFFO4, 840 MW DNC were given contracts which was about one tenth of the applications.

6.5 *Strike Price versus Bid Price*

All NFFO2 projects competed within a technology band by bidding in a price per kWh for their project. However, projects were not paid their bid price but a strike price which was the price bid in by the most expensive capacity accepted within that technology band. The NFFO2 strike price mechanism was criticised at the time because it gave a windfall payment to developers who had bid in at a lower level . Nevertheless, it can be argued in hindsight that the high prices provided enough incentives to reduce the risks sufficiently to attract investors (primarily ex-nationalised companies rather than new independent entrants), banks, lawyers and acountants to form the nucleus of a small, UK renewable energy industry.

However, once the NFFO contracts were extended to 15 years, the price paid to NFFO3 generators was the price they bid in. This meant therefore that the price falls between NFFO2 and NFFO3 were not only due to the diffference in contract length but also due to a move from the payment from strike to bid. On the one hand the NFFO3 applicants were tempted by the longer contracts and on the other hand they were forced to move towards greater competition by being paid their bid price.

The fall in price between NFFO3 and NFFO4 is the most genuine result of a fall in the economic costs of renewable generation since the basis of the contracts is the same.

6.6 *Removing and Adding Eligible Technologies*

The NFFO application procedures has altered the eligibility of technologies considerably over the process, as shown in Table 4. On the one hand, this has allowed newly emerging technologies to be included (eg biomass gasification) or sub-bands, for example wind farms under a cetain size, to support community endeavours. On the other hand, it has excluded technologies where arguably they would have benefitted by further inclusion such as sewage gas projects.

Moreover, it is the one area where the NFFO has been unable to reduce the sense of uncertainty or risk. The combination of adding or removing eligible technologies combined with the huge over-subscription has meant that the risk of failure is quite high with no necessary expectation that the technology would be included in the next Order. This has exacerbated the problems for smaller developers.

6.7 *Altering Government Targets*

Government targets for renewables have altered significantly since the inception of the NFFO. As mentioned above, there was no capacity goal for renewables at the beginning although a 600 MW DNC target was announced fairly early on. A House of Commons Energy Select Committee produced a positive report in 1992 on Renewable Energy calling for a higher NFFO target. Shortly afterwards the Renewable Energy Advisory Group (REAG) was established and produced a report which also called for a higher NFFO target[23] and this led to a formal Government policy increase to 1000 MW by 2000.

Following NFFO2, there was a long gap before NFFO3. With hindsight, this must have been a time of serious internal Government lobbying between those who wanted to support renewable energy and therefore wanted longer contracts and those who were less concerned about the problems of the 1998 end-date. Finally, in July 1993, NFFO3 was announced with the changes to the length of contract and an increase in the Government goal to 1500 MW DNC of new generation by 2000.

6.8 *Introducing a Review Process*

A review of the NFFO3 procedures was established after NFFO3. This meant that those wanted to complain or argue for a particular change to the application or contractual procedures could do so. The same is occurring after NFFO4. This is to be welcomed and formally allows the airing of views and ideas which can then be incorporated.

7. Key Success

The key success of the NFFO process has been to bring down the price of renewables considerably and quickly. This should fundamentally alter the dynamics of policy discussions. Renewable proponents have, in the past, talked of renewable environmental benefits and rather underplayed their cost penalties. However, current policy discussions in the UK centre around the value of renewable electricity since it can be argued that renewables are competitive in certain situations if their embedded generation benefits are

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[23] Energy Paper 60 (1992) Renewable Energy Advisory Group: Report to the President of the Board of Trade, Nov, HMSO, ISBN: 0114142874.

taken account of. Furthermore, it is clear that renewables can now be said to be a pragmatic and cost-effective policy tool for ensuring that pollution reduction agreements are met (for example SO2 emissions in 2010 or carbon dioxide reduction targets in 2010). The NFFO4 prices have shown that not only do renewables have environmental qualities but they are also not so very expensive.

8. Key Problems of NFFO Process

It would be extremely unlikely that any mechanism of support would be considered to be without problems. The NFFO is no exception. However, the author would argue that there are two key problems with the NFFO. The first is that the competitive basis has clearly favoured large scale development by large scale developers. Originally this was because economies of scale could be gained through larger sizes and more recently because larger companies have access to cheaper finance and hence the ability to propose a lower bid.

The second problem is that competition is so fierce that the bid prices of some technologies are now, arguably, below their value to the electricity system. In the UK, the majority of electricity contracts are known as Contracts for Differences (CfD) whereby a fixed price, above the pool price, is agreed upon. Although all such contract prices are unknown, it is known that the average selling price of PowerGen and National Power (which account for around 75% of electricity generation in the UK) is around 3.5p/kWh, about a penny above current average pool price. Moreover, embedded generation clearly has a higher value to suppliers because of the avoided costs embedded generation provides to those suppliers. Yet, renewable prices in the UK, through the NFFO process, are being driven down towards pool price, clearly below their value.

9. A Potential Problem

The NFFO has been extremely successful in establishing an initial market. However, it is less clear that it is a mechanism which will allow the seamless and direct movement of a technology from the cushioned environment of the NFFO to being able to compete successfully in the UK privatised electricity system without support. Indeed, this seems to be too much to ask of it. An obvious interim policy step is an interim measure between the cushioned NFFO and the hard privatised world.

The NFFO has also been successful in developing a contract which combined enough incentives and reduced risk to ensure such popularity and reduced prices. This led to the development of a number of knowlegable actors in fields hitherto uninvolved with renewable energy: lawyers, planners, accountants, bankers, in addition to the regional electricity companies. Furthermore, it has allowed the creation of many companies, of differing sizes, hoping to generate renewable electricity.

Nevertheless, a worrying trend can be identified. Of the commissioned NFFO3 or Scottish Renewable Order wind farms, most are now owned by PowerGen, National Power or Scottish Power. PowerGen and Scottish Power did not take the risk of developing the projects but have bought them as a source of steady income supported by the copper-bottomed NFFO contract. It is not yet clear which companies were successful in NFFO4 but it is to be hoped that the level of competition in the NFFO has not reached the stage whereby only companies with access to cheap, corporate finance have the ability to bid in low enough prices to get a contract. If this were the case, then a worry for the future of NFFO technologies would be that those who currently are involved within the NFFO because of it's bankable contract will walk away from renewable development or financing when that contract is no longer available. This supports the argument for an interim measure either to keep the large generators involved or to allow the re-emergence of the original developers and financiers who were pushed out in NFFO3 and NFFO4 by the larger generators.

10. The Future of Renewables in the UK - regulated or market based?[24]

It can be argued that the NFFO process can only be said to be successful when it can be shown that the NFFO technologies are able to survive within the privatised electricity system without an NFFO contract. It is currently not clear to what extent the NFFO technologies will be able to do this. The evidence so far is not good. Sewage gas projects were made ineligible in NFFO3 on the grounds of their good economics. However, the development of sewage gas plants outside of the NFFO process has since been limited. Furthermore, the NFFO1 and NFFO2 projects are currently discussing future contracts with RECs and so far the available price for their electricity is around pool price, below it's value. The local RECs have more market power compared to the renewable energy developers and may use it.

Thus, a key issue for the NFFO1 and NFFO2 developers is the extent to which renewables can enter a retail market in 1998 through a renewable energy broker. Moreover, these

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[24] For a more detailed discussion, see C Mitchell, 1996, Future Support of Renewable Energy in the UK - Options and merits, Energy and Environment, winter issue.

NFFO1 and NFFO2 projects are in an extremely fortunate position compared to new projects in that they have had high NFFO premium prices for their 6-7 years of NFFO generation. New projects will have to be developed as a result of the contract and price they are able to obtain through green broking or direct sale. These are unlikely to be long-term contracts, certainly not compared to the NFFO contract.

It is to be hoped that these contracts will allow projects to develop but even in the most optimistic situation it is extremely unlikely that the rate of momentum attained by the NFFO will continue in the market, for no other reason than that the NFFO is an efficient way of assessing and giving out several contracts in a fairly short time period. Without the NFFO and assuming the market contracts are bankable, individual negotiations are likely to slow the process down.

Nevertheless, it is clear that any generation supported by the NFFO effectively reduces renewable generation which can be traded through the market. Since the goal of the renewable community is to generate competitive renewable electricity, then the gradual easing of renewables into the market is to be supported. For a market to develop for renewable electricity in the UK, some renewable electricity will have to be outside of the NFFO and this will be the cheapest ie electricity from landfill gas and waste.

However, there are two major points to be noted. Firstly, the value at which renewable electricity has to be competitive must be established. As noted above, some NFFO electricity prices appear to be below their value to the electricity system thereby undervaluing renewable electricity. Secondly, it is extremely likely that the rate of deployment of renewable technologies outside of the NFFO will dip, if not fall, considerably once they move into the market place. It can be argued that both of these outcomes are undesirable. The first because of market failure and the second because it is a squandering of the NFFO momentum which should rightly be captured and used as an important tool in the UK effort to meet it's pollution reduction agreements.

This paper argues therefore that a full relinquishing of NFFO support, for even the cheapest NFFO technologies, is too soon and too risky; is a waste of the FFL and is likely to lead to the undervaluing of renewable electricity. Some interim mechanism should be developed which will allow renewable electricity to receive a contract and a payment which reflects it's value to the system.

11. A Future Policy for the UK

The NFFO should continue for the technologies which are not close to their value to the electricity system, for example biomass gasification.

The much more difficult policy questions are those concerned with the cheaper technologies. This paper argues that there should be an interim support measure for technologies which can generate electricity close to their value to the system . They should be assured of a contract for their electricity at around this level. Requiring a payment per kWh equivalent to it's value to the electricity system is not a subsidy. It is simply ensuring that a renewable kWh displaces a non-renewable kWh for the same price.

A possible way to do this may be to place an obligation on Licensees as a Condition of License. All actors within the gas and electricity industry are required to have a license and there is provision for the Secretary of State to require a payment by the Licensees.

It would of course be preferable for renewables to exist through market trading alone but this paper argues that this is too hard a step to take, too soon. Moreover, if the UK is serious about developing a sustainable energy industry and in meeting it's international pollution reduction agreements, a less risky policy, albeit less market orientated, is required to ensure a continued and steady deployment of renewables.

12. Conclusion

The NFFO is a successful example of the diffusion of technologies by regulation. The renewable NFFO developed as a result of the need to subsidise nuclear power and the choices available of how best to support NFFO renewable electricity were constrained. Moreover, the renewable energy policy was required to follow the wider political philosophical support of competition. Given these contraints, the NFFO has proved to be a very flexible mechanism. The current worry is how to ensure that renewable energy technologies continue to develop steadily after NFFO5, the last formally agreed Order. It is important to bear in mind that the NFFO's success in bringing down prices and stimulating such over-application is a result of it's contract. It is not clear that the same prices or interest would occur without the contract. There is a danger that renewables will be perceived to be more competitive and independent than they actually are and as a result too much may be asked of them too soon, thereby squandering the momentum and success of the NFFO so far.

Table 1 Summary of Fourth Renewables Order (NFFO)

Technology	Contracted Capacity (MW DNC)	Number of Projects	Lowest Price (p/kWh)	Capacity Wieghted Average Price (p/kWh)	Highest Price (p/kWh)
Landfill Gas	173.7	70	2.8	3.01	3.2
Waste Fired /CHP	115.3	10	2.79	3.23	3.4
Waste Fired Fluidised Bed	126	6	2.66	2.75	2.8
Small Hydro	13.3	31	3.8	4.25	4.4
Wind Energy 0.768 MW DNC+	330.4	48	3.11	3.53	3.8
Wind Energy 0.7688 MW DNC or less	10.4	17	4.09	4.57	4.95
AD of agric. wastes	6.6	6	5.1	5.17	5.2
Biomass Gasification/ Pyrolysis	67.4	7	5.49	5.51	5.79
TOTAL	843.1	195	-	3.46	-

Table 2 NFFO Price Falls (p/kWh)

Technology	NFFO1	NFFO2 (strike)	NFFO3 (average)	NFFO4 (average)
Wind	10	11	4.32* 5.29**	3.53*** 4.57****
Hydro	7.5	6.00	4.46	4.25
Landfill gas	6.4	5.7	3.76	3.01
M&IW mass burn	6.0	6.55	3.84	-
M&IW fluidised bed	-	-	-	2.75
M&IW with CHP	-	-	-	3.23
Energy Crops & Agricultural & Forestry Waste				
- Gasification	-	-	8.65	5.51
- Residual	-	5.9	5.07	-
- AD	6.0	-	-	5.17
Sewage gas	6.0	5.9	-	-
AVERAGE	7.0	7.2	4.35	3.46

*1.6 MW DNC and above

** below 1.6 MW DNC

*** 0.768 MW DNC and above

**** below 0.768

M&IW = Municipal and Industrial Waste; AD = Anaerobic Digestion

Table 3 Summary of NFFO Status as of December 1996

Technology	Contracted Projects		Commissioned Projects
	Number	Capacity (MW DNC)	Capacity (MW DNC)
Biomass/ECAFW*	22	196.87	0
Hydro	84	50.49	20.26
Landfill Gas	167	343.5	119.23
Municipal and Industrial Waste (Mass Burn)	34	553.98	99.33
Municipal and Industrial Waste (Fluidused Bed)	6	126	0
Municipal and Industrial Waste with CHP	10	115.3	0
Other	8	75.63	57.98
Sewage gas	31	33.86	33.3
Wind	178	603.06	70.88
TOTAL	540	2094.35	400.98

Table 4 Eligible Technologies by NFFO Order

Technology	NFFO1	NFFO2	NFFO3	NFFO4
Wind	*	*	*	*
Hydro	*	*	*	*
Landfill gas	*	*	*	*
Sewage gas	*	*	-	-
M&IW mass burn	*	*	*	-
M&IW fluidised bed	-	-	-	*
M&IW/CHP	-	-	-	*
Biomass (steam generation)	*	*	-	-
Biomass (gasification)	-	-	*	*
Wet Farm Wastes (anaerobic digestion)	-	-	-	*

M&IW = Municipal and Industrial Waste

M&IW/CHP = Municipal and Industrial Waste with Combined Heat and Power

Table 5 Expressions of Interest by Renewable Energy Technology in NFFO4

Technology	Number	Capacity (MW DNC)
Landfill Gas	177	358
Waste Fired Combined Heat and Power	89	1982
Waste by fluidised bed combustion	195	3801
Wind Power	227	1461
Hydro power	79	40
Agriculural waste by anaerobic digestion	34	48
Energy crops by gasification/pyrolysis	89	707
TOTAL	890	8397
GIVEN CONTRACTS	195	843.1

Table 6 The Fossil Fuel Levy

Year	Total (£m)	Nuclear	Renewables (£m)	%
1990-1	1,175	1,175	0	0
1991-2	1,324	1,311	13	1
1992-3	1,348	1,322	26	2
1993-4	1,234	1,166	68	5.5
1994-5	1,205	1,109	96	8
1995-6	1105	1010	95	8.6

Table 7 Status of NFFO1 as of December 1996

Technology Band	Projects Contracted		Projects Generating		Projects Terminated		Projects Yet to Commission		Completion Rates (%)	
	No	MW	No	MW	No	MW	No	MW	No	MW
Wind	9	12.21	7	11.66	2	0.55	-	-	78	96
Hydro	26	11.85	21	9.75	5	1.85	-	-	81	82
Landfill Gas	25	35.5	20	28.85	5	3.82	-	-	80	81
Waste Combustion	4	40.63	4	39.63	-	-	-	-	100	98
Other Combustion	4	45.48	4	45.48	-	-	-	-	100	100
Sewage Gas	7	6.45	7	6.45	-	-	-	-	100	100
TOTAL	75	152.1	63	141.8	12	6.22	-	-	84	93

Table 8 Status of NFFO2 contracts as of December 1996

Technology Band	Projects Contracted		Projects Generating		Projects Terminated		Projects Yet to Commission		Completion Rates (%)	
	No	MW	No	MW	No	MW	No	MW	No	MW
Wind	49	84.43	26	52.77	22	30.31	1	0.21	53	63
Hydro	12	10.86	8	10.25	-	-	4	0.61	67	94
Landfill Gas	28	48.45	26	45.91	2	2.06	-	-	93	95
Waste Combustion	10	271.5	2	31.50	8	239.9	-	-	20	12
Other Combustion	4	30.15	1	12.5	1	9.45	2	8.2	25	42
Sewage Gas	19	26.86	19	26.86	-	-	-	-	100	100
TOTAL	122	472.2	82	179.8	33	281.8	7	9.02	67	38

Table 9 Status of NFFO3 as of December 1996

Technology Band	Projects Contracted		Projects Generating		Projects Terminated		Projects Yet to Commission		Completion Rates (%)	
	No	MW	No	MW	No	MW	No	MW	No	MW
Wind	55	165.6	3	6.45	-	-	52	159.2	5.5	4
Hydro	15	14.48	2	0.26	-	-	13	14.22	13	2
Landfill Gas	42	82.07	243	44.47	-	-	18	37.50	57	54
Waste Combustion	20	241.9	1	28.20	-	-	19	213.7	5	12
Energy Crops	9	122.9	-	-	-	-	9	122.9	0	0
TOTAL	141	626.9	30	79.48	-	-	111	547.4	21	13

Implications of Danish Regulatory Policies for Technologies Supporting Sustainable Energy Development

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The goal of the official Danish energy plans is to establish a sustainable energy development. In this connection the target for CO_2-emission is a reduction by 20% in year 2005 and by 50% in 2030. The main strategic elements are technologies with improved energy efficiency and a supply system with increasing contributions from renewable energy. The Danish energy strategy has promoted innovations in both areas.

According to the plans, renewable energy shall provide 12-14% of the Danish energy demand in 2005, and 35% in 2030. This includes an installed wind power capacity of 1,500 MW (1,200 MW on land, 300 MW off-shore) by 2005 covering about 10% of the electricity demand, and 5,500 MW (1,500 MW on land, 4,000 MW off-shore) in 2030. At present wind power covers about 6% of Danish electricity demand.

Large contributions are also planned from biomass, including biogas from animal manure and organic industrial waste. These developments have been promoted by government programmes and regulations in different ways. The government has established test stations to secure a high quality of the new technologies and to certify the different products. Extensive development and demonstration programmes have been sponsored by government money in the fields of biogas and wind power followed by government investment subsidies. The electric utilities have been involved by government in several wind power programmes regulating them to build wind parks of 100 MW scale. The utililities have also been made responsible for using 1.2 million tonnes of straw and 0.2 million tonnes of wood per year in central power plants by year 2000. This has promoted new technological innovations in this field as described in the paper.

Regulations by the EU Commission have been counterproductive in several cases and the present liberalisation of the electricity market is raising serious questions for a sustainable energy development. This will also be discussed in the paper.

1. Introduction

Environmental regulations (including environmental taxes) are often opposed by the industrial sector referring to an assumed loss of international competiveness. According to traditional industrial arguments, such regulations are only acceptable, if they are applied on an equal level for all industrial countries - or at least for all countries within important trade markets like the EU.

If the governments within the EU could agree on common environmental regulations on a sufficiently high level to secure a sustainable development, the industrial strategy would be acceptable. In real life, however, experiences have shown, that it is extremely difficult to reach agreement on environmental regulations even at a modest level. It is therefore important to analyse alternative national strategies, including evaluations of positive and negative consequences of national environmental regulations on a higher level than is generally applied in other countries within the same trade region.

The results of such evaluations will often depend on the applied time horizon. With a short time horizon, the cost of new investments required by environmental regulations may appear to have a clear negative effect on the economy of industrial producers. With a longer time horizon, however, these investments may well give the industry concerned a clear advantage by being first in a development which will penetrate the market in any case.

The energy sector in Denmark has been characterized by regulations in the form of norms, standards, taxes and subsidies based on environmental considerations. These regulations have promoted innovations in the use of renewable energy sources such as wind and biomass, and has also initiated innovations concerning energy efficient systems (energy conservation). The Danish regulations have typically not been harmonized formally with the other countries in the EU. On the contrary, Denmark has unilaterally introduced a CO_2 tax and introduced a number of public obligations on e.g. electric utitilities. Danish energy policy is thus useful as an example of possible consequences for innovations of government regulations.

2. History of Danish energy policy

In the following a brief summary of the historical development of Danish energy policy is given as a background for the subsequent description of technological innovations in selected areas within the energy sector.

The oil crisis in 1973/74 initiated new activities concerning governmental energy planning in many industrial countries. This also applies to Denmark.

The main steps in this process are outlined below together with some of the unofficial initiatives:

1976: First official Danish energy plan [1] (with proposed introduction of nuclear power).

1976: First alternative Danish energy plan [2] (without nuclear power, by independent energy researchers from Danish universities).

1979: Parliamentary law on a national heating plan and construction of a natural gas system.

1979: Establishment of a Ministry of Energy.

1981: Second official Danish energy plan [3] (with proposed nuclear power).

1983: Second alternative Danish energy plan [4] (without nuclear power).

1984: Start on the Danish natural gas project (North Sea gas).

1985: Parliamentary decision: No nuclear power in the Danish energy supply system (one year before Chernobyl accident).

1990: Third official Danish energy plan, "Energy 2000" [5] (with priority to a sustainable energy development and strong emphasis on CO_2-reduction).

1992-

1994: Evaluation of progress in CO_2-reduction [6], and new initiatives.

1995: Report from the new ministry for Environment and Energy: "Scenarios for Danish Energy Futures" [7].

1996: Fourth official Danish energy plan, "Energy 21" [8] (with priority to a sustainable energy development and strong emphasis on CO_2-reduction).

During these two decades the overall goal shifted its emphasis in the following way:

1975-1980: Supply security (fuel for electricity was shifted from 90% oil to 90% coal).

1980-1987: Economy, especially improvement of trade balance.

1987-1997: Environment, especially reduction of CO_2-emission.

The next section describes some of the main elements in the last two official energy plans [5,8].

3. Main elements of recent Danish Energy Planning

For the past 10 years the priority of official Danish energy policy has been to create a sustainable energy development. This has been substantiated by two action plans from the Danish Ministry of Energy in 1990 [5] and in 1996 [8]. The targets of the two plans are essentially the same, but evaluations of the actual progress during the early nineties have given rise to supplementary action programmes. The main targets and features of these plans are illustrated in the following.

3.1 Main targets of Danish energy policy

The targets for CO_2-reduction are based on the IPCC scenario leading to a saturation of CO_2-concentration in the atmosphere at 450 ppm during the next century [9]. In addition, the Danish government has assumed that the annual emission quota per capita should converge towards the same value of around 1.5 tonnes of CO_2 for all nations in the world at the end of the next century. This has resulted in the following targets for reduction of CO_2-emission compared to year 1988:

- In year 2005: a reduction of 20% in CO_2-emission.
- In year 2030: a reduction of 50% in CO_2-emission.

The target in 2005 compares well with the recommandations of the EU Council of Ministers from the Spring of 1997 in relation to the international climate negotiations.

The main targets for renewables as percentages of the total energy supply are as follows:

- In year 2005: a coverage by renewables of 12-14 %.
- In year 2030: a coverage by renewables of 35 %.

A more detailed description would need to take into account the exergy content of the different energy elements e.g. by dividing into electricity, transportation fuels, high temperature heat, low temperature heat etc. However, this is not the purpose of the present paper on innovative features of the Danish energy policy. The description will be limited to some characteristic illustrations of the targets for penetration of renewables in the Danish energy supply as indicated below:

Wind in year 2005: around 10% coverage of electricity demand (1,200 MW capacity on land, 300 MW capacity off-shore).

Wind in year 2030: around 30% coverage of electricity demand (1,500 MW capacitiy on land, 4,000 MW capacity off-shore).

Biomass in 2030: covering around 20% of primary energy demand corresponding to a contribution from biomass of 145 PJ.

The main contributions from biomass in year 2030 are planned to be waste straw, waste wood, organic waste from industry and households, energy crops, and manure from agriculture. Energy crops are planned to contribute 45 PJ/year from 250,000 hectares, corresponding to 10% of present agricultural land.

3.2 Means of implementation in Danish energy policy

A wide range of means have been applied in order to realize the targets set up in the Danish energy programme. These have included:

- Investment subsidies for wind turbines, solar collectors, biogas plants, heat pumps and insulation of houses.
- Favourable tariffs for electricity from wind and biomass and favourable conditions for access to the grid.
- Support and certification from governmental test stations for wind, solar and biomass technologies.
- Government funding of development and demonstration programmes for wind, solar and biomass installations.
- CO_2 tax and energy tax on fossil fuels.
- Government regulations obliging electric utilities to install 200 MW of wind power capacity.
- Government sponsored local offices concerned with information about renewables and energy efficiency.

Typically the investment subsidies have been around 30% for new technologies with a subsequent gradual reduction as the technologies become commercially competitive. For wind turbines the investment subsidy was phased out in the late eighties, while solar collectors and biogas installations still receive subsidies between 15% and 30%.

Electricity from wind and biomass has a special tariff of about 0.57 Danish kroner (D.kr.) per kWh corresponding to about 8.8 US cents/kWh (with an exchange rate of 6.5 D.kr. per US dollar). This tariff is calculated as the sum of the following elements: production cost of electricity on coal fired plants of about 0.30 D.kr./kWh (4.6 US cents/kWh), refunding of CO_2-tax of 0.10 D.kr./kWh (1.6 US cents/kWh) plus an environmental credit of 0.17 D.kr./kWh (2.6 US cents/kWh).

The Danish CO_2-tax is levied on fossil fuels except in connection with electricity production where it is a consumer tax. For space heating the CO_2-tax on fuels started at 100 D.kr. (15 US dollars) per tonne of CO_2 in 1993. For process heat in industry the CO_2 tax varies up to a level of 60 D.kr. (9 US dollars) per tonne of CO_2 in 1997. This level is planned to increase to 90 D.kr. (14 US dollars) during the next two years. The electricity CO_2 consumer tax of 0.10 D.kr./kWh is calculated to correspond to 100 D.kr. per tonne of CO_2 with the present fuel mix in Danish electricity production. The major part of the tax on process heat is recycled to industry for energy conservation projects. In addition to the CO_2 taxes, there are general energy taxes (including SO_2 tax) that add up to a total green tax on space heating corresponding to 500 D.kr. per tonne of CO_2 in 1997 increasing to 600 D.kr. per tonne in 1998.

As a major demonstration project it is planned to make one of the Danish islands energy autonomous within a decade or so [8]. The island of Ærø with 7,500 inhabitants is one of the favourite candidates in this connection.

4. Government activities in support of renewables

In this section we shall illustrate some of the main government activities in support of renewables. These will include regulations, test stations, and research and demonstrations programmes.

4.1 Government regulations

- Agreement with utilities on use of biomass, June 1993: The Danish utilities are obliged to use 1.2 million tonnes of straw and 0.2 million tonnes of wood in central electricity plants before year 2000. In 1996 a total of 0.3 million tonnes of biomass is used for this purpose. This agreement is taken up for evaluation in 1997 which may result in lower and more flexible targets for the use of biomass in central electricity production.

- Law concerning Integrated Resource Planning (IRP), 1994: Utilities are obliged to carry out analyses based on IRP methodology before major investments. This includes comparison with alternative solutions based on energy conservation and renewables.
- Stricter Building Code, 1995: In the new building code heat intensity is reduced by 20-25% in new buildings.
- Energy evaluation and labeling of houses before sale, 1997.
- Agreement with utilities to install wind turbines in two programmes during the late eighties and early nineties: The two programmes each includes instalment of 100 MW capacity of wind power on land. The last programme has been delayed due to siting problems. Negotiations are now taken place concerning utility responsibility for further 100 MW programmes sited off-shore.

4.2 Government development and demonstration programmes

The Danish government has supported development and demonstration programmes for promotion of renewables since the early eighties. For the past five years the government support has been more or less constant at a level of about 150 million D.kr. (23 million US dollars per year). This amount includes investment support for solar collectors, biomass plants, and heat pumps, in addition to the funding of test stations for wind, solar, biomass and heat pumps.

A number of projects have contributed to innovations in the field of renewables. Some of these projects are listed below:

- Efficient blades for wind turbines.
- Noise reduction of wind turbines.
- Efficient solar collectors.
- Communal biogas plants (both mesophilic and thermophilic).
- Gasification of straw (pyrolysis).
- Large solar collectors combined with district heating.
- Off-shore wind parks, including low cost platforms.
- Wave power.

4.3 Government investment subsidies

The governmental investment subsidies for systems based on renewables have varied over time as mentioned above. The investment subsidies for renewables in 1996 are shown in Table 1.

In the period from 1975 to 1984 the Danish government has subsidied buildings insulation by about 700 million US dollars resulting in total insulation investments of around 2,000 million US dollars, or around 1000 dollars per Danish household. This has reduced the heat intensity in buildings by about 50%. Further heat savings are possible but they will require a new programme of public subsidy in order to be realized with the present level of fuel prices.

Table 1. Number of renewable energy systems installed in 1996 with government investment subsidy, and the total subsidy in US $

Type	Number of installations	Total subsidy million US $
Biomass heat	2093	6
Solar heating	4207	7
Heat pumps	298	0.3
Conv. of electric heating	1016	3.7

4.4 Other government activities

The government test and certification stations have played an important role for the development of technologies using renewable energy sources. A test station for wind turbines was established already in 1978 and was subsequently followed up by test stations for solar heat systems, heat pumps and biomass plants. The official testing of these new technologies has given credibility in relation to the consumers and has supported the export, especially for wind turbines.

The penetration of wind power has also been supported by government funding of a Danish wind atlas (1981) and by a number of detailed siting evaluations on land and off-shore during the period from 1986 to 1995. This has given a sound basis for evaluation of the Danish wind power potential. Similar evaluations of the biomass and solar potential have been supported by government in connection with official Danish energy plans.

The first advisory committee to the Danish government on renewables was established in 1981. It was reorganized in 1991 and has been merged into a committe for energy and environment in 1996. The first advisory committe has played an important role in the early phase of development of technologies based on renewables by supporting innovative proposals in the field. The advisory committees have also supported broad information campaigns, especially in the field of solar heating.

In 1997 a fund for electricity conservation is being established. It will be funded by an extra consumer tax of about 0.1 US cents per kWh resulting in a revenue of about 15 million US dollars per year. The revenue will be used for a number of conservation projects, including conversion of direct electric heating of buildings to systems with higher exergy efficiency and development of efficient electric equipment.

5. Examples of innovative systems and technologies

In this section we will describe some examples of innovative systems and technologies resulting from the Danish official energy policy.

5.1 Biogas

Since 1986 a development and demonstration programme on community biogas plants have been supported by government funds. The project is supposed to solve two problems at the same time. The first is to reduce pollution of the ground water from animal manure used as fertilizers in too high concentrations at times of the year when it can not be fully absorbed by the fields. The second is to reduce CO_2-emission by producing biogas from animal manure which is CO_2 neutral.

The animal manure from cows and pigs are collected from typically 10 to 50 different farms and brought to the biogas plant in special vans. Addition of 10-15% of organic industrial waste has turned out to boost the yield of gas considerably. Both mesophilic and thermophilic plants have been included in the programme. In the first case an extra thermal treatment of the outgassed manure is necessary for sanitory reasons before it is returned as fertilizer. The outgassed manure is stored at the biogas plant until it can be efficiently absorbed by the agricultural fields.

Many technical problems have been solved since the start of this programme. Today 18 community biogas plants are in operation, where the biogas is used for cogeneration plants and district heating supplying local villages with heat and electricity. The capacity of the electric generators range from 200 kW to 2 MW.

A smaller programme on individual farm biogas plants have resulted in yields which are comparable to those of the community plants. Typical results for one of the individual plants (1996) are as follows:

- Horizontal process tank (200 m3).
- Gasstorage tank of 200 m3 corresponding to 12 hours production. This allows to save gas for peak load periods.
- Technique container with 87 kW generator/engine.
- Input: 12 m3 of manure plus 0.5 m3 of organic waste from fish industry per day.
- Electricity production: up to 1,800 kWh per day.
- Pay-back time: less than 5 years with investment subsidy of 30%.

5.2 Wind

Some of the innovations in the Danish wind programme have been institutional and social in nature. Thus, public support in the form of information campaigns and investment subsidies have resulted in a large number of "collective wind turbines" where a number of local households own shares in the turbines. Today about 75% of the Danish wind turbines are organized in this way while most of the large wind parks are owned by utilities. As a result, there has only been minor problems in finding sitings for the "collective wind turbines", while there are increasing problems with sitings for the utitility turbines. Psychologically, it is much easier to overlook the noise and visual pollution of your own turbine than of turbines owned by some utility.

The latest technological innovations are related to off-shore wind parks, where the Danish government has supported development of low-cost platforms. Taking advantage of experiences from platforms for oil drilling, it now appears that the relative cost of the platform for an off-shore wind turbine may be reduced from about 30% to about 10%.

The second off-shore Danish wind farm at Tunø Knob between Jutland and the island of Samsø was made operational in October 1995. It consists of ten 500 kW turbines and is producing electricity at a price around 0.49 D.kr. per kWh (7.5 US cents per kWh). The combination of cheaper platforms and larger turbines (1.5-2 MW) is expected to bring the production price below 0.40 D.kr. per kWh (6.2 US cents per kWh) during the next couple of years. This is still higher than the best results for land based turbines with production costs of less than 0.30 D.kr. per kWh (4.6 US cents per kWh).

5.3 Biomass

In order to fulfil the agreement between the Danish government and Danish utilities concerning the use of waste straw in central electricity plants, the utilities have carried out development programmes on special boilers for straw. The main problem is related to strong corrosive effects from the content of chlorine and alkaline elements in the straw. A development programme was initiated by the Danish utilities in 1992 with support from EU and the Danish Energy Agency. It has included superheating (additional 100 degrees centigrade) of the boiler unit in order to reduce the content of corrosive elements.

The latest innovation in this field is a process where the straw is washed by water at 80 degrees centigrade yielding a strong reduction in the content of chlorine and other corrosive elements. It is estimated that the energy consumption in this washing process corresponds to about 8% of the energy content of the straw. A demonstration plant based on this principle is expected to be in operation in 1998.

5.4 Solar heating

The Danish energy planning gives high priority to district heating. This has been an incitement for developing large solar heating systems coupled to district heating. The following are examples of the three largest Danish solar collector systems:

- **Saltum**, Jutland (1988) with a collector area of 1080 m2. Solar heat covers about 5% of heat (415 MWh per year) for 267 households connected to district heating system.
- **Ry**, Jutland (1991) with a collector area of 3000 m2. Solar heat covers around 4% of heat for 1,300 households connected to district heating system. Total cost of solar collector system is 1.4 million US dollars including 0.6 million US dollars in public support.
- **Marstal**, Ærø (1996) with a collector area of 8,000 m2. Supplies total heat for 1,250 households in the three summer months, equivalent to 13-15% of annual heating

consumption. A heat accumulation tank with a volume of 2,100 m3 can store heat corresponding to about 3 days demand in the summer period.

5.5 Energy conservation

Innovations in the field of energy conservation may include both informative activities and technological innovations. Denmark was one of the first countries to demonstrate low-energy houses with solar collectors and heat storage. The socalled zero-energy house at the Technical University of Denmark was constructed in 1975 with government support as a demonstration project headed by V. Korsgaard. A review of the Danish programme of low-energy houses for the period 1974-1986 has been given by Byberg [10].

A special element in the programme on low-energy houses has been the development of windows with low heat losses. As an example, a programme with public support for development of vacuum windows has been carried out at the Danish Technological Institute from 1989 to 1997. The vacuum window pane consists of two layers of glass which are asembled with a completely tight rim seale. Deep vacuum is then establised. Approximately 1000 nearly invisible spacers per m2 are placed between the two layers of glass.

In this way the window achieves an insulating property which, depending on the nature of the low emission coating, can reduce the heat loss to around 0.7 W/m2*K [11]. The vacuum window pane is thinner, weighs the same, has largely the same optical quality and better resistance to wind, wheather and mechanical influences than ordinary double glazing windows.

In this paper we shall further describe two examples in the areas of consumer information and household equipment.

The first example is concerned with labeling of household refrigerators which are grouped into seven categories from A to G with increasing energy intensity. There is now about two years of experience with consumer reaction to the labeling, and the result has been rather convincing based on sales data from the two largest shop chains covering about 25% of the total market. The sales in the three most energy efficient groups A, B and C covered about 40% of the total sales before labeling. After two years with labeling starting January 1995 these three groups now count for more than 85% of the total sales [12].

The second example concerns the development of low-energy refrigerators. A prototype low-energy refrigerator (LER) developed at the Technical University of Denmark in 1984 [13] reached the market in 1988 as LER200 [14]. This 200 litre refrigerator includes a number of electricity savings features, including increased thermal capacities of evaporator and condensor. The unit has an electricity consumption of 90 kWh per year which is a factor of three lower than the average on the market in 1988.

5.6 Heat pumps

The test station for heat pumps was created at the Danish Technological Institute in 1981. Until the end of 1996 about 150 tests according to Danish Standards have been performed. The sales of heat pumps in Denmark was only 266 units with public investment support (15%) in 1996. This is probably primarily a price problem combined with too low efficiences.

There are, however, special cases with good economy of heat pumps, e.g. in relation to the use of exhaust heat from animal stables. A recent example concerns a farm at Fyn with 50 cows, where a modern 15 kW heat pump was installed in 1995 and supplies the heat demand of the farm buildings. The heat pump absorbs heat both from the ventilation air and from surplus heat in connection with the cooling process of the milk [15].

The heat exchanger for the ventilation air is sited under the roof of the stable, where stainless steel tubes for the air outlet are wrapped with several hundred meters of plastic tubing for the heat exchange medium for the heat pump. The milk is cooled down to 4 degrees centigrade and the surplus heat typically raises the water in the storage tank from 35 degrees to 55 degrees. When the cows are out on grass fields during the summer, the system works on the surplus heat from the milk cooling only. This is enough to supply the reduced heat demand of the farm during the summer.

6. Liberalised electricity markets

Negotiations concerning the socalled liberalised electricity market in EU were started back in 1988. They have been lengthy and difficult due to different structures and priorities of the power sectors in different countries. Furthermore, several of the utilities have shown considerable reluctance to accept the proposed changes. It was not until December 1996 that the EU directive was finally passed by the Council of Ministers.

Some countries have already started their own liberalisation independently of the EU. This includes UK, Norway, Sweden and Finland. Outside Europe countries like the US, New Zealand and Australia, among others, are presently liberalising their markets for electricity.

In most EU countries, utilities and governments have been preparing for the expected development over the last few years. As an example, the Danish Parliament passed a new Act on Electricity in June of 1996 with wording that is close to that of the EU directive. More details about the international development in this field up to early 1997 may be found in a report to the Danish Energy Agency by Olesen, Brendstrup and Meyer [16]. This project was initiated in 1996 in order to evaluate the consequences of the liberalised electricity market for Danish energy policy which gives high priority to establishing a sustainable energy development. That includes promotion of renewables, energy conservation and decentralised cogeneration plants as substantiated by the last two official energy plans for Denmark from 1990 and 1996 [5,8].

6.1 Planning dilemma

The expressed goal of the EU Inner Electricity Market is to promote efficiency through commercial competition resulting in lower consumer prices and more economic growth. This raises some difficult questions in relation to the parallel desire of creating a sustainable development requiring long range planning with high priority to environmental considerations. The priority of commercial competition is profit maximizing over a time horizon which is seldom longer than five years. The commercial strategy usually includes market expansions. This is in striking contrast to a strategy based on energy conservation and shrinking markets with necessary planning horizons of 30 to 50 years.

In the EU directive an attempt has been made to resolve the dilemma between short range commercial interests and long range societal interests through the introduction of socalled "public service obligations" (PSO's).

6.2 Public service obligations

The EU directive allows the possibility for national governments of introducing obligations for the actors in the electricity market based on considerations of supply security, quality, price and environmental protection. This possibility has been used by the Danish government to include a paragraph that gives priority to renewables and cogeneration in the Act on Electricity from 1996, including the right of the government to decide minimum tariffs for electricity from plants based on renewable energy sources (e.g. wind and biomass).

In practice this could raise some problems if it results in higher consumer prices, thus making Danish electricity companies less competitive in an open market where consumers are not bound to local suppliers.

One possible countermeasure could be taxation of imported power that is produced without constraints of the type used in Denmark. Such an approach is likely to be opposed by the EU Commission as it conflicts with the rules of the Single Market. The method would also give rise to considerable administrative problems.

A more realistic approach is proposed in the new Danish Electricity Act: a consumer tax on all electricity in Denmark, including imports, based on objective criteria. The tax will be collected by the local utilities and used to compensate for their public service costs.

6.3 System operator

The socalled system operator has the responsibility of supply security by balancing demand and supply. The EU directive demands that the system operator be managed independently of other activities, and that all utilities split up the accounts for production, transmission and distribution activities.

The system operator plays an important role for the electricity market, and the Danish Electricity Act requires that the system operator promotes renewables by suitable development programmes. The responsibility of the system operator thus may include both technical and policy tasks. In the report to the Danish Energy Agency [16] it is proposed that the system operator should be a goverment body as is the case in Norway and Sweden.

6.4 Ownership of utilities

Development towards a liberalised European power market has already initiated a wave of buy-outs and mergers across the borders. Vattentall (Sweden) and PreussenElektra (Germany) are examples of companies that have systematically bought shares in power companies in neighbouring countries. If this trend continues, the entire power sector in the EU may end up being dominated by a few giant power corporations, likely to gain considerable influence over energy policy all across Europe. At the same time, this may limit the desired competition.

It is uncertain to what extent it will be possible in practice to carry through national energy policies which are contrasting with the policy of the large utilities. As an example, several of the large utilities in EU focus on nuclear power and large coal fired condensing plants, while Danish energy policy gives priority to renewables and decentralised cogeneration. The formal constraints based on PSO's may not suffice to avoid serious conflicts between government policy versus a utility policy dominated by coal and nuclear.

German experiences indicate that large power companies have a considerable influence on the national energy policy. The combination of vast economical and technical resources, along with a widespread network of political relations, enables the companies to influence legislation.

On this background it is official Danish policy to preserve the ownership of the Danish utilities on Danish hands, preferably by some kind of local consumer ownership. However, this is not in agreement with the basic principles of a competitive commercial market and it remains to be seen how far the Danish principle will hold up.

6.5 Integrated resource planning

The key issue of the socalled "integrated resource planning" (IRP) is a balancing between the need for new power capacity versus the possibilities for electricity savings. IRP also includes considerations of alternative supply systems including renewables. The intention is that IRP should contribute to fulfil the objectives of the official energy policy with a minimum of resource consumption and a maximum of consideration for the environment. This requires a close co-operation between utilities and the authorities, drawing up long-term planning on a socio-economic basis. Relative large resources have been used in Denmark in order to develop the necessary methodologies in this connection.

It is difficult to see how a coherent and long-term energy planning based on IRP fits with a liberalised market populated with many competing parties. This point of view is shared by some of the Danish utilities who believe that IRP in its present form will die away. Utilities in some EU countries (e.g. Italy [17]) have already stepped down their long range research activities. However, consideration is being given to utilizing the competitive element in new types of broad energy companies to strengthen the electricity saving efforts.

6.6 Renewables in a liberalised market

As mentioned above, each country has the option, but not an obligation, to promote systems based on renewable energy sources in its national requirements of utitilities through the PSO's. However, it remains to be seen how far it is possible to go before these requirements can be interpreted as illegal trade barriers.

A British analysis by Grubb and Patterson [18] concludes that small, decentralized systems will be advantageous in a liberalised market. Investments in large power plants (like coal and nuclear) with a lengthy planning and construction period are claimed to be too risky when the market becomes more dynamic.

This development will suit small, decentralised systems, if they are not too capital intensive, e.g. combined cycle cogeneration based on natural gas. However, most systems based on renewables are relative capital intensive which will give them a competitive disadvantage compared to systems based on natural gas.

Many systems based on renewables are still in an early phase of their development, so the production price can be expected to drop in the long perspective. The problem is, that the commercial market does not have a long perspective, and that large economic interests are supporting systems based on fossil fuels. Thus the liberalised market may well retard the penetration of renewables as compared to a situation where governments are free to give selective support to renewables.

One way to secure a more fair market competition for renewables is to internalise external social costs from fossil fuels in the market price. This can be done through environmental taxes, but so far it has not been possible to agree among EU members on the introduction of such taxes, including a CO_2-tax.

Decentralized plants based on renewable energy sources are often located close to the concumers, reducing the need for long-distance power transmission. Such producers should benefit from the resulting reduction in total transmission cost through higher tariffs for their electricity.

A recent problem has arisen in connection with the programme of off-shore wind parks in the sea around Denmark. The two large Danish utilities ELSAM and ELKRAFT are already applying for the officially selected sea areas for future off-shore wind farms. Recently, also foreign investors have expressed interest in these areas. As mentioned above, local ownership (or co-ownership) of wind turbines have turned out to be important for a positive public reception of the turbines. This may be counteracted by an open commercial market where investors from other countries must be treated on an equal footing with local Danish investors. The question is presently under consideration in the Danish Energy Agency.

All in all, it seems more difficult to secure the penetration of renewables in a liberalised market than in a system where the state has more direct influence on the choice of fuels. Even if national energy laws are passed imposing requirements concerning special technologies and giving priority to renewables, these measures might conflict with the basic principles of a free market.

It is recommended in the report to the Danish Energy Agency [16] that all the actions of the system operator must be fully open to the public, even in cases where this may be in conflict with commercial interests of specific companies. The system operator should report to a board with broad representation of societal interests including governmental energy planners, environmentalists, consumers, municipalities and independent energy experts.

The controversy between short range commercial interests and long range environmental interests can only be resolved politically, i.e. by giving clear priority to one or the other. So far free trade has been the winner in EU policy, but time may have come to reconsider this priority. The PSO's of the EU directive may be a sign of such a change.

7. Conclusions

Danish energy policy has over the last two decades promoted technological and institutional innovations over a broad range in the energy field. The most striking results have been obtained in the field of wind power, where Danish companies have more than 50% of the world market today. Other fields with positive results have been biogas, large solar collectors combined with district heating, low-energy houses, and energy efficient household equipment. Public support in the form of investment subsidies, demonstration programmes, norms and standards have been essential in obtaining these results.

Several of the new technologies are still in a developing phase where they need public support in order to penetrate a commercial market. Especially as long as external social costs from competing energy systems based on fossil fuels are not fully included in the market price. The trend towards liberalised energy markets may therefore delay the creation of sustainable energy systems based on renewables and energy efficiency.

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Danish Energy and Technology Policies with respect to Alternative Energy Sources and Innovation

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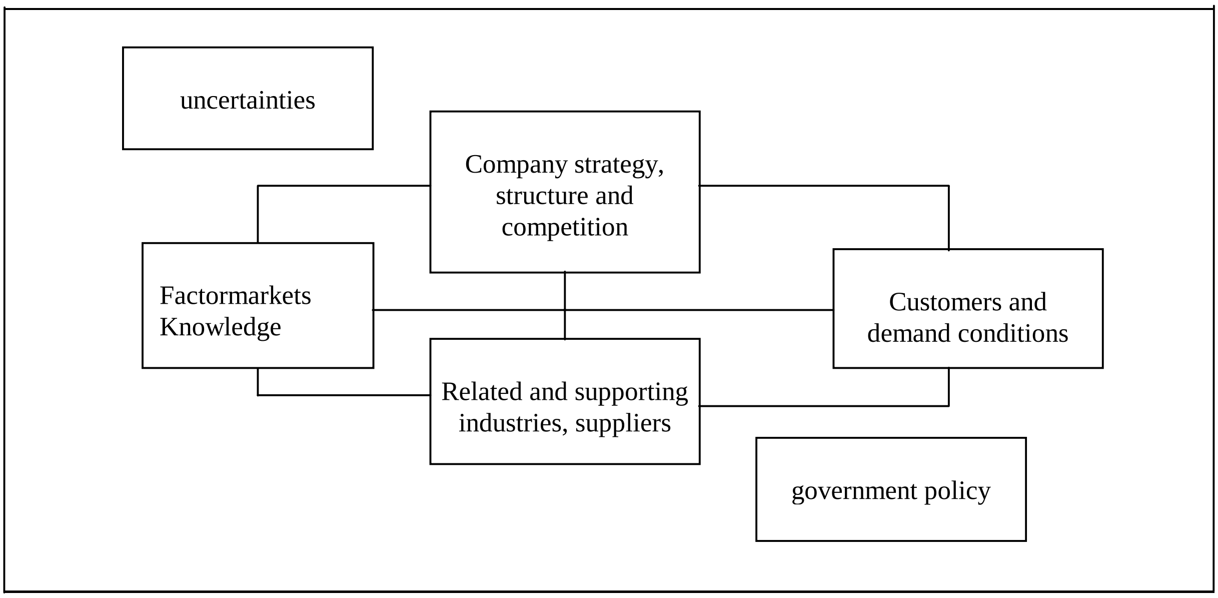
This paper is based on a study about Danish energy and support policies and their influence on the future of Danish wind turbine industry. The study was conducted for the Danish Energy Agency in cooperation with assoc.prof. Peter Karnøe, Copenhagen Business School. Information about the Danish experiences with cogeneration technologies has been added to the study.

Theoretical inspirations

As the study in some respect goes against standard economic reasoning about the role of subsidies and research for the development of a competitive industry a brief overview of the theories that have guided the study will be introduced. We found it very important to understand the technological characteristics of specific designs and how knowledge has been acquired and used in the process of innovation, which made technology studies an interesting field to add to the economics of innovation and industrial economics.

One important theoretical source has been the Porter inspired ideas of industrial networks and clusters (Porter 199) as the relevant unit to analyze and understand the foundations of industrial competitiveness and technological change. The Porter diamond has been used as a guideline to identify important relations and supporting factors behind the development of both the wind turbine and the cogeneration plant industry.

Actor network theory and studies of technology as a social construct (Bijker 1988) show the complex role of a number of actors not limited to the traditional industries and laboratories but including policy institutions, energy movements, power plants and investors in wind parks (Jørgensen & Karnøe 1995). The development of wind technology and especially the later introduced successful bottom up approach in technical innovation (Karnøe 1991 & 1993) and learning show the importance of studying the process of technical change as a mutual process shaping both technical solutions and visions of an energy supply based on renewables. These theories are used in combination with elements of institutionalism to bring in all the other stakeholders and especially opening for an integrated approach to understanding the embeddedness of technology policy options.



Our basic understanding of technological change has also been inspired by studies from the history of technology showing the path dependency and trajectories in technical change (Dosi 1982). From the economics of innovations the role of complementary assets and the importance of continuous small steps in innovation - piecemeal engineering - has shown valuable.

Infant industry policies, the critique of subsidy schemes, ideas of 'picking winners' and technology dynamics based of the ideas of demand pull and technology push has been drawn from industrial economics (Rosenberg 1982 & Teece 1986). This has been combined with a number of standard approaches to the analysis of market segments, industry structure, finance and competition.

It is not my intention to focus on the theoretical aspects of the study, only to give the reader an impression of the theoretical backgrounds for the study. For more details about the study I must refer to the book published in Danish (Jørgensen & Karnøe 1995).

The history of Danish wind turbine industry

The historical roots of Danish wind technology are located around the turn of the century where wind technologies were developed as part of the rural modernisation policies supported by the peasants movement and by government. Electricity was seen as an important support for technical change and social improvements. For a period electricity in the rural areas was as widely spread as in the cities, but the establishment of electrical grids and diesel based generators took over the power production and the role of the wind turbines decreased. Besides a short period of experiments in the 50ies set in motion by the growing need for power and the lack of fuels, wind technology was first reinvented in the 70ies.

But without any doubt the existence of especially design experiences from the 50ies were important for the self-consciousness of the grassroots. This group of people recruited from the energy movement, who in the first phase of the contemporary Danish wind technology developments, became the new entrepreneurs and innovators. But also the policy interests after the energy crisis and the search for energy production systems based on renewable resources were important social factors behind the new innovative phase. In fact the term 'social construction' of Danish wind technology has a very obvious meaning for this period of innovation. It was also of importance that the alternative energy movement was very interested to find alternatives that could be used in opposition to the atomic energy plans of the Danish government.

After a period of massive experimentation where more than 30 different designs and variants were tested in full scale, a limited number of technical designs were found useful to put into production and the first Danish wind turbine plants were established. The basic Danish design of a turbine with 3 blades and a gear transmission in the following years was refined based on experiences from Danish sites and a fast growing export to the US. The phases of industrial development and the up-scaling of the wind technology are shown in TABLE-1.

The central role of the wind turbine industry in the wind turbine cluster is based on strategic knowledge of construction and assembly of the turbines. Generators and transmission gears are typically imported. These component industries have their own and independent knowledge base, not easily copied and utilized by newcomers. But the wind turbine industry still plays a part in advising the component manufacturers about noise reduction and design principles to match the specific requirements of wind turbines.

Although the wind turbine industries primary competence has been in developing and producing reliable wind turbines, new competencies have been added during the period of growth in markets. Already the Californian experiences showed the importance of maintenance and technical services, and the opening of new markets also added the need for knowledge about local wind regimes and the costs and possibilities of connecting single turbines and wind parks to the grid. The companies had to establish competencies also in project planning, project management and finance to serve the new markets.

TABLE-1 Development of wind technologgy

Phase	Wind turbine size	Industrial phase	Number of designs
(1) 1974-79 Entrepreneurs and grassroots	15-30 kW	(re)birth	38
(2) 1980-83 Early industrialisation	55-65 kW	establishment	5
(3) 1984-85 Forced industrialisation	75-99 kW	expansion and heated activity	4
(4) 1986-88 Crisis and dropping exports	130-160 kW	technological stabilization, but economic crisis	3
(5) 1989-92 Stable growth in home market and exports	200-500 kW	economic and technological stabilisation	2
(6) 1993-96 Fast growing exports	200-750 kW	economic and technological development	2

TABLE-2 shows the changing conditions in the foreign and domestic markets, but also the growing exports and the expansion of the new industry. There has never been a closed and protected home market in the traditional sense, although the home market in some periods has served as the back bone that made continuous manufacturing activities possible.

TABLE-2 Market Development					
Year	Installed MW world excl.DK	Danish exports MW	Danish export market share %	Danish home market MW	Danish total market share %
1979-1983	240	20	8	19	15
1984	380	110	30	7	30
1985	385	220	54	23	58
1986	223	180	81	32	83
1987	147	55	37	33	49
1988	48	20	40	82	79
1989	84	70	80	66	90
1990	119	81	61	81	81
1991	170	93	50	70	68
1992	293	121	40	45	49
1993	449	181	40	29	44
1994	690	316	41	52	50

The development since 1994 has shown continuous growth both in the world market and in the domestic market in Denmark, and the Danish manufacturers have kept their market shares almost unchanged.

The history of Danish cogeneration systems

Danish cogeneration technology has a long history like the wind technology. The first cogeneration installations were established in 1912 to serve dense populated areas in cities with both heat and power. These systems were mainly planned and produced by local companies and for a long period of time, the technology stayed relatively unchanged. The primary elements of the system was a huge system of iron pipes transporting heated water, which served as cooling agent in the power plant to the households. The major breakthrough that made Danish industry an exporter of cogeneration systems was the invention in the 60ies of prefab insulated iron pipes, which reduced the costs of installing cogeneration system significantly.

TABLE-3 Development of Danish cogeneration systems

Phase	Industrial phase
(1) 1960-78 Concentration based on prefab pipes	restructuring of industry; new distric heating (from 1970)
(2) 1979-85 Heating planning and energy saving	steady growth and exports
(3) since 1986 Decentralized cogeneration systems	technological renewal; imports of components growing; largs scale systems dominates exports

The industry structure in the field of cogeneration is in general more diverse than in the case in the wind turbine industry. The strategic competencies are concentrated around the production of the pipe systems and the related competencies in project management and planning. In this field there are a number of component manufacturers in Denmark, but no industry in Denmark produces the generators and gas turbines, which has to be imported.

The Danish heating policies, which proved very successful during the later 70ies in reducing the energy used for heating purposes to almost 50% of the initial use, furthered the introduction of cogeneration system in all major cities and a lot of smaller townships too.

To avoid the critique, that this article only focuses on success stories. And also the impression, that just focusing and working with a technology leads to remarkable and successful breakthroughs, it is worth remembering that e.d. the production and utilisation of biogas for power production was put on the agenda at the same time as the wind turbines and the renewed interest for cogeneration systems. But due to unsolved technological problems and more complex processes is, this field is still not expanding. A number of problems has been solved but the test plants still face problems in maintaining stable gas production.

The approach to research and learning in innovation

It is astonishing to recognize that the larger part of the money spend by government both in the US and in other countries including Denmark has not shown very important or successful for the development of commercial wind technology. TABLE-4 gives an overview of the investments made in large scale, research based wind turbines, primarily set up for test purposes. It also shows the amount of R&D money spent on commercial turbines.

TABLE-4 Approaches towards R&D

	TOP-DOWN		BOTTOM-UP		TOP-DOWN
	US government R&D		US market driven	DK market driven	DK government R&D
(A) Type of technology					
- turbine size	big	small	small	small	big
- advance level	high	high	high/medium	low	medium/low
(B) R&D expenditures $m 1974-1992	396	130	n.a.	29	31
(C) Market share of US home market (1980-92)	0	0	40%	45%	0
(D) World market share					
i 1993	0	0	25%	53%	0
(E) Number of companies					
i 1985	2	0	11	5	1
i 1992	0	0	1	5	0
i 1995	0	0	4	6	0

The historical data show, that in this field the research activities based on large scale technology and design strategies often inspired from e.d. aeroplane industry in the US has not been successful. Contrary to this the continuous innovative activities in industry has proven successful and today the commercial turbines have reached the size of the test turbines, set up for research purposes, but much more efficient in both cost and energy terms. Even the hypothesis that the two different strategies might close up on each other so that the commercial innovations could benefit from the R&D financed test turbines has not been confirmed. The two development strategies are not easily linked.

The effects of the slow and steady innovation activities in the wind turbine industry is illustrated in TABLE-5. The table shows a step-wise scaling up of the turbines size from a starting point of 55 kW pr turbine to the latest turbines of 1.5 MW. It also shows the increasing cost-efficiency of the commercial turbines. The cost of wind energy today can easily compete with e.d. diesel generators, and prices are closing up on the costs of the most efficient Danish coal heated steam turbine plants in Denmark.

TABLE-5 Performance of wind turbines

Model/ year	Generator size (kW)	Blade length (m)	Blade weight (kg/m^2 rotor area)	Tower weight per 24m (kg/m^2 rotor area)	Efficiency	Price (c/kWh)	Number of private houses supplied
1979-85	55	7.5	1.8	32	0.35-0.40	10-12	30
1984-87	90	9.0	2.33	26	0.38-0.42	9.6	57
1986-	140-180	11.0	1.9	18	0.42-0.46	7.5	81-110
1991-	450-500	17.0	1.51	9,4	0.44-0.48	5.3-5.4	250
1992-	500	19.5	0.92	9,1	0.48	5-5.3	275
1994	600-750	20-21	n.a.	n.a.	n.a.	4.7-5	300
1996	1000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

The story of wind turbine innovations also tells the importance of a longer period of continuous experimenting with a new technology. The results could not easily have been foreseen. On the contrary, a number of official reports have doubted that wind energy could be cost effective at all. Of course there is no automatic guaranty of success just by working with a new technology as the example of biogas production shows. But the experience at the same time is, that technological forecastings based on expert knowledge and historical economic figures often underestimates the results from learning by producing and using. The lesson in this respect must be, that experimentation and the furthering of multiple technological solutions is a very important part of technological development.

Of course this argument can also be used to promote atomic energy solutions. The only risk involved here is that historical data do not support the idea, that the number of problems and the effects of learning has lead to reduced costs and has solved the basic problems - on contrary the costs have been growing and the maintenance of the contaminated rest products has not shown any progress, despite the enormous investments and efforts directed to solve these problems.

The actual international position of Danish wind turbine industry

Today, the Danish wind turbine industry is positioned as a global market leader on a fast growing international market. After the large California market almost collapsed in 1987 the Danish wind turbine industry has succeeded in establishing strong positions in new, European markets as well as Eastern markets like India and China. These markets are characterized by increased growth, and Danish companies hold high market shares indicating the strong position. The Danish companies have been exposed to increased demands for developing complementary assets to serve the new markets (i.e. joint ventures in foreign cultures and financial arrangements) as well as confronted with new international competitors. Despite these challenges Danish industry increased its global market share from 39% in 1993 to 50% in 1994.

During the period from 1983 to 1994 the accumulated global market share for Danish industry was 52%. This corresponds to a total export of DKK 10.5 billion and some 10,000 wind turbines.

From 1993 to 1994 the export doubled and the total export amounted to DKK 2 billion with a total turnover of DKK 2.4 billion. In 1994 some 6,000 people worked in the industry, with some 1,720 people manufacturing and selling wind turbines. The rest were employed by suppliers and different service functions. An important factor in this progress is the continuous improvement of the performance and cost-efficiency of wind power relative to conventional power production based on coal or oil.

Even conservative growth scenarios estimate that the total global market for wind power from 1995 to 2000 will amount to 9,200 MW. Taking into account the present strong position of the Danish industry and the to be realized in 1995 there is good reason in expecting that the Danish export will increase to DKK 4 billion per year in 2-4 years. Due to the fast growing market and increased number of competitors the Danish market share may fall to 40 %, but still export and employment will increase.

Globally, there are some 35 competitors in this emerging industry. 10 manufacturers dominate the market and have 93 % of the global market. Of these ten companies six are Danish, and it was only due to a strong position on their domestic markets that American U.S. Windpower and German Enercon and Tacke were among the top ten (see TABLE-6). No other single companies or national industries are as strongly internationalized as the Danish industry.

TABLE-6 Market shares of wind turbine suppliers

Producer and nationality	Share of the world market in 1994 (% of MW)	Export share (%)
Vestas Wind System, Denmark	19.3	84
US Windpower/Kenetech, US	13.5	15
Enercon, Germany	13.4	3
Tacke, Germany	9.9	2
Micon, Denmark	8.2	90
NEPC, India (DK licencee)	8.1	0
Bonus Energy, Denmark	7.2	88
Nordtank, Denmark	7.2	90
Windworld, Denmark	3.1	90
Nordex, Denmark	3.1	100

On the one hand, the possibilities of defending the strong Danish position depend on the competencies and complementary assets within the Danish companies, and on the other hand the developmental conditions given on the national home base. The national home base refers to the way in which industry and energy policies jointly provide the industry with factor and demand conditions that sustain technological development and learning in existing and new wind-turbine concepts. To this should be added the ways in which the Danish financial system might support the industrial stage of growth. The recent takeover of two major Danish firms by two large international investment banks suggests that local Danish financial mobilization has had difficulties.

The company-based complementary assets evaluated in this study are:

1. product technology
2. production competence
3. financial strength
4. internationalization forms and strategic alliances
5. competencies in evaluating site-specific wind resources and handling installation, operation and service of wind-power plants.

These asset profiles could be targeting one or several market segments. The segments vary on the basis of project size, customer type, supplier involvement, service contracts and terms of financing projects. In one end of the continuum of sales are 1 to 5 wind turbines to local, private customers and in the other extreme are fully financed, build-own-and-operate or turn-key plants, which may also include local co-production and transfer of technology.

This study shows that the Danish industry to a large extent master these competencies. Due to the differences between the specialization of each company the strength of each type of competence vary. Nevertheless, it is the general picture that the Danish windturbine companies are able to take the wirdturbine technology further in terms of cost-efficiency and also to take its product to the global market segments meeting most of the demands.

Such competencies are not built from one day to the next, and it takes time for new competitors to develop design and production experience, product performance references and not to forget establishing solid foot-holds on the new export markets. The German and American competitors have only limited experience in exporting whereas the Danish companies have been active on all export markets for several years.

New entrances and technological alternatives

The Danish industries position might be threatened by the new competitors, but it is our view that it takes 2-3 years before they have equivalent competencies, and since the Danish companies are presently also mobilizing resources and competencies it is not likely that they are easily outperformed.

There is a continuous risk that large capital groups are waiting to enter the wind turbine market, but e.d. the crisis of Kenentech (US Windpower) backed by Westinghouse is still leaving the field to the smaller companies. There is a potential for Mitsubishi and/or MAN to enter the field, but still they seem to wait or even withdraw from this area.

An alternative threat is represented by alternative designs to the standard Danish turbine design. The actual alternatives are still not too promising:

a. The Dareius design of a turbines with vertical shafts can be used in remote areas, but are more dangerous to set up in populated areas.

b. Single bladed and two-bladed turbines work at high speeds and consequently they are noisy.

c. Slow speed generators (ENERCON) have a high market share in Germany, but they are relatively costly and difficult both to produce and repair.

d. A number of experiments are conducted with bending blades and variable speed.

There is still some potential for size up-grading, but component manufacturers to supply these large turbines are few and the costs of mounting the turbines locally is growing with size. Bigger turbines for off-shore installations based on new technological solutions for the foundations for the turbines seem to be the most promising area for new developments.

The role of the Danish home base

In studies of industrial development the home market is often mentioned as an important base for the initial development of the industry, while later globalization become dominant and the role of the home market is reduced. This model also holds in general for the wind turbine industry. But an important aspect has to be added to this model of development. The study conducted in Denmark points to another role of the local conditions for development, with less focus on the economic role of the home market by size or price, and more focus on the role of demanding customers forcing industry to develop cost-efficient, low maintenance and low noise turbines.

TABLE-7 shows the changing role of the home market parallel to the role demanding customers, governmental policies, R&D activities and supplier networks.

TABLE-7 Industrial development and the home market

Phases of development	Role of the home base					
	test of new turbines	home-market	relations to customers	supplier networks	R&D and knowledge	energy policy
1978-82 home market established by volume and technology	local creativity is supported	enables experiments, start of industry	supports creative efforts	local industry, esp. blades	exchange of knowledge	support for new technology, sites
1983-86 export-boom in US, growth in home market on govmt. support for wind parks	reference for exports	supports expansion	not so important	more specialized industries	tests and certificates	grants for wind parks
1987-90 export decline, home market sustains volume and innovation incl. 100 MW for the utilities	demonstrates innovative capabilities	saves industry	focus on economic efficiency	stable netvorks etablished	development of wind models and maps	utilities forced to buy turbines
1991-1994, new export markets growing, home market unstable	new places are at hand	volume not so important	more efficient and less noise	close cooperation on innovations	general knowledge	decentral planning of sites

Instead of leaving the development of industrial competencies to the companies after an initial support to innovation and R&D, the role of energy and technology policies is to build up demanding markets, to support knowledge exchange and to support experimentation and competition amongst industries.

Lessons to be learned from Danish technology policy

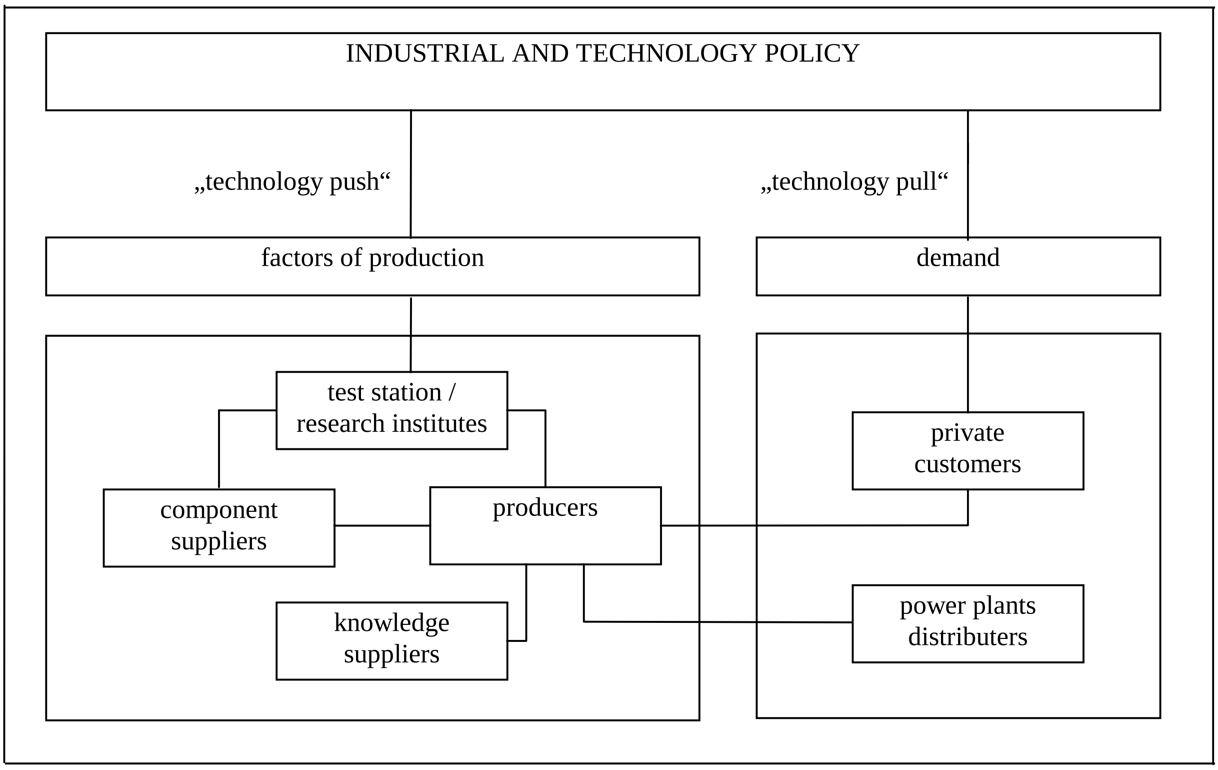
The national development conditions - the home base - is here seen as those created by industry and energy policies. Till now, the Danish industry-enabling policies have been based on three elements: First, the demand side was supported by a direct economic investment subsidy to the buyer of wind turbines (which stopped in 1989) and a specific 'green' payment for supplying non-polluting power to the national grid. Second, the supply side was supported by R&D investments which primarily were allocated to the National Test and Research Centre for Wind Turbines. Third, the priorities in energy policy which in the early 1980s made it easier for windturbine owners to negotiate with local authorities (municipalities) and utilities about location and payment.

It is somewhat remarkable that there was no direct subsidy to wind-turbine manufacturers. Instead, the demand-side subsidy and the supply-side R&D support created an infant industry incubator in which the producers have developed and competed as if it were a 'free market'. In this sense the developmental policy can be characterized as a market-based industrial development policy, which did not have any 'picking the winner' characteristics. As expressed in the analysis this was not a rational ex ante design of the best recipe for developing new industry, but nevertheless, it created an environment which helped the successful development of the Danish industry.

These elements in industrial policy are shown in the following model, which focuses on the importance of establishing networks of industries (and competencies) on the one hand, and on the strengthening of demanding customers who are competent to set the standards for innovation.

The elements of the successful Danish policy can be summarized as follows:

1. support to establish test sites, reference technologies and certificates are important factors in the constitution of new areas of technologies;
2. the shaping of demanding initial markets are important as test sites and grounds for experiments;
3. while the funding of formalized research in government laboratories and industry is not securing success;
4. the fostering of qualified customer demands is crucial in developing new markets, professionalising customers is underestimated in technology policy; and
5. support for knowledge networks of engineers and business making experiences available is safeguarding in a business areas characterized by high risk and changing markets.



It was the result of the Danish study, that there still is a need for continued commitment to develop wind power in Denmark. This is important in order to support the sustaining international development of the Danish industry. It does not refer to the volume or size of the domestic market nor a strong subsidized market, but it refers to the existence of a stable market which could serve as reference and testing of new wind turbines, and document that wind power could plan a part in the national energy supply. At present, more than 4% of the Danish electricity consumption is supplied by wind power.

In this sense, the role of the home base in the present situation of the industry is different from the traditional view of the domestic market as the economic basis for exports. The role of Denmark as a pioneer in the area means that other countries still look at the Danish policies and experience. The industrial policy could also support the technological development in ways that continue to make Denmark an attractive place to localize design, manufacturing and some production.

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