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Nordic Training Programme for Energy Experts in the Baltic States
The PROCEED Programme
(PROgramme for Cooperation in Energy-efficient Economic
Development)

Feasibility Studies and Public Regulation in a Market Economy

The Implementation of Environmental Objectives and
Technological Change in the Energy Sector

Frede Hvelplund and Henrik Lund
Aalborg University
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Preface

This publication “Feasibility Studies and Public Regulation in a Market Economy” is to be used in module 4 and 5 in the PROCEED programme, which is a training programme for Energy Experts in the Baltic States. The PROCEED programme is financed by the Nordic Council of Ministers. The material has a general character, and is to be used in connection with the case material developed in each of the Baltic countries.

Frede Hvelplund and Henrik Lund
30 January 1998

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Chapter 1

Market Institutions and Technological Change

1.1 The Consequences of Changing Conditions

Feasibility studies include both design of feasible technical alternatives and an evaluation of social, environmental and economic costs of those alternatives. In socioeconomic feasibility studies the question is, whether a project is feasible for the society as a whole, whereas in business feasibility studies it is analysed, whether a project is feasible for a specific company.

Coherent technical descriptions of alternative ways of achieving certain energy policy goals can be established by the use of computer models such as SESAM and KVDESIGN. From such alternative strategies the purpose of a *socioeconomic feasibility* study is to find the best solutions under the combination of present and prognosticated conditions. The purpose of *public regulation* studies is to identify and develop the best set of means for the implementation of the most feasible strategy. Figure 1.1 summarises the content of socioeconomic and public regulation studies as well as the relationship between those two areas of study.

	1) Design of alternatives	2) Socioeconomic analysis of alternatives
3) Socio-economic feasibility studies	Establishment of technical scenarios and technical alternatives.	Finding the best solution from an analysis of economical, environmental, political and social feasibility.
4) Public regulation studies	Establishment of Implementation scenarios or alternatives.	Forming a strategy of implementation from an analysis of economical, environmental, political and social feasibility of implementation strategies.

Figure 1.1: *Socioeconomic feasibility Studies and Public Regulation.*

It should be emphasized, that both feasibility- and public regulation studies have to be placed in a historical context. This implies, for instance, that in periods of massive technological and institutional changes, feasibility- and public regulation studies have to include thorough analysis of the consequences and possibilities of such changes. In the present situation in both Denmark and the Baltic countries feasibility and public regulation studies therefore must include a description of the character of the technological and institutional context.

1.2 The Character of Technological Change

The existing energy system is characterized by at the one hand often large electricity and heat supply companies, and at the other hand many differentiated consumers divided into households and public and private enterprises.

The existing *supply system* is characterised by

- *single purpose* companies, i.e. enterprises which have production and/or sale of energy services as their only purpose.
- being *sectorized* in heat systems, electricity systems, natural gas systems, etc.
- having investments that are *capital intensive* and almost 100% *asset specific*. By asset specificity is meant, that the assets, district heating systems, power stations, power grids, etc. can only be used for their present purposes.
- having investments in equipment with a very *long technical lifetime*, often 20-40 years.
- often being organisationally linked to fossil fuel-based systems.
- being consolidated from a capital point of view.
- being consolidated from a political point of view.

The existing *consumers' system* is characterised by

- many *multipurpose* organisations, by which is meant, that the households, and private or public firms have other main purposes, than for instance investing in electricity and heat conservation.
- organisations with a lack of capital for investing in energy conservation activities.
- having no common organization of the electricity- and heat conservation activities.

The necessary technological changes cannot be implemented by “end of pipe” solutions such as for instance rebuilding the existing energy system by building better power plants, undertaking smoke pollution abatement measures and building heat pumps for electrical heating. Such solutions are not sufficient when wanting to decrease for instance the CO₂ emissions by 50%-80% within a period of 20-40 years. Conservative “end of pipe” solutions are not even sufficient for countries who find it necessary just to make their existing energy systems function.

The existing energy system shall naturally function from a technical point of view, but at the same time it is necessary to keep the innovative perspective alive. If countries with very scarce financial resources undertake a very defensive attitude towards participating in the needed technological innovation processes at the energy scene, they will stay behind in the technological development process, and continue to be dependant receivers and not developers of new technology. It therefore is necessary to be able to discuss solutions which go beyond the short term "end of pipe" thinking. The implementation of such solutions demands not only technical changes but also changes in organisation, knowledge, infrastructures etc.

In order to localize the need for institutional changes, it therefore is necessary to establish long term technical scenarios. Such scenarios have been developed in several countries within the last 20 years, and they all end up with the following main groups of technologies:

- (a) Energy conservation technologies within heat as well as electricity at the consumer level.
- (b) Renewable energy systems, e.g. wind generators, biomass energy, wave generators, direct solar energy, etc.
- (c) Improved efficiency of supply systems, which are based on fossil fuels (including uranium). Essentially is the change to co-production of electrical power and heat in DCHP systems (Decentralized Combined Heat and Power production).

These are the technological categories, which have been included in official Danish Energy Plans such as "Energy 2000" (Ministry of Energy, 1990) and "Energy 21 " (Ministry of Energy, 1996). Those plans show how CO₂ emissions in Denmark can be reduced by at least 20% before the year 2005, and 50% before 2030.

As opposed to the old technologies such as coal-fired power stations, the above mentioned new technologies are being widely distributed throughout the geographical areas of consumption, and the implementation is therefore characterised by the following:

- The technical solutions will *differ from one place to another* and sometimes new, partly unsafe and not well-proved technologies will have to be implemented. The maintenance of such new technologies will depend on ownership and organisation. Along with the implementation of new technologies it is therefore likely that *new types of organisations* will evolve. Maintenance of biogas plants and straw-fired district heating systems have already brought about new organisations in which corporations of farmers own one part of the plants while corporations of district heating consumers own the other part.
- Investments will have to be carried out by *multipurpose* organisations. Thus, electricity savings will have to be implemented by private households and industries with only little awareness of electricity consumption and with quite different main objectives than producing or consuming electricity. This has to be compared with the former situation in which investments in supply technologies were carried out by *single purpose* organisations such as utility companies and gas supply companies with energy production as the main objective.
- The technologies will have to be implemented by many *mutually independent* organisations. Again this has to be compared with the former situation of a limited number of utility companies.
- The financial capital of these new organisations will often be comparatively scarce in relation to the financial capital of the fossil fuel supply companies.
- The political capital of these new organisations will be relatively scarce, compared with the existing fossil fuel companies.

All together, the technological change can be seen as a change from undifferentiated solutions implemented by few single-purpose organisations to differentiated solutions implemented by many multipurpose organisations (Hvelplund, 1995). And this rather radical change in technology is a challenge to Public Regulation. The character of this challenge can be shown by figure 1.2.

The above-mentioned characteristics of the needed technological innovation at the energy scene require the following political and institutional capabilities of change:

- (a) The capability to cross the boundary between the supply system and the consumers' system in order to make the consumers cope with the dynamics of the suppliers.
- (b) The capability to escape from fossil fuel systems, and to replace these with renewable energy sources.
- (c) The capability to break with the mono structure of electricity supply and enter a combined district heating and power supply (co-generation) structure.
- (d) The capability to cross the boundary between the short term optimizing of existing technological systems, and the long term development of new technological systems.

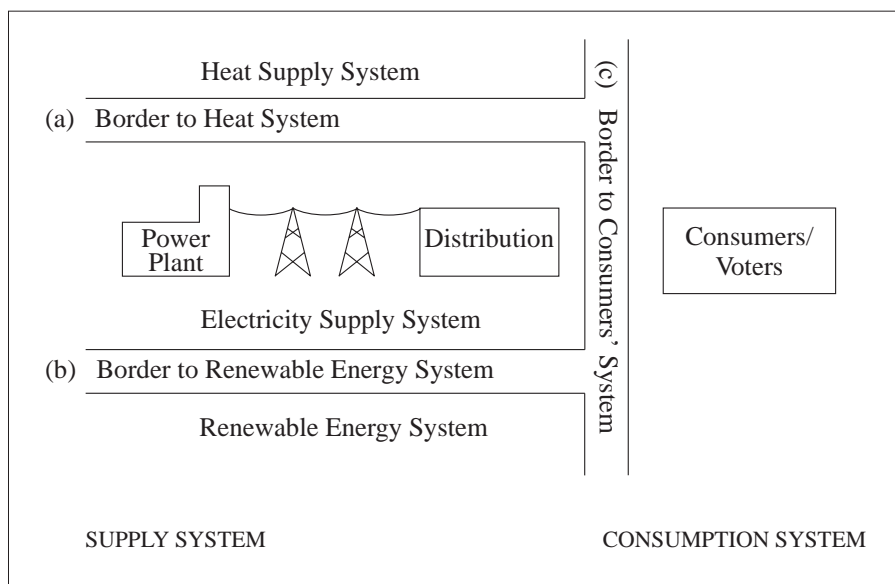


Figure 1.2: The “spatial” boundaries that energy systems must be able to cross. The figure shows the supply system and the consumer system, and the borderline (c) between those two main systems. It also shows the borderline between the heat and electricity system (a), and the borderlines (b) between the renewable energy supply system and the fossil fuel-based energy supply systems.

In order to transcend the above borderlines technically, it is necessary to establish institutions that make the crossing of the line possible. Politically this has always in Denmark been done in a process of conflicts. The borderlines, around existing institutional and organizational settings, cannot be crossed by the settings themselves. One cannot expect that an electricity company which is accustomed to building and use large coal-fired plants will initiate the introduction of DCHP plants or electricity saving programs, when the consequence is that part of the companies employees will be fired, and the total turnover of the company will decrease. The existing power companies have their comparative technological advantage within the centralized coal plant technology, and a change to DCHPs will be a change to a technology where this comparative advantage does not exist, neither technologically nor organisationally. Therefore such a change is risky for the existing power companies and it could be expected that they have a tendency to use their power to avoid such a transition.

1.3 The Character of Market Institutions

Every market economy is formed by a number of market institutions. In Neoclassical economy those institutions are often regarded static and non changeable. But in the case of implementation of technological change changes in market institutions are needed.

Neoclassical Economy

Neoclassical economy is based on the concept of a free market. The "free market" in the sense described by Adam Smith requires among others the following institutional preconditions:

- Many mutual independent suppliers of a product.
- Many mutual independent buyers of a product.
- Full information regarding quality and prices of products at the market.
- Agents at the market, with rational behaviour.
- Sellers that maximize profits and buyers maximizing utility.

When these and other conditions are fulfilled, it is argued, that the market is a democratic place, where the free and rational buyers with full information about their opportunities, by means of their money notes, are buying ("voting " upon) the goods which they want. Therefore, when the above mentioned institutional preconditions are present, the outcome of the market process is based upon the "votes" of free voters with full information, and any interference into this free market "voting" process is regarded as

undemocratic. It is worthwhile to emphasise, that a "free market" is not a market without public intervention, but a market where the public regulation in some decisive way acts to establish and maintain the institutional preconditions of the free market.

Most market economies are mixed economies consisting of a private and a public sector. In the private sector there is an exchange on a market, based upon supply and demand, between sellers and buyers of goods, labour and capital. The public sector redistributes incomes, and produces, mainly outside the market, goods and services.

In neoclassical economy the economy is usually considered as having the following characteristics: Regarding *the market*, it is considered as having the characteristics of a "free market", which means,

- that activities at the market are a result of well informed, free and rational agents each optimizing their utility function (premise(1)),
- that there is no private regulation of the market influencing the allocation process (premise(2)).

Regarding the *relationship between the public sector and the market sector* is in neoclassical economy mostly described as having the characteristics:

- Parliaments are via public regulation measures autonomously constructing the laws and institutional framework of the market.
- Taxes are defined as neutral from an allocation point of view.
- Goods and services from the public sector are defined as neutral from an allocation point of view.

Consequently in neoclassical economy the public sector is defined as neutral regarding its regulation effects upon the market processes (premise (3)).

The combination of the premise (2) and (3), that the private and the public sector do not distort the allocation process of the market, and premise (1), that the market process is governed by free, rational and well-informed actors, has as its consequence, that the production at a given point of time can be regarded as *optimal*. *This premise of optimality is a precondition in most of the econometric models, inspired by neoclassical economy thinking, being used for energy planning purposes by macro economists.*

From this premise that *we are living in the best of all worlds*, can be deduced, that any change away from this optimum is considered as representing socioeconomic costs for society. Any policy implemented to

reduce greenhouse gas emissions is, for instance, in all computations regarded as causing extra costs to society. In these econometric models there is no such thing as systematical institutional mistakes in the economic process. This premise is wrong. It is necessary to see the economy as an institutional economy, where the present situation very probably may not be socioeconomically optimal at all.

Towards an institutional economy

The design of a successful energy policy cannot be found from analysis based on the abovementioned precondition. The main problem is, that the needed technical solutions, which secure the possibility of transgressions described in figure 1.2, requires new organizations and new institutions. The neoclassical model does consider the institutional conditions as given and not within the reach of systematic public regulation. It is essential to distinguish between the "*free market*" as it is described above, and the "*real market*" with its institutions at a given place and a given time.

The "real market" is the market with its specific institutions as they are in reality, regarding private market power, public regulation, the infrastructure, information accessibility, business structure, etc. etc. This market very often has a considerable level of private regulation. Especially the energy scene is monopolistic or oligopolistic, with one or only a few suppliers of given goods. Or it can have many suppliers, which are interconnected by ownership relations and therefore are not mutual independent. Often information is kept secret by referring to the commercial interests, despite the fact that full information and openness are preconditions for well functioning free markets. All together the "real market" does not fulfill the institutional preconditions of the "free market" of the economic textbooks. The interplay between the "real market" and the "free market" is often one of ideology, where the strongest actors at an oligopolistic "real market" uses the ideology of the "free market" to argue for no public regulation, without to remove their own private regulation of the market. The argument, "let the free market decide" is, in the world of reality, often synonymous with the sentence "let us decide". "Us" means the largest energy supply companies at an oligopolistic market with only a few suppliers.

Also, the "free market" premise of the public sector being neutral with regard to the market allocation processes is not fulfilled. It seems obvious, that the use of public money for education, roads, harbours, defence, medical cares, etc. all have different effects upon the direction the market processes

are taking. A high level of infrastructure investments in roads will support the sections of economy linked to the car industry. Military expense's supports economical sectors linked to the military projects of a given period. The examples are infinite, wherefore we do not believe in the premise (2) which tells, that the activity of the public sector does not influence the direction of the market processes. So even if the market sector was "free" in the sense of the textbooks on economics, the market would still not be free, due to the interference of the public sector. It therefore can be concluded, that in the world of market realities, there is always one or another form of either public or private hierarchical regulation. Regulation defined as any organised, purpose directed influence upon the framework of the market and organisation of cooperation at the market.

1.4 Feasibility Studies and Public Regulation

Regarding the present technical and institutional situation the following can be concluded:

Technology should be regarded as consisting of technique, organization and knowledge. If only the technique component is changed, we define it as an "end of pipe" solution. An example could be increased efficiency of the same technique as before, for instance smoke abatement measures, a better power plant, etc. *In a large number of energy plans it is concluded, that "end of pipe" solutions are not sufficient, and that an energy conservation strategy requires changes in the combination of technique, organisation and knowledge.*

The established energy supply companies are capital intensive and have techniques with a long technical life time. At the same time this equipment is almost 100% asset specific, which means, that it cannot be used for other purposes, than energy production and distribution. When this is combined with the fact, that established supply companies often are comparatively financially strong and have established considerable political backing, it becomes difficult to introduce new technologies, which takes market share away from the established companies.

The result of these difficulties is, that *feasibility studies and public regulation analysis are often influenced by the interests and thinking of the established energy supply companies. This often means that public planning tends to favour short term considerations, as short term solutions are*

organisational conservative and supports the interests of the established energy supply companies. The results of such planning procedures are "end of pipe" solutions in existing organisations; i.e. better power plants, smoke pollution abatement measures, heat pumps for electrical heating, etc.

The precondition that the "real market" is in economic optimum, as it is usually supposed in macroeconomic models, is not realistic. For one thing, the market sector itself does not function according to the institutional presumptions of the "free market" ideal. Any market, and especially the market for energy is regulated either by private or public organizations. The public must be able to distinguish between the "free market" utopia of the textbooks and "real market".

Using market forces as one of the mechanisms of allocation is often advisable. If the public regulation process decisively supports the preconditions for a "free market" it can be a part of a regulation process which supports the transgression of the boundaries of figure 1.2. This for instance, is done by removing the barriers to entry at a regional level, so that decentralized renewable energy technologies can get market access. By supporting a tariff policy, with a very low fixed share.

Instead of taking the neoclassical economic optimum as the point of departure, any public regulation activity has to begin with some very concrete analyses of the institutional context around the given project in the given country/region. This is not an easy task, but a rather interesting one, as it can, potentially, result in the finding of projects which are both economical and environmentally feasible from a socioeconomic point of view.

The above-mentioned conclusion regarding the present technical and institutional *situation* has the following consequences for feasibility studies and public regulation analysis.

Socioeconomic feasibility studies should:

- Perform analysis with a very long time horizon in order to find the best solutions relatively independent of existing technical systems.
- Analyse the bindings of existing technical systems. This is especially important under conditions of overcapacity in the energy system. A system with overcapacity tends to result in either energy prices close to the short term marginal costs, or a pressure from the energy companies upon the political process, urging the politicians to protect the existing

energy companies from the competition of newcomer technologies. In figure 1.3 we call this process the “sunk cost” trap.

- Analyse the links between the economy of a project, and the future changes of the technical energy system. If we are dealing with an energy conservation project; which impacts would a period of overcapacity have upon our project? What happens to the economy of solar heating systems in a system with much nuclear power, or a system with much cogeneration? Etc. Etc. We call this technical sensibility analysis.
- Analyse the links between the economy of the project and the legislation which is necessary for the feasibility of the project. What happens if a carbon dioxide taxation is introduced? What happens if the rules assuring the right to sell electricity to the public grid are abolished? What happens if economic policy results in increased interest rates? Etc.Etc. We call this for institutional sensibility analysis.
- Analyse the links between the above institutional sensibility analysis and the political process. Which agents at the energy market have the financial and political motivation to “kill” newcomer technologies? Are there counter forces which can support the newcomer technologies? How can the political balance of power at the energy scene be described? Which political scenarios can be developed, and which effects will they have upon our project? We call this analysis political sensibility analysis.

Public regulation analysis should:

- Analyse not only regulation by means of taxes and subsidies, but also regulation by developing new institutions around the market.
- Be aware of the asymmetry of financial power between the old fossil fuel-based technologies, and the new energy conservation technologies. Often public regulation measures will not require subsidies for the new technologies, but just equal terms with regard to financial possibilities, by removing the capital advantages of the existing energy companies.
- Be aware of the asymmetry of political power between the old fossil fuel-based technologies and the new energy conservation technologies. Often it is necessary to create organisations within research, price and monopoly control, advisory committees, and funding, which are totally independent of the established fossil fuel companies.

The consequences, and their links to the description of the historic technical and institutional situation are shown in the figure 1.3.

Present technical and institutional situation	Consequences for socioeconomic feasibility studies	Consequences for public regulation proposals
Existing technological system: <ul style="list-style-type: none"> - Single purpose companies - sectorial companies - Long lifetime of investments - 100% asset specificity - Strong from a capital point of view - Politically strong 	(1) Necessary to make feasibility studies with a long time horizon (2) Necessary to be aware of the “sunk cost “ trap, binding the future technologies to the old technologies.	(1) Public regulation which is able to generate change and transgress: <ul style="list-style-type: none"> (a) The sector boundaries. (b) The “sunk cost” bindings.
Coming technological systems: <ul style="list-style-type: none"> - Multi purpose organisations - Technology differs from place to place - Long lifetime of investments - 100% asset specificity - Weak from a capital point of view - Weak from a political point of view 	(3) Necessary to make thorough analysis of the innovation consequences of different projects. (4) Necessary to make technical sensibility analyses in order to evaluate the effects of a given project in different technical systems.	(2) Establish a technological development process, which is independent of the existing fossil fuel companies. (3) Establish rules at the market, which makes the existing technical system open for new technologies.
General market conditions: <ul style="list-style-type: none"> - The existing situation is not optimal - Economy consists of market+ institutions - There is public as well as private regulation of the allocation processes. 	(5) Necessary to analyse the links between institutional conditions at the market and the economy of a project (institutional sensibility analysis). (6) Necessary to analyse the links between socioeconomic of a given project, and the political conditions influencing this economy (political sensibility analysis)	(4) Establish a public regulation, which makes it possible to establish new institutions. (5) Suggest improvements in the political process , so that it can become increasingly independent of the fossil fuel technologies.

Figure 1.3: The present technical and institutional situation and its consequences for socioeconomic feasibility and public regulation studies.

Chapter 2

Feasibility Studies

In chapter 1 we developed a set of **general guidelines** linked to the present technical and institutional situation, regarding the contents of feasibility studies. In this chapter we deal with two main areas:

- The development of a procedure helping to decide how feasibility studies should be performed in different situations (chapter 2.1).
- A concrete description of principles and methods of socioeconomic feasibility studies in particular(Chapter 2.2).

The procedure of performing feasibility studies may be divided into the main steps described in figure 2.1.

Step 1	Step 2	Step 3
What should be studied? Alternatives). For whom should it be studied? Why should it be studied?	How should it be studied? (The Diamond-E-analysis)	Implementation of the feasibility study according to the concept developed under step 1 and step 2.

Figure 2.1: The main steps in a feasibility analysis

Step 1 deals with *what* should be studied and for *whom* and *why* should it be studied(The www- analysis).

Step 2 deals with the detailed design of the contents of feasibility studies (The Diamond-E analysis).

Step 3 deals with the concrete feasibility study and requires the major part of the feasibility study work.

2.1 Performance of feasibility studies in different situations

Step 1: The www-analysis

Some very important questions to be answered, when designing feasibility studies are: *what* should be studied, for *whom*, and *why* is the study made (www-analysis). Furthermore these questions have to be placed in a context, where the *time horizon and time priority* in the feasibility study is decided upon. When these questions have been answered, we can begin systematically to find out, *how* a specific feasibility study should be performed; i.e. questions like *which consequences* of a project one should analyse, and *how such analyses should be carried out*.

What should be studied?

The studies can be *single project* analyses, where for instance a power plant, a heat plant, a combined heat and power plant, energy conservation measures in an apartment complex, etc.etc., is analysed. This type of studies may, for instance, be performed by means of Kvdesign. The studies may also be *energy systems* analyses, where an energy scenario consisting of a set of technologies is analysed. The SESAM program can be used for this type of analysis. At present it is common to make *single project* analyses without any systematic discussion concerning the effects of different future energy scenarios upon the economy of the single project. But the situation has changed in such a way, that *single project* analyses are no longer sufficient, neither when making business - nor socioeconomic feasibility studies.

It is important to note that the energy efficient technological systems needed are characterized by *an increasing number of interrelations* between the components of the system. The necessity of analysing the interrelationship between electricity and heat production, when cogeneration is increasing its share of the market, is one of the more obvious examples of this development. Furthermore the expectancy of long technical life for the transmission and distribution system of any power or heat production and the even longer life often expected from conservation improvements in buildings, makes it likely that the newcomer technologies could be very different from the technologies of today, within the lifetime of a power plant built today.

Concludingly it is emphasized that feasibility studies of power plants, distribution systems and efficiency improvements at the consumer level should include studies regarding the feasibility of the specific investment

seen in relation to scenarios of technical changes in the energy system of which it is a part. Calculation tools for this analysis are the Sesam model and Kvdesign.

For whom and why are feasibility studies made?

Feasibility studies can be made for the national government, municipalities, energy supply companies, housing companies, private companies, etc.etc. The direct purpose of such studies may be to demonstrate the necessary documentation when for instance deciding which investment to choose among technical alternatives and which implementation strategy to choose among implementation alternatives. The same applies when demonstrating documentation regarding project feasibility in connection with applications for for loans.

As mentioned in chapter 1, feasibility studies are often divided into *socioeconomic feasibility studies, where the purpose is to examine whether a given project is feasible from the point of view of the society as a whole, and business feasibility studies, where the purpose is to examine whether a given project is economical from the point of view of a specific firm.*

When dealing with the above division, we find it important to point out, that it gets less important, in very long term infra-structural projects. In projects with a technical life of 20-40 years, the technical and institutional conditions around the project will change very much during its life time.

When dealing with such time horizons, it is therefore necessary to analyse a broad spectrum of socioeconomic consequences of different energy scenarios. Within a time span of 20-40 years it has no sense to calculate as if the legislation, technological possibilities etc.etc. would not change. Within such a time span tough CO₂ taxation policies could be carried out, making for instance coal based energy systems obsolete many years before they are technically worn down.

In figure 2.2. the relationship between business, socioeconomy and public regulation is illustrated for capital intensive technologies with a long technical lifetime.

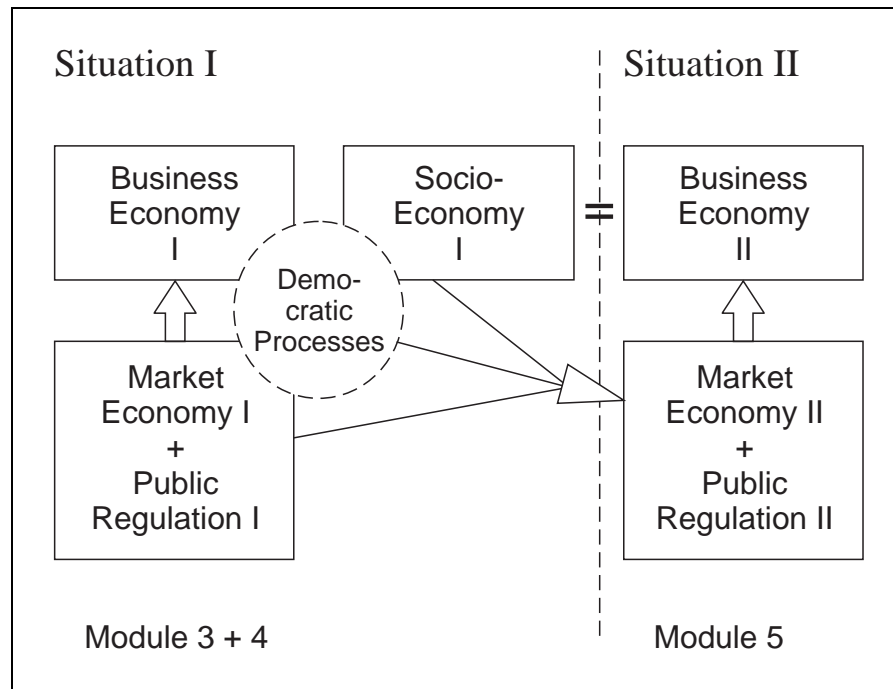


Figure 2.2: The relationship between business economy, socioeconomy and public regulation.

The figure shows that in Situation I you have specific conditions in the market and a specific legislation (public regulation I). Under these conditions there might be economic conditions favouring the existing technologies based upon extensive use of fossil fuel. And the economy in energy conservation might be bad from a business economic point of view (business economy I). Nevertheless socioeconomic feasibility studies (socioeconomy I) might show, that development and investment in cogeneration, renewable energy and energy conservation might be feasible from the point of view of society as a whole. If that's the case, we shall find ourselves in a situation, where what is good for society is not good for business. This situation is then discussed in the democratic institutions (the dotted circle), including Parliament, and a "public regulation II" is developed and implemented. This public regulation should assure that what is best from the point of view of the society is also best for business, as a business economy II is established, which results in the same priority as socioeconomy I. Now an ideal situation is established, where the market companies will act in accordance with what is best for society.

In Situation I in figure 2.2, a *company* who wants to investigate whether a cogeneration plant, investments in conservation measures, etc., should carry out business feasibility studies (evaluate business economy I) in order to estimate the economic consequences under given institutional and technical conditions (market economy I, and public regulation I). But we *also recommend*, that the same company performs socioeconomic feasibility studies (analyse socioeconomy I) in order to evaluate the socioeconomic feasibility studies, which the government might be making. In this way a company might find out in advance which types of changes in public regulation (public regulation II) the Government could introduce.

The *government* should carry out socioeconomic feasibility studies (analyse socioeconomy I) in order to develop an energy policy which pursues the goals of society. But we *also recommend*, that the government undertakes business economic feasibility studies (analyse business economy I) , in order to understand the calculations made by the companies under the given market conditions.

Concludingly it is emphasized, that both business - and socioeconomic feasibility studies should be elaborated by both governmental institutions and private organisations.

An Example:

In figure 2.3, the difference between the type of socioeconomic feasibility studies made by the Danish administration and business economic feasibility studies is resumed. It should be emphasized, that this is an illustrative example, just to show what it is all about. It does, however, not encompass all the features which according to this chapter, should be contained in feasibility studies.

Handling of costs and income data	Socioeconomic feasibility studies as they are carried out in the Danish energy planning procedure	Business economic feasibility studies
Scenarios regarding costs and prices	Exclusive taxes on goods and services	Inclusive all taxes
Energy price scenarios	According to estimates made by the Ministry of Environment and Energy	According to estimates made by the company for whom the study is made
Interest calculation-rate	In Denmark a "net" interest calculation rate of around 7% p.a.	Usually scenarios regarding interest rates at the market.
Environmental costs	Are included, either as a cost assessment or as an emission limit	Normally not included.
Employment effects	Considerations are included	Normally not included
Importation effects	Considerations are included	Normally not included

Figure 2.3: An example of the difference between business and socio-economic feasibility studies.

Which time horizon and time priority should be used?

The time horizon is the period within which our calculations are made. When dealing with single investments the time horizon is often equivalent with the expected technical life time of the investment. When dealing with energy systems and energy scenario developments the time horizon is chosen in accordance with the specific purpose of the study. Regarding time priority, this refers to the priority within the time horizon. This priority is usually effectuated by means of a calculation interest, giving relatively higher values to costs and incomes in the near future, than costs and incomes in the far future.

It is characteristic for the present dynamics in the market, that many firms optimize their investment decisions by looking only at their short term marginal costs particularly when they have overcapacity and scarce financial resources. It is even more characteristic, that public energy planning is dominated by optimization based on such short term optimization of existing plants and energy systems. At the same time the needed technological changes reinforce the need to establish long term strategies.

Important questions when preparing feasibility studies	Questions in relation to present situation of change	Important answers when preparing feasibility studies
What should be studied?	Energy efficiency scenarios implicate an increased level of interrelations between the different components of the energy system.	The feasibility of a specific project should be seen in relation to scenarios of technical changes in the energy system of which it is a part.
For whom and why are feasibility studies made?	Energy techniques have a long life time (20-40 years). Within this period technical as well as institutional conditions will change.	Both governmental and private organisations/investors who carry out feasibility studies should elaborate business as well as socioeconomic feasibility studies. This combination would include analyses of the long term processes of technical and institutional changes.
Which time horizon and time priority should be used?	Tendency for short term optimization, which is in conflict with long term strategy.	Feasibility studies should include studies of the socioeconomic consequences of the conflict between short term optimization and long term strategies of technological innovation. (SESAM is one tool for this analysis).

Figure 2.4: Important questions and important answers, when preparing feasibility studies.

This situation of economic conflict underlines the necessity to concentrate upon the very difficult task of establishing a short term policy, which is synchronized with the long term strategy. The difficulties are caused by the fact, that in the present situation of technological change within the energy area, there is a relatively strong contradiction between what is economic within a short term perspective, and what is the best long term energy strategy. But although not easy, the task should be carried out, and it is therefore unwise to divide sharply between short term and long term effects of investments and investment scenarios. The analyses should rather focus upon making an “analytic” bridge between short and long term effects of investments or investment scenarios in order to find “economic” transition paths between the existing technologies and the necessary future technologies.

Concludingly we therefore emphasize the necessity of integrating the near future with the long term perspective, in business- as well as in socioeconomic feasibility studies. In figure 2.4 the above discussed important questions are linked with some important answers.

Step 2: The Diamond-E analysis

After *step 1*, the www analysis above, we establish a set of criteria telling us which consequences of a project one should analyse, and how such analyses should be carried out. A way of systematizing this analysis is to use the Diamond-E framework described in figure 2.5 is useful.

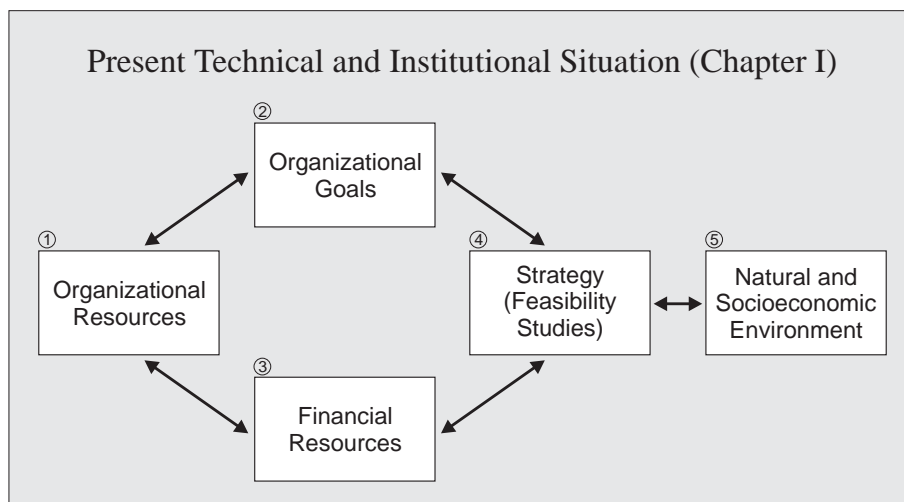


Figure 2.5: The diamond-E framework. Feasibility studies are elaborated as a tool in the process of designing a strategy (box1). This design of strategy is, in the Diamond-E (Fry 1986) framework a part of a system consisting of:
a) Organisational goals (box2)
b) Organizational resources (box3)
c) Financial resources (box4),
d) Natural and socioeconomic environment (box5)

The discussion regarding the exact design of feasibility studies may pass through an analysis of each of the areas a),b),c) and d). This discussion is coloured by the background discussion in chapter 1, regarding the “present technical and institutional situation”.

One can design a feasibility study by discussing a combination of organisational goals, organisational resources and financial resources, all of it seen in relation to the natural and socioeconomic environment.

Organisational goals:

If the organisational goal includes a demand for technological innovation, employment generation, national energy independence and environmental sustainability, then the feasibility study should naturally focus upon the effects within these areas. If the goals are more short term economics, then the feasibility study should concentrate on these goals. *A feasibility study must relate to the specific goals of the project investor. This also means, that in any feasibility study, these goals must be made explicit and open.*

Organisational resources:

If the organisational resources are of such a character that good skilled workers and factories are available who are able to build and maintain a new cogeneration plant, then this technology is a rather uncomplicated possibility. If there are good skilled workers and firms available who are able to improve the energy efficiency of the buildings, then this type of investment is also relatively uncomplicated. If these organisational resources are not available, then education programmes might be necessary before investing. Or it might be necessary, in initial stages of investment, to import “turn key” projects. But quite often this is not easy from a financial point of view. *A feasibility study must locate and relate to organisational key characteristics, linked to the implementation of a specific projects.*

Financial resources:

Obviously the access to financial resources may influence the focus of feasibility studies. If for instance the consumers have a low ability to pay their bills, feasibility studies should focus upon this problem. If this is not a problem, feasibility studies may focus upon other areas. If the financial situation is characterized by turbulence, with inflation risk, devaluation risk, etc. etc., then feasibility studies should establish sensitivity analysis around these topics. So before designing the feasibility study, one should establish a preliminary profile of the financial opportunities and problems. *A feasibility study must relate to the financial key characteristics, linked to the implementation of a specific project.*

Natural and socioeconomic external environment:

Which demands regarding air pollution, for instance green house gas emissions will develop in the international community? How do such demands influence the loan conditions, when borrowing money in international banks? Regarding the socioeconomic environment, it seems obvious to include considerations regarding the ongoing “liberalization” process in the electricity and gas sector within the European Union and Scandinavia. It might also be worthwhile to analyse the development of

ownership structure in the energy sector. In the Baltic countries the impact of the “Baltic ring” activities could be of interest. *A feasibility study must relate to the main external socioeconomic and environmental impacts.*

In the following a couple of Danish examples illustrate what is meant by using the Diamond-E framework. These illustrations would be far more comprehensive in a real feasibility study.

<p>Diamond-E analysis</p> <p><i>Organisational goals:</i> Among others the goals of the Danish energy policy (Danish Ministry of Environment and Energy, 1996), are to assure:</p> <ul style="list-style-type: none"> - That the Danish CO₂ emission is reduced by 20% from 1988-2005 - That energy efficiency is improved by 20% from 1994-2005. - That the proportion of renewable energy is increased to between 12-14% of the total energy consumption in 2005, - That a flexible, robust and cost efficient energy system is developed. - That the public is engaged in formulating the objectives of energy policy. <p><i>Organizational resources:</i></p> <ul style="list-style-type: none"> - A population which can participate actively in political processes. - A business structure with many small firms, 250,000 - 4,500,000 without employment. - A demographic structure with many people in the work force until around 2010. After that the work force will decrease with around 200,000 persons. <p><i>Financial resources:</i></p> <ul style="list-style-type: none"> - A rather weak economy in the sense, that there is a high level of foreign debt. - A high level of public debt. - A rather stable economy, where the consumers can pay there energy bills. <p><i>Natural and socioeconomic environment:</i></p> <ul style="list-style-type: none"> - A high Danish greenhouse gas emission, which makes it environmentally and politically necessary to lower the Danish greenhouse gas emission. - In Europe an increasing level of so-called liberalization reforms take place in the energy markets. - There is a tendency of internationalizing ownership of energy systems. - A very open economy which making the Danish international competitiveness sensitive to any implementation strategy within the energy area. - A period from 1995 to around 2010- 2020 with a high level of oil and natural gas self sufficiency. After this period Denmark, and Europe are again increasingly dependant upon oil from the Middle East. 	<p>Proceeding from the Diamond-E framework analyses to its consequences for the design of feasibility studies required in the specific analyses, we state the following about the Danish energy planning case:</p> <p>Consequences for the contents of feasibility studies</p> <p>The <i>organisation goals</i> tells that</p> <ul style="list-style-type: none"> - examining energy efficiency scenarios is essential. - examining the technical robustness and flexibility of scenarios is important. - the suggested solutions should be calculated in a way that makes it possible to establish a participatory planning process. <p>Analyses of the <i>organisational resources</i> tell that</p> <ul style="list-style-type: none"> - Analysing the employment effects of different scenarios is important, - calculations should be made where labour has a rather low shadow value - energy strategies with a focus upon decentralized technologies should be analysed, as they might fit well with the Danish industrial structure, - accelerated investments in energy efficiency measures before 2010 should be represented in the Scenario analysis. (High unemployment rates combined with a relatively high percentage of the population in the labour force until 2010). <p>Analyses of the <i>financial resources</i> suggests that</p> <ul style="list-style-type: none"> - proposed public regulation's schemes should not increase the public debt or the foreign debt. Taxes should finance subsidies. <p>Analyses of the <i>natural and socioeconomic environmental</i> conditions suggest that,</p> <ul style="list-style-type: none"> - solutions should be analysed regarding their effects upon the international competitiveness of the Danish firms, - solutions should be analyses regarding their robustness within the ongoing "liberalization" and internalization processes within the energy area. - solutions should decrease the Danish dependence upon fossil fuels considerable before the year 2010.
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Example 2: The Sønderholm DCHP case

<p>Diamond-E analysis</p> <p><i>Organisational goals :</i></p> <ul style="list-style-type: none"> - To decrease expenses in a long term perspective without higher short term heat prices than now. - To have a stable heat supply system. - To establish a heat supply system without direct consumer investments. <p><i>Organisational resources:</i></p> <ul style="list-style-type: none"> - 259 households who want to establish a DCHP plant, if they do not have to spend time organizing the implementation of a DCHP. - A group of 4-5 persons which are willing to spend time in organizing the feasibility studies and the implementation of a DCHP. - Consultancy companies and production companies who are able to deliver trustworthy advice and reliable hardware. <p><i>Financial resources.</i></p> <ul style="list-style-type: none"> - Consumers which are willing, and able to pay the heat bill. - A public guaranty for loans in district heating systems. - A financial system which is able to supply long term index regulated loans for district heating systems. <p><i>Natural and socioeconomic environment:</i></p> <ul style="list-style-type: none"> - A public policy which includes DCHP as an important part of necessary energy conservation activities. - A public policy giving municipal guaranties for investments in district heating systems. - A public policy establishing the necessary institutional conditions, making DCHP economically feasible. - A public energy policy willing to support DCHPs against the attacks from the established power companies. <p>Consequences for content of the feasibility studies</p> <p><i>From organisational goals:</i></p> <ul style="list-style-type: none"> - The implementation alternative should look for financing models assuring, that the future heat prices are not higher than the oil furnace alternative. - The consumers do not require nor expect decreases in heat prices the first years . <p><i>From organisational resources:</i></p> <ul style="list-style-type: none"> - Solutions which are robust and with low maintenance costs should be preferred, and therefore thoroughly analysed. 	<ul style="list-style-type: none"> - Evaluating different technical solutions is possible, due to a gender group of 5-6 very active persons in the village. <p><i>From financial resources we have:</i></p> <ul style="list-style-type: none"> - Due to a municipal guaranty, it is possible to establish a district heating system , although it includes rather high investments. On the other hand it should be emphasized, that index regulated loans is a relatively unknown method of financing, and it might be difficult to understand what happens in conditions of inflation in connection with lowered wages and pensions. - Therefore there has to be a focus upon a very thorough set of sensibility analyses, to prepare measures to be taken in the different risk situations. This process should include that the management of the local DCHP plant is completely open towards the consumers regarding the risk situation and the risk management. <p><i>From natural and socioeconomic environment we have:</i></p> <ul style="list-style-type: none"> - Some difficulties with the established electricity power stations, which tend to be unwilling to pay the long term marginal avoided costs for the electricity which they buy from the electricity companies. Therefore, the feasibility study should include sensibility analyses regarding changes in the price on electricity sold to the public grid. - The same type of problems with the natural gas company and the same reaction regarding sensibility analyses. - That an association of DCHP plants has to be organized to protect the necessary “frame conditions” on the market. - An upcoming “liberalization “ of the electricity and gas market might change the economy of Sønderholm DCHP substantially. <p>The consequences for the feasibility study are:</p> <ul style="list-style-type: none"> - Considerations regarding the political risks, and especially their possible consequences upon the economy of the plant is necessary. - Considerations regarding the political strenght of the relatively new DCHP organisation. To what extent can it cope politically with the power- and gas companies. - Also from this point comes, that it seems very important to make many sensibility analyses, to establish risk management procedures and to assure total openness regarding these procedures, so that they are easily understandable for the consumers.
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2.2 Step 3: Socioeconomic feasibility studies

	Socioeconomic analysis
<u>The space dimension</u> (a) The interdependence between a technology and the surrounding energy system. (technical sensibility analysis)	- the economy of single technologies as a function of the surrounding energy system. - sensibility to overcapacity in the surrounding energy system
(b) Analyses the interrelations between the project and the socioeconomic environment. (institutional and political sensibility analysis)	- employment effects - foreign exchange effects - income distribution effects - effects on state finance - balance of power in the existing market - political situation around essential legislation.
(c) Analysis of the environmental effects of energy investments.	Analysis of environmental effects, for instance: - risk area connected to greenhouse gas emissions, and other types of air pollution. - ground water pollution, radiation, resource depletion, etc.etc.
<u>The time dimension</u> (a)Time priority	- selection of an interest rate to be used in calculations. - analysis of interest rate built into existing organizations
(b) Impacts of historical investments.	- analysing how to handle “sunk costs” in the alculations. - analysing the sensitivity to sunk costs in the surrounding energy systems
(c)Technological development	- analysis of the effects upon technological development.
<u>The risk dimension</u>	- Sensibility analysis linked to different scenarios/single technologies.

Figure 2.6: The areas of space, time and risk in socioeconomic feasibility studies.

From chapter 2.2. we have gone through the www- analysis, step 1 , and the diamond-E analysis step 2 in the feasibility studies. Here, in *step 3*, the socioeconomic feasibility study designed in step 1 and 2 will be performed. In this chapter we discuss some important methods to be used, when performing a socioeconomic feasibility study. From Chapter 1 figure 1.3. we have developed some requirements which socioeconomic feasibility studies should fulfill. They are resumed in figure 2.6 and discussed in detail in this chapter. The requirements are divided into the geographic space dimension, the time dimension and the *socioeconomic* risk dimension.

By the *space dimension* we mean that we go from the *near surroundings*, the energy system environment, to the *more distant* general socioeconomic surroundings and to *far away* surroundings, the relationship to for instance global clima. By the *time dimension* we mean how the time horizon is treated

in our calculations. The *risk dimension* is linked to both the space and the time dimension. The longer the time horizon the more difficult to foresee, what could happen.

The Diamond-E analysis helps to decide the specific content of a feasibility study as described above. Example: In the case of the Danish energy policy this Diamond-E analysis tells that feasibility studies should include:

- Energy efficiency and low greenhouse gas emission scenarios.
- Examinations of employment and balance of payment consequences of different scenarios.
- Examination of strategies that donot increase the public debt.
- Examinations of strategies that do not impede the international competitiveness of the Danish industry and agricultural sector.
- Scenarios with accelerate investments before 2010.
- Decentralization energy scenarios.
- Scenarios which make a participatory planning process possible.

Analysing the interdependence between a given technology and the energy system environment.

Here the question is how a specific energy scenario influences the socioeconomy of a single technology over time.

Example 1. The interplay between windpower and energy system. In Denmark an important question has been and still is,

- (a) which percentage windpower is it technically feasible to introduce into the energy system, and,
- (b) which value has wind energybased electricity for the energy system as a whole.

The answer to question (a) is that it depends upon the character of the energy system in which windpower is embedded. This is illustrated in figure 2.7.

“Surplus electricity” is defined as electricity for which there is no Danish market at the time of production with the given technical system. The amount of “surplus” electricity is higher in a power generating system consisting of mainly large power plants, than in a system consisting of many decentralised cogeneration units linked to water storage and heat pump systems (here called LOCUS systems). In 1983 the DEFU, a research unit financed by the Danish power companies, carried out calculations which showed, that a 10% windpower supply would result in a situation, where 30% of the windpower would be “surplus electricity”. In case of a 30% windpower supply they demonstrated, that around 70% could be regarded as

“surplus electricity”. The conclusion was, that windpower could not supply any substantial part of the Danish electricity production.

This conclusion was true under the presumption that, windpower was placed in an energy system with only large (and inflexible) coalfired power plants. What was wrong was that it was not mentioned that if the power plant system was made flexible, a much larger proportion of windpower could be introduced. In a later study (Lund 1986) it was proved that flexible LOCUS systems consisting of decentralized combined heat and power plants, heat pumps, and a water storage system, did not have similar problems, as “surplus electricity” is converted to heat by means of a heat pump, and stored in the water storage system. Due to the use of heat pumps, this type of flexibility is achieved without losing the energy efficiency of the system. The way of analysing such questions today is to make energy systems scenarios with the SESAM model.

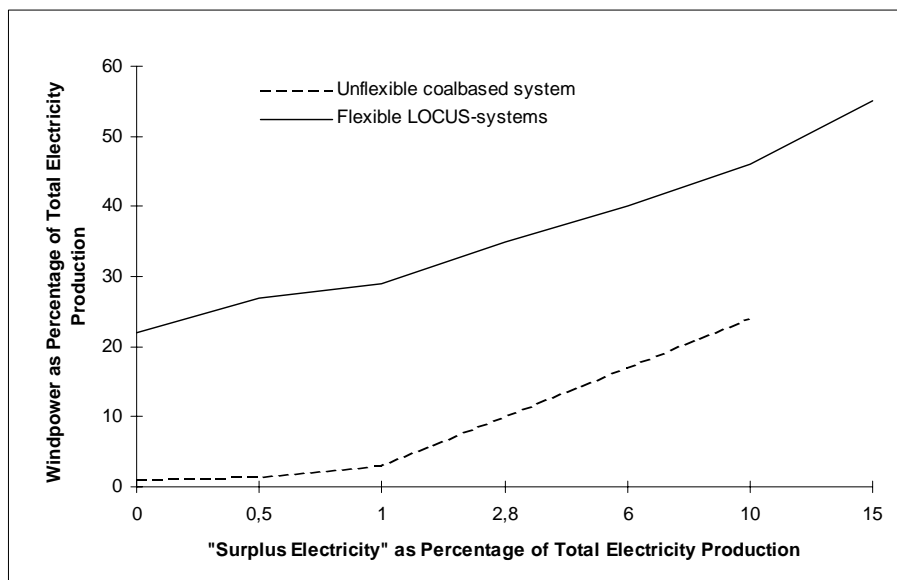


Figure 2.7: “Surplus” electricity as a function of percentage windpower of total electricity production.

Our conclusion is that it is necessary to establish in depth investigations regarding the interrelation between a single technology, and the development of the energy system in which this single technology is placed. This is

necessary because of the long technical life time of most energy investments and because of the increased interrelationship between the different components of the energy system. This interdependence is increased because of increased use of cogeneration, renewable energy systems and energy conservation technologies. The SESAM simulation system can be used for this type of investigations.

Analysis of the interdependence between energy systems and the socioeconomic environment

Consumer income distribution and ability to invest in energy technologies.

It is an important part of the Danish experience, that the concrete socioeconomic situation of the different consumer groups, private households, public companies and private companies has a huge influence on the possibilities of energy policy. These measures were taken after a public debate, among others from different analysis of the socioeconomic situation of different consumer groups.

For instance it was concluded in (Kvistgaard 1983) that different income groups had very different possibilities for investing in energy conservation in North Jutland. Quite often pensioners were in a situation, where they could only invest in energy conservation, if they could save more than 3000 Dkr/year, when investing 10000 Dkr in house insulation with a technical life time of around 20-30 years. Average income families would only require to save around than 1500 Dkr/year, as they could easily get loans in banks or other credit institutions.

Analysis of this type resulted in an energy policy, with public payment of around 25% of the heat bills of low income pensioners, in combination with a 50% subsidy for investments in heat conservation measures. A special municipal guaranty for investment in district heating systems was introduced in the late eighties to assure that low income groups could afford to join the system. This reform was important for the introduction of decentralized district heating systems based on cogeneration of heat and electricity.

In 1983 it was analysed to what extent the farmers could finance investment in biogas plants (Hvelplund 1983). It was concluded that the farmers who could get the necessary loans were old and unwilling to enter innovative investments, and that the innovative farmers could not finance biogas plants. No public policy was ever introduced to handle these problems financially. Consequently the introduction of farmer biogas plants never has had any success.

One may conclude, that also in Denmark, with its rather stable socioeconomic development, it has been necessary to analyse the concrete socioeconomic situation of different consumer groups.

In countries with larger socioeconomic changes, analyses within this area are even more important.

Such analyses should be characterized by a thorough investigation of:

- Where are the large energy conservation possibilities?
- How are the different consumer- and income groups distributed within these possibilities?
- How is the financial and organizational situation of these groups?

Employment and importation effects of different energy scenarios

The purpose of analysing employment and importation effects is:

- a) To make it possible to select energy scenarios and energy systems with a high fraction of local regional and national employment, and a low importation content.
- b) To foresee the character of employment in order to establish the needed qualifications in the labour force.

Employment and importation analyses in the eighties were an official part of the heat planning procedure performed by the municipalities. It was, and is motivated by a situation with a rather high unemployment rate and a foreign debt of around 300 billion Dkr.

It is important to understand, that giving priority to projects with a high employment effect and low importation ratio, should not be used in case the project is not in accordance with the goals of the Danish energy policy. The special situation in the energy scene is that energy conservation, renewable energy systems and district heating systems are all technologies needed for an energy efficiency policy, with a high employment effect and a rather low importation ratio. In a situation with high unemployment rates and a high foreign debt, it is therefore advisable to make systematic analyses of the employment and importation effects of the different energy scenarios and the different single technology alternatives which are analysed.

In Denmark several feasibility studies of energy projects or energy plans have included the consequences on employment and the balance of payment. The calculations of such consequences have been based on extensive statistical material which has been collected as part of two research projects carried out at Aalborg University, one in 1985-86 and one in 1995-96. The calculation of employment and foreign exchange rates based on the collected

data is based on a computer model, which has been constructed by Klaus Illum (Lund 1986).

The results are directed towards energy planners in central and local government, employees in interest organisations and others who have an interest in calculating and analysing the balance of payments and employment effects, which are related to different energy investments.

The collection methods and presentation of the tables are identical for the investigations from the 1980's and 1990's, in the following points:

- Employment information is divided to correspond with categories of employees.
- Assessments are based on the accounts (or budgets) of specific plant investment with indication of the stages in the production chain immediately prior to the energy plant. The chain of production is analysed in reverse, stage by stage.
- In the first stage there has been direct information collection from the suppliers of the components and labour. Further back in the chain, there is a greater use of statistical input/output figures.

In the investigation from the 1980's, input/output statistics were not used in the calculation of direct and indirect effects. The problem then, as now, was that the statistics did not disaggregate electricity supply, gas supply and district heating supply, just as the statistics could not be disaggregated for the calculation of the factor demands for sustainable energy and energy saving practices. As a result, a lot of information was collected directly from the suppliers of the equipment and plants in the 1980's investigation. This has influenced the degree of detail, in relation to how the suppliers of components make demands on a number of branches in the tertiary sector. In the 1990's investigation, disaggregated statistics are used for 27 branches (in some cases even more disaggregated data are used). This improvement has enabled the results to be more precise, with reference to the calculation of effects in the service branches.

The results are shown in figure 2.8. The results are expressed with employment shown as the number of persons per million DKK invested (price level 1995). The research project also provides figures divided into trades.

Energy technology	Persons per Million DKK	Import share
Coal fired district heating	2.5	0.20
Straw fired district heating	2.4	0.21
Wood fired district heating	2.4	0.20
Gas fired district heating	2.6	0.19
Oil fired district heating	2.7	0.16
Electrical heat pump (Danish)	2.7	0.13
Electrical heat pump (imported)	1.0	0.69
Natural gas engine plant(3 MW)	2.1	0.37
Waste fired combined cycle plant	1.7	0.46
Waste fired steam turbine plant	2.1	0.33
Natural gas combined cycle plant	1.6	0.48
Waste burning plant	2.3	0.26
Coal fired cogeneration (Imported boiler)	1.5	0.44
Coal fired cogeneration (Danish boiler)	1.8	0.37
Natural gas fired boiler (400 MW)	1.8	0.35
Solar energy capture field	1.7	0.31
Wind generator - 500 kW	1.7	0.37
Marine located wind generators	2.1	0.28
Solar electricity plant	2.4	0.22
District heating supply pipes	2.4	0.20
Natural gas supply pipes	2.5	0.22
District heating pipe network	3.0	0.15
Electricity transmission lines	2.5	0.13
Domestic heating installation	2.8	0.13
District heating installation	2.8	0.15
Domestic oil fired boiler	2.7	0.18
Replacement of domestic oil fired boiler	2.4	0.19
New domestic oil fired boiler(incl. fuel oil tank)	2.4	0.22
Natural gas fired boiler	2.1	0.32
Electrical heating	2.1	0.45
Wood chip fired boiler	2.0	0.25
Domestic solar energy capture plant	2.3	0.22
Farm biogas plant	2.3	0.21
Energy advisory services, domestic	1.2	0.21
Lighting	0.9	0.54
Freezers	1.4	0.37
Refrigerators	1.1	0.48
Cooking stoves	0.9	0.54
Washing machines	0.9	0.54
Tumble driers machines	0.9	0.54
Dish washers	0.9	0.54
Energy advisory services, industrial	3.0	0.03
Pumps	3.4	0.10

Energy technology	Persons per Million DKK	Import share
Compressors	2.5	0.20
Cooling plants	2.3	0.20
Process	1.8	0.39
Lighting	1.2	0.58
Insulation of roofs/roof spaces	2.2	0.19
Cavity wall insulation	2.4	0.15
Pipe insulation	3.5	0.04
External insulation	2.4	0.14
Double glazing	3.2	0.15
Double windows	2.2	0.18
Glazed facades	2.8	0.24
Sealing of joints	2.2	0.29
Clock steered night heat reduction	2.1	0.39
Thermostatic valves	1.9	0.12
Heat recycling	2.0	0.25
Wood briquet production (wholesalers)	2.2	0.23
Wood briquet production	2.2	0.21
Coal	0.2	0.90
Natural gas	0.2	0.90
Fuel oils	0.2	0.90
Petroleum gas	0.3	0.85
Petrol	0.3	0.85
Straw	2.2	0.13
Wood chips	1.9	0.22
Animal manure	2.2	0.13
Waste	2.2	0.20
Wind generated power (distribution agreement)	2.6	0.08
Coal-fired Power Station's operating account	2.7	0.19
Operation and maintenance of biogas plants	2.9	0.16

Figure 2.8: Schedule of results for the employment investigation 1995. Employment rates are pr. 1 million DKK investments in construction works. Price level is year 1995. The costs do not include taxes or subsidies. The capital cost includes complete plant costs.

Application of the statistics

The quantitative information in figure 2.8. indicates which employment and import effects are caused by the different energy investments. It is possible to calculate the effects on employment, e.g. by producing 1 kWh electricity,

in one way or another. This is used to compare a wind generated kWh with a coal fired kWh as shown in figure 2.9.

	Wind generation	Coal firing
Preconditions		
Construction costs	DKK 7000/kW	DKK 8000/kW
Operating time	2200 hours p.a.	7000 hours p.a.
Operational life	20 years	30 years
Interest	7%	7%
Opera.&Maint.costs as a percentage	2%	3%
Efficiency	47%	
Coal prices	DKK 13/GJ	
Results		
Price	DKK 0.306/kWh	DKK 0.197/kWh
Import	DKK 0.112/kWh	DKK 0.123/kWh
Employment	53 persons/GWh	20 persons/GWh

Figure 2.9: A comparison of the effects on employment and balance of payments in the production of electricity by means of wind generation and coal firing.

The calculations indicate that wind generation creates more Danish employment than coal firing. It also indicates that wind generation would be better for the balance of payments. But there is a significant problem with this comparison. It is very sensitive to the preconditions concerning the technical system one assumes the two technologies to be placed in. In the calculations in figure 2.9 there is no consideration of what happens when the wind does not blow. Thus, it is implicitly intended for wind generation to be placed in a system which is able to store electricity or which has the necessary reserves for production of electricity. Furthermore, it is assumed that the coal fired power generating station produces for an operating time of 7000 hours per year, thus implicitly assuming that the station is not part of a system where it can advantageously take over production from older generating stations. An operating time of 7000 hours per year would be unrealistic over a 30 year period.

	Wind generation	Coal firing
Preconditions		
The same preconditions as in figure 2.9, except that in the case of wind generation there is an investment in reserve effect (new coal fired power generating station), and an operating time of 4000 hours p.a. is used for coal		

firing as compared to 7000 hours p.a..		
Results		
Price	DKK 0.467/kWh	DKK 0.266Wh
Import	DKK 0.168/kWh	DKK 0.147/kWh
Employment	82 persons/GWh	32 persons/GWh

Figure 2.10: A comparison of the effects on employment and balance of payments in the production of electricity by means of wind generation and coal firing, with alterations in the system preconditions as compared with figure 2.9.

The stated system preconditions are extremely important. In figure 2.10, the same calculations have been made as in figure 2.9, but with the following differences: For wind generation a reserve effect is calculated the form of a new coal fired power generating station, and for coal firing an operating time of 4000 hours p.a. is calculated, corresponding to the distribution of average Danish electricity consumption including reserve.

The results in figure 2.10 appear to indicate that investments in wind generation would be important for increased employment, but that they would also be bad for the balance of payments. It should be noted that this presentation is hardly reasonable, because a new coal fired power generating station would not be the most appropriate means with which to provide a reserve effect for wind generation.

The significance of the comparison is the illustration of the need to specify which technical system each technology is placed in, when it is to be assessed in terms of economics, foreign exchange and employment. Development of wind generation is very sensitive to whether the system is a coal fired steam turbine system, or a system with decentralised cogeneration with heat storage and control possibilities. Development of cogeneration is very much dependent on the size of the variations in the demand for heat and the demand for electricity. Insulation activities are very dependent on whether the heating is from domestic oilfired boilers or from cogenerated district heating plants.

Therefore, the comparisson of systems is significantly more informative than the comparing of individual technologies. This is what the “Green Energy Plan” illustrates.

Collection of Data for Employment analyses

The method of employment analyses seeks to examine employment and import effects of all sections of a production chain behind the establishment

of a specific energy investment. The added value step by step is found and so are the division into salaries and factor income. For the analysis a computer model has been used. A specification of a certain investment is fed into the model, and so are general statistics in the form of average salaries for certain handcraft works ect. General input/output statistics from the Danish national account is also used in the model.

The collection of employment and import data is based on established energy investments wherever possible. The method is illustrated in the following with decentralized cogeneration as an example. In this case the data took its starting point in a 3 MW cogeneration plant built in 1990/91. The Plant is placed in the industrial area of a town, and was connected to an existing district heating system with a transmission pipe line.

The plant includes three 1 MW units and a 600 m³ heat storage for the purpose of storing heat from electricity price highload periods to low-load periods. Back-up boilers already existed at the old plant and are not included in the price. The plant is equipped with office and meeting facilities. Construction prices were collected from construction accounts. (see figure 2.11.)

Engine (incl. installation)	11605
600 m ³ heat storage	990
550 m ² building	2320
Transformer and grid connection	905
Ground ect.	325
Consultancy	250

Sum	16395

Figure 2.11: Construction price 3 MW gas-engine cogeneration plant 1000 DKK

3 Gas engine units	6500
Cooling system and exhausting exchange	571
Sound reduction, pipes ect.	1500
Ventilation system	215
Management and control system	1415
Chimney	355
Installation	1049

Sum	11605

Figure 2.12: Construction price for gas-engine incl. installation 1000 DKK.

The most important parts of the investment are then examined in more detail, while other parts are based on general statistics. In this case the engine incl. installation and the building were analysed further. The engine enterprise was divided into investmentparts as shown in figure 2.12 and the building as shown in figure 2.13

Bricks ect	26,600
Concrete ect.	93,000
Mortar	6,000
Carpenter materials	196,000
Iron	24,000
Metal material	40,000
Electrical articles	152,167
Pipes and fittings	67,801
Digging and drain	40,000

Sum	645,568
Bricklayer	224,452
Electrician	53,184
Blacksmith	67,200
Carpenter	61,272

Sum	406,108
Sum	1,051,676

Figure 2.13: Construction price for parts of the building works DKK.

On the basis of the shown division of the construction prices and general input/output statistics the investment in a 3 MW cogeneration plant has been analysed and results in figure 2.14.

Import	37
Added value (Danish)	48
Production factor income	15

Sum	101

Figure 2.14: Import and added Danish value: 3 MW cogeneration unit, percent

The investment is also found to result in the employment shown in figure 2.15.

	Construction	Production	Total
Trainee	0.01	0.10	0.11
Unskilled	0.15	0.42	0.57
Skilled	0.17	0.45	0.62
Functionaries	0.16	0.64	0.80
Sum	0.49	1.61	2.10

Figure 2.15: Employment: 3 MW cogeneration unit (Person year per million DKK)

Analysis of the environmental effects of energy investments.

“We must change the economic and financial methods of calculation in order to estimate the social and environmental effects of our decisions. “, Ismail Serageldin, Vice President, the World Bank (Kristeligt Dagblad, 19. December 1997). It is increasingly necessary to analyse the environmental effects of energy investments. The global warming problem is looked upon as increasingly serious. Consequently some financial institutions, as for instance the World Bank, demand environmental assessment analyses in the feasibility studies they require before giving loans to new projects. Although there has been no real consensus on a world scale about how to handle this problem, it is difficult to imagine that such international measures will not be taken within the next 20-30 years. This means that it is not conceivable that international measures against increased greenhouse gas emissions will be taken within the technical lifetime of most energy projects. The SESAM model calculates the greenhouse gas emissions linked to the different scenarios.

Time priority

When dealing with energy projects, which often can be characterized as long term infrastructural projects, treatment of over time payments is important. The interest rate used in the calculations expresses the weight with which the future is treated. An easy way to handle this question is to simply use the market interest rate for the calculations. Obviously this might be the only sound solution, when dealing with the investments of private organizations. Other considerations must be taken into account, when deciding which interest should be used, when estimating the feasibility of different regional or national energy strategies. Figure 2.16 shows a present value index of oil saved 20 years from now.

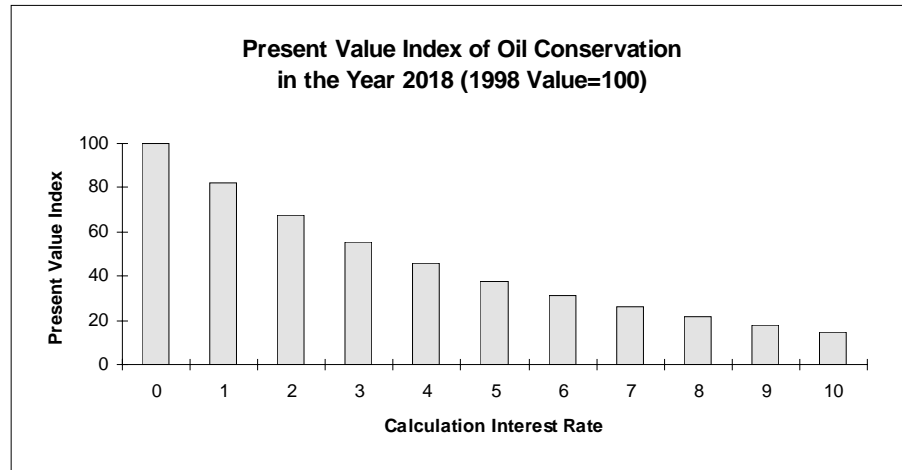


Figure 2.16: Index showing the present value of oil saved 20 years from now for different interest rates.

With a 0% interest rate, one litre saved 20 years from now has the same value in the calculations, as one litre saved tomorrow. With an interest rate of 4% the value has decreased to less than 50%, and with 10% interest, the value of a litre of oil saved in 20 years is only given the value of around 200g oil saved tomorrow. That is how an interest rate functions in our calculations. Furthermore the interest rate used for our calculation is not neutral regarding its effects upon comparisons between different technologies. The following example illustrates this. We have three investments:

- a) Continued oil consumption costing 10000 Dkr/year.
- b) Investing 70000 Dkr and halving the oil consumption to 5000 Dkr/år.
- c) Investing 150000 Dkr. and bringing the oil consumption down to zero.

In figure 2.17. the present value for these three investments is shown for different interest rates.

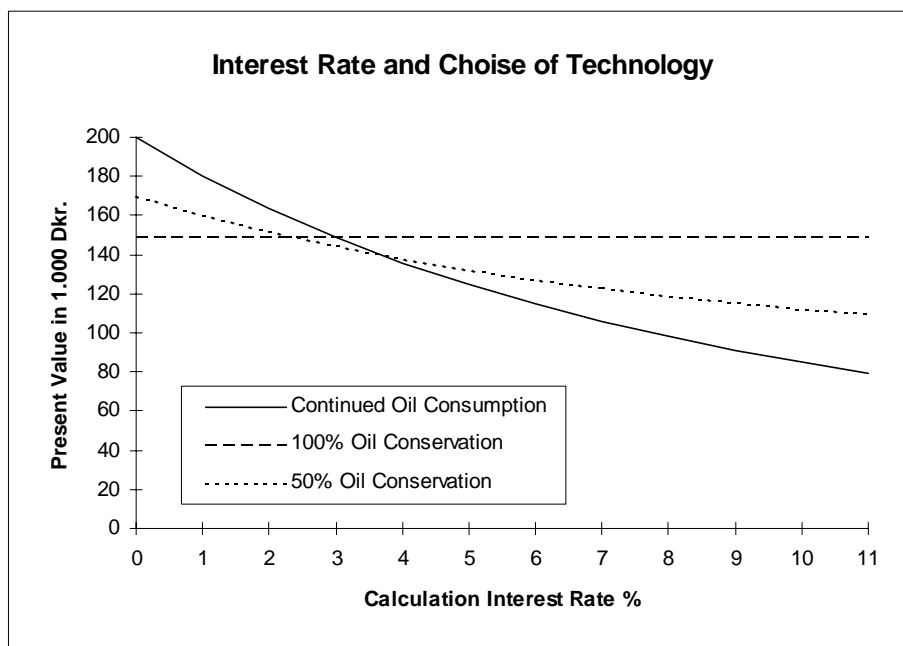


Figure 2.17: The interdependence between interest rate and project priority.

We here see, that at an interest rate up to around 3,2%, 100% energy conservation has the lowest cost. Between 3,2% and 5,4%, a 50% decrease in oil consumption is advantageous, and above interest rates higher than 5,4% continued oil consumption is the most economical solution. The example reveals, that the level of an interest rate used in the calculations will have decisive influence upon our selection of solutions.

It is one of the basic assumptions in the theory of investment analysis, that the investments compared should be comparable over a relevant time horizon. Therefore, to use a market interest at a level of 5-7%, when calculating the socioeconomical feasibility of a long term infrastructural investment is problematic, when dealing with technologies using different rates of scarce resources, and having different levels of greenhouse gas emissions. Such technologies are not comparable over a longer time horizon. And the above differences usually exists when energy scenarios are compared.

Obviously it is difficult to use an interest rate which is lower than the market interest rate, as it requires liquidity in a starting period to do so. But it should be done, and in Denmark a way of compensating for this interest problem

has, been to give a subsidy in the initial phases of the introduction of renewable energy technologies and when investing in energy conservation technologies.

Conclusion:

- a) using a rather high interest rate is acceptable (7-10%) when comparing investments with the same level of pollution and use of scarce resources.
- b) using a much lower interest is necessary (0-3%), when comparing investments with different levels of pollution and use of scarce resources.

Impacts of historic investments (sunk costs)

The socioeconomic costs in the future are not the only costs which determine whether an energy scenario is feasible or not. The costs of the past, which are built into the present technological systems have a significant influence upon the way in which one should invest in order to reach the goals for the energy systems of the future. Using a picture from sailing, it is important to know your point of departure, when you travel to any desired destination. But it is important that the desired destination governs your voyage, and not the point of departure.

In energy planning we often deal with large and consolidated technical and organizational systems with a very high level of “sunk costs“ regarding technical and organizational investments. A precise knowledge of the “point of departure “ situation is essential for a successful travel to the desired destinations. Nevertheless there is a strong tendency, that “the point of departure” determines the destination, instead of just being the “point of departure” for destinations decided by the travellers. Said with words from the energy scene, there is, for instance, a strong tendency, that capital intensive energy systems establish price structures which bind the customers to a high level of consumption by means of a system of price differentiation and high fixed tariffs. This makes energy conservation measures uneconomical, and impedes the “travel” towards the destination “energy conservation”.

Invested capital is often regarded as “sunk costs” which is regarded as having the cost of zero, when competing with energy alternatives. It is correct, from a static point of view, to use zero as the price of this type of sunk costs, but in reality there are always repair costs linked to such systems. When applying a dynamic point of view, it is important to include, in the feasibility studies, the long term replacement capital costs of the existing technical and organizational systems. If this is not done, “the point of

departure” will determine the destination, and there will be no real strategic development process at the energy scene.

The conclusion is that in feasibility studies it is important to use a long time horizon and to make calculations which compare the long term marginal costs of the alternatives. In this way it is possible to make sure that the short term marginal cost structure of the existing energy systems do not completely dominate the calculations and determine the energy strategy.

Technological development

It is well known, that technologies are more expensive in an initial phase of the technological development than in a more mature phase. This has been the case with the windpower development in Denmark, where the price pr. Kwh produced has gone down with a factor 2-3 since the beginning of the eighties, and where prognoses estimate a further 20-40% decrease in the prices before the year 2010. By then windpower based electricity is supposed to be almost as cheap as oil and coal for power production. The same tendency has been seen within the development of district heating systems and to some extent within solar heating systems and biogas plants.

When making a long term socioeconomic feasibility study, it is a difficult question to assess the future prices of energy technologies in the different scenarios. But it should be kept in mind that estimates which do not include relative price decreases on the newcomer technologies, are biased and more often than not result in an overestimation of the prices of new technologies.

Nor is it easy to estimate the innovative processes which can be started, when introducing new technology lines in a development process. When the Danish windpower industry started from almost nothing twenty years ago, nobody in any Danish feasibility study foresaw that windpower development would result in a large advanced industry within a period of 10-20 years, with around 10000 employed and an export amounting to 6 billion DKK.

We have no specific methods to use when estimating future prices of newcomer technologies, and their impacts on the technology development process in a country. Nevertheless we think that this point is one of the most important in a socioeconomic feasibility study, and we recommend that it is given a place and discussion in the structure of such studies.

The risk dimension

Energy systems are mostly long term and capital intensive. Some organization or group of persons have invested large amounts of money in power plants, transmission grids, district heating systems, natural gas

pipelines, energy efficient houses, etc. which may last technically for 20-50 years.

The return of capital is dependant upon an array of conditions such as the development of fossil fuel prices, consumption, new competing technologies, inability to pay the bills, environmental problems, liberalization of the markets, etc. etc. This combination of capital intensivity and a very turbulent development, makes investment in energy systems a very risky business, if companies are not able to foresee or control some risk areas. Socioeconomic feasibility studies should include:

- a) A map of the risk areas.
- b) A discussion of the background of those risk areas.
- c) Sensibility studies calculating the consequences of different risk scenarios.
- d) Investment redesign to be able to react on risks.
- e) A warning system with a systematic description of risk indicators.

Chapter 3

Examples of Feasibility Studies in Practise

The following two examples from Denmark will be shown in order to illustrate some of the main conclusions in chapter 1 and chapter 2 regarding the design and implementation of feasibility studies. The “Green Energy Plan” case shows how feasibility studies for a “whole country” energy strategy is designed. And it especially shows how systematic analyses of the goals and situation of the country influence the structure as well as the content of a socioeconomic feasibility study. Once more it is illustrated, that there is no such thing as one universal model regarding the structure and contents of socioeconomic feasibility studies, but that such studies should be adapted to the concrete situation. In “Danish Biogas Strategy” we focus upon the necessity of making systematic wvw- and Diamond-E analyses by discussing the different results of two reports made for the Danish energy administration.

3.1 A Green Energy Plan

“Elements of a Green Energy Plan” (Lund 1996) was an input to the public debate on the future of energy in Denmark in the spring of 1996. The Ministry for Energy had determined the frame of reference for this debate by presenting two courses of development: everything or nothing! If Denmark does "nothing", we cannot achieve the environmental goals. If Denmark does "everything" we can achieve more than these goals. For some specific proposals the Plan has calculated what can be done. The primary aim is that new employment can be created by doing something to reach the environmental goals, and it is possible to do this in a way that has no adverse effect on the balance of payments.

This case shows

- that it is possible to find energy strategies which both improve the balance of payment, the employment, the environment and the public finance account and the gross national product
- that there does not have to be a contradiction between economy and environment
- that it is possible to develop energy strategies, where improved environment and improved economy goes hand in hand
- that this can only be done by making systematic socioeconomic feasibility studies, where what, whom and why analyses (Step 1, *www-analysis*) are systematically discussed and combined with thorough Diamond-E analyses (Step 2 analysis).

The Green Energy Plan consists of a number of initiatives, which Denmark can choose to implement, as a supplement to the official energy policies. The choice of elements in the Plan is made on the basis of a total evaluation of environment, economics, the rate of foreign exchange, consumption and employment. Primarily, the aim is to enable Denmark to continue to obtain the reduction of CO₂ emissions. This is achieved by means of long-term, investment dependant alterations in the infrastructure, towards a more decentralised energy system. The changes in question will require investments, but these will provide an improved employment situation and a better environment.

Regarding the *www-analysis* the “what” consists of long term energy system scenarios. And these scenarios are supposed to be used by the Government (“whom”) as a tool for the establishment of an energy strategy, which can fulfill the goals of the Government (“why”).

The Green Energy Plan does not compare a number of individual technologies in an undescribed system, but rather compares a packet of solutions in a well-defined system. In this way it can be ensured that two alternatives with the same capabilities, i.e. the ability to meet the Danish energy requirements in the period up to the year 2015, are being compared. Only in this way will it be possible to reach a conclusion with reasonable accuracy about the effects on employment.

The Plan is compared with the official energy policies, as they appeared in Spring, 1995, when the calculations were made. At that point in time, the Danish Energy Agency assessed that the carrying out of "Implementation of Energy 2000" would be insufficient to achieve Parliament's adopted aim for a 20% reduction in CO₂ emissions by the year 2005 (compared with year

1988). The reduction would only be 14%. Therefore, the calculation focuses on illustrating how a total implementation of all the elements in the Green Energy Plan could ensure that Denmark obtains the 20% reduction in CO₂ emission by the year 2005, and also continues on the way to further improvement by the year 2015.

The elements in the Green Energy Plan are examples of what could be done in order to effectuate a reduction in CO₂ emissions - both a 20% reduction by the year 2005, and a further reduction in the following years. The Plan contains the following elements:

- Conversion from electrical heating, in areas without a supply of district heating and natural gas
- A general activity to improve insulation, including in the larger urban areas where low temperature district heating can be established
- Change from individual natural gas fired boilers to cogeneration district heating
- Decentralised use of straw and wood fuels
- Development of community biogas plants
- 3000 MW produced by wind generators in the year 2015
- 20% reduction in electricity consumption in the industrial sector by means of employee training

The Plan has the implementation of the above-mentioned elements in the course of a 20 year period, from 1996 to 2015.

The Green Energy Plan is compared with the Reference on the basis that the Green Energy Plan is implemented in the period from 1996 to 2015, both years included. Detailed technical calculations are made for the years 2005 and 2015 on the basis that half the above mentioned measures will be implemented by the year 2005, and all of them by 2015.

From a Diamond-E analysis it is known that the aims of the Government among others are to improve the environmental situation, GDP, balance of payment and employment and the public finance account. Consequently the socioeconomic feasibility study has to study the effects of the energy scenarios upon the fulfilment of these goals. That is the reason for this socioeconomic feasibility study to focus upon environment, foreign exchange, employment and the public finance accounts.

Furthermore it is known from the Diamond-E analysis that Denmark has 250,000-300,000 unemployed people, and that they may be regarded as a resource in the process of achieving all the aims mentioned..

In comparison with the Reference the Green Energy Plan provides the following consequences:

Environment and fuel consumption

The total fuel consumption in the Danish energy sector (excluding transport) will be reduced by 5% in the year 2005 and fossil fuels will be reduced by 9%. When fuel consumption for transport is included, it means that CO₂ emissions will be reduced by 20% in the year 2005, in comparison with 1988. In 2015 the Green Energy Plan proposes an additional reduction of CO₂ emission by 34% in comparison with 1988.

New power generation capacity

In addition to two power stations which are already under construction, the Reference requires two more power generating stations of 400 MW to be constructed before the year 2005, and a further six or seven in the period from 2005 to 2015.

In the Green Energy Plan the following elements:

- increased development of decentralised cogeneration,
- low temperature district heating in larger urban areas,
- energy conservation in the industrial sector
- and replacement of electric heating,

prove that there is no need for the construction of new power production capacity (except for those under construction) until 2015.

Costs, foreign exchange and employment

In the case of *constant fuel prices* the Green Energy Plan would increase the total costs from DKK 27 billion p.a. to DKK 32 billion p.a. (not including taxes or subsidies). This is largely owing to the increased investments. Foreign exchange consumption would have a minor rise in the beginning (DKK 0.7 billion p.a. in 1996) but would fall thereafter, so that in 2015 there would be a foreign exchange saving (DKK 0.6 billion p.a. in 2015). In the case of minor *increases in fuel prices* (according to the latest forecasts from the Danish Energy Agency, where prices rise 25 to 50%), the additional expenditures would fall to approximately DKK 4 billion p.a., and the savings in foreign exchange would be DKK 1.4 billion p.a. in 2015.

Thus, the Green Energy Plan involves a number of additional Danish investments. In the reorientation period the effect of the Plan on the balance of payments would be largely neutral.

Regardless of fuel prices, the reference continues with an employment parameter of slightly less than 40,000 persons. The implementation of the Green Energy Plan would increase employment by approximately 12,000 persons in 1996 and rise to additional employment for approximately 17,000 persons in 2015.

Public finance accounts

In the model, a calculation has been made for the net effect on the public finances, according to the following:

- + Reduced social and unemployment benefit
- + Increased revenue from income tax
- + Increased revenue from company tax
- + Secondary effects
- Reduced revenue from energy levies
- Reduced surplus contributions from natural gas companies

 Changes in the public accounts
 =====

The calculation includes the increased taxation revenues and reduced social benefit payments, the reductions in energy levies and the results on the profits of the natural gas companies (which in Denmark are owned by the State and municipalities). Furthermore, the secondary effects from the increased turnovers in the national community are included. A Danish subsidy of between 0,10 and 0,27 DKK/kWh to electricity produced from renewable energy and decentralized cogeneration is calculated on the basis that the present level remains constant, until the year 2005, thereafter being gradually reduced to 50% in 2015.

The calculations are detailed in the case of the consequences on revenues and public service contribution charges in the natural gas companies. With reference to the secondary effects, an estimate rather than a detailed calculation has been made. The calculation is based on an income multiplier, as well as tax and import quota, which are difficult to estimate in a forecast for 20 years. Therefore, round figures have been chosen. Small variations in the contributions from the secondary effects are not decisive for the main conclusion.

The efficiency is calculated as the difference between the implementation of the one or the other scenario, i.e. the Reference compared with the Green Energy Plan. Changes in the individual items of the public accounts are calculated for the direct and the secondary effects. The following variables are specified as input to the calculations:

Average social/unemployment benefits	DKK 110,000 p.a.
Average wage	220,000 DKK p.a.
Marginal income tax (personnel)	50%

Marginal income tax (company)	40%
Marginal import quota	30%
Multiplier	1.2

The main result is shown in figure 3.1 for the calculation with constant fuel prices expressed as the consequences of implementing the Green Energy Plan, rather than the Reference. Rising fuel prices do not alter the final results to any great extent.

It should be emphasised that the above means of showing the consequences for the public finances, presuppose that the employments of the 12,000 to 17,000 additional persons cause neither bottleneck problems nor rising wages. At present, as seen in the Diamond-E analysis, there are 250,000 to 300,000 unemployed in Denmark, although employment figures have improved recently. In such a situation, the public sector should be careful about taking initiatives that would lead to an overheated economy. The above calculation will not be valid, if, within the period, a situation arises with more or less full employment. In such a situation, the same advantages would not be achieved by substituting fuel imports with Danish employment.

Billion DKK	Year 2005	Year 2015
Additional costs	4.7	5.2
Foreign exchange costs	0.2	-0.6
Employment effect	13000	18000
Reduced benefits	+1.5	+2.0
Increased tax	+1.3	+1.7
Natural gas company deficit	-0.2	-0.5
Reduced energy levies	-1.1	-1.4
Energy subsidies	-1.1	-1.4
Secondary effects	+0.6	+0.8
Effect on public finances	+1.0	+1.2

Figure 3.1: Green Energy Plan Net Effect on the Public Finances, not including public regulation costs

Consumer economics and public regulation costs

An estimate has been made for the public operational costs for the State, in the implementation of the Plan. The starting point has been that consumer prices (total energy costs for households and industry) remain the same, in the Green Energy Plan and in the Reference. Thus, it is an attempt to

calculate how much the public finances will have to contribute, in order to maintain the average purchasing power and competitiveness, at the same level in the two alternatives.

We refer to the publication, "Democracy and Change, Energy Action Plan 1996" (Hvelplund, 1995) for a more detailed description of which means would be of special importance. Below is listed a number of important measures to be taken to allow a cost estimate.

The public regulation means are:

- Changes in the regulation of electricity tariffs
- Prohibition of the use of electrical residential space heating after the year 2000
- Specifically aimed subsidies
- Improved insulation standards for houses offered for sale
- Continuation of the CO₂ levy and the subsidies for sustainable energy (but with a gradual reduction so that the subsidies would be reduced by 50% through a 20 years period)
- Demand for the conversion from individual consumption of natural gas to a cogeneration of electrical power and district heating supplies
- Training programmes in electricity saving for industrial employees
- More research, e.g. in straw gasification
- Subsidies for biogas and gasification plants

According to the Green Energy Plan an implementation of these measures would cost the public finances approximately DKK 1.3 billion p.a.. Thus, these costs are similar to the expected increase in revenue to the public finances.

Therefore, there are good possibilities of implementing the Green Energy Plan in such a way that it would have an almost neutral effect on the public finances.

Total assessment

On the minus side, mention must be made of:

- extra investment costs in the period of change of approximately DKK 5 billion p.a.
- extra foreign exchange costs of approximately DKK 0.7 billion in the beginning (although the costs would fall to between minus DKK 0.6 billion and minus DKK 1.4 billion depending on the development in the fuel prices)

On the plus side, mention must be made of:

- reduced foreign exchange consumption in 2015 of between DKK 0.6 billion and minus DKK 1.4 billion depending on the development in the fuel prices (although there would be higher foreign exchange costs in the first few years)
- CO₂ reduction of 20% instead of 14% in the year 2005 (and a reduction of 34% instead of 20% in 2015)
- reduced fuel consumption
- additional employment of approximately 12,000 persons in 1995 and rising to approximately 17,000 in 2015
- better capital goods in 2015
 - district heating to 50% of the Danish households
 - biogas and straw gasification plants corresponding to 35 PJ gas p.a.
 - decentralised cogeneration plants for 4000 MW (although fewer central plants)
 - central heating in all houses
 - an improved insulation standard in the large urban areas
 - better trained industrial workers
 - more wind generators

The value of the additional capital goods in 2015 can be estimated at approximately DKK 80 billion in 1995 DKK as new purchase price. The average age at that time would be 10 years, and the expected operational lifespan would be 20 to 30 years. Therefore, the value would be approximately DKK 50 billion. It should be emphasised that the possible effects on exports of developing such new technologies as wind generation, biogas, straw gasification, decentralised cogeneration, etc., are not included in the above calculation. Any expected advantage would be an additional advantage to the Green Energy Plan.

3.2 A Danish Biogas Strategy

In 1990 the Danish energy administration was in a process of evaluating the status of the biogas development, in order to establish a new biogas development strategy. 15 reports were made, among which one was about the socioeconomic effects of biogas plants (Risø, 1991) and one was about biogas plants and public regulation (Lund, 1992).

The analysis of the socioeconomic effects of biogas plants (The Risø report) concluded that biogas plants were not socioeconomic feasible for society. Why should biogas plants be supported, if they were not socioeconomic feasible? Why write a report on Public Regulation? It was contradictory to support a massive implementation of biogas plants in Denmark, if biogas were not socioeconomic feasible for the Danish society.

Consequently a report was written by Aalborg University, in which it was both analyzed, whether it was correct that biogas were not socioeconomic feasible for the Danish society, and a public regulation strategy was described (The AAU report). The conclusion was that a biogas implementation scenario was socioeconomic beneficially for the Danish society, when seen in relation to the aims of the Danish Parliament.

Finally there were two reports, one concluding that biogas is not - socioeconomically feasible for society, and the other report coming to the opposite conclusion. This case deals with a description of these two reports, and the causes to the different conclusions. This discussion is currently related to the methodology developed in chapter 1 and 2.

The Risø socioeconomic analysis

The socioeconomic calculations in (Risø, 1991) are elaborated as present value comparisons over a time horizon of 20 years of three different existing biogas plants: The Fangel-, Davinde- and Lintrup biogas plants. The two first have oil fired district heating plants as their reference alternatives, whereas the Lintrup Biogas Plant has a natural gas fired district heating system as its reference alternative. The prices used in the calculations are market prices excl. Value added tax and energy taxes. The price prognoses used for fossil fuel are based upon the official prognoses from the Ministry of Energy. The results of these calculations are shown in figure 3.2.

Million DKK	Fangel	Davinde	Lintrup
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Investment	26,7	4,3	45,2
Present value	-15,2	-5,1	-26,8
Annual surplus	-1,4	-0,5	-2,5

Figure 3.2: *Risø Report, 1991 Socioeconomic results exclusive environmental costs.*

As is seen, the conclusion is that the projects are not socioeconomically feasible, when environmental costs are excluded. Furthermore the Risø Report had calculations, where some environmental costs were included, i.e. (SO₂) 14 DKK/kg, (NO_x) 8 DKK/kg, (CO₂) 100 DKK/ton. When including these environmental costs, the socioeconomic results are as illustrated in figure 3.3.

Million DKK	Fangel	Davinde	Lintrup
Annual surplus	-0,9	-0,4	-2,2

Figure 3.3: *Risø Report, 1991 socioeconomic results inclusive environmental costs.*

As both figure 3.1 and 3.2 illustrates, the results of the Risø socioeconomic calculations were that biogas was not socioeconomically feasible even when taking the environmental cost into the calculations.

The Aalborg University (AAU) calculations

The main criticisms coming from the AAU analysis were linked to the fact, that the Risø calculations did not systematically analytically adapt their analysis to the specific situation. An adaptation which could be performed by systematically using the combination of *www-analysis* (*what* should be analysed, and for *whom* and *why* is the analysis done), and the *Diamond - E* analysis. In this case the *www* analysis would show the following: *What should be studied?* The socioeconomy of biogas scenarios. This means that the study should have a long term perspective with the study of technological changes as an integrated part. *For whom and why?* The study is essentially done for the Danish Parliament who wants to get information to be used deciding the future biogas strategy.

A very short Diamond -E analysis would give the following result:

Regarding the *organizational aims* some important socioeconomic aims of the Danish Parliament are:

- a) Economic growth, defined as GNP growth
- b) Full employment in a period where 10% are unemployed (1990).
- c) Development of new export oriented technologies
- d) Decrease in the foreign debt in a situation, where the foreign debt is around 300Billion DKK.
- e) A decrease in the CO₂ emission by 20% from 1988-2005.

Regarding *organizational resources*:

- f) 10% unemployed (350,000 persons)
- g) Many small firms which are able to produce well functioning biogas plants

Regarding the *financial resources*:

- h) A high level of public debt which indicates, that solutions should not increase this problem.

Regarding the *natural and socioeconomic environment*:

- i) CO₂ reduction in Denmark is a must in a country with the third highest CO₂ emission pr inhabitant in EU, due to the extensive use of coal in electricity production.

This analysis reveals that energy solutions which increase employment, decrease importation, decrease pollution and increase GNP are important in order to fulfill the aims of Parliament. They also tell us that labour is a rather abundant resource, as there was an unemployment mounting to 350,000 in 1990.

When going back to the Risø study, it is important to note, that this study has as the presumption of full employment, and that foreign debt is no problem. In all the calculations positive effects upon technological development, balance of payment, state finance and employment was given no value, although such effects are given high priorities in the aims of the Danish Parliament.

As a consequence of this, the AAU study included these effects in its socioeconomic analyses. In these analyses calculations were made regarding a biogas scenario (50%), assuming that 50% of the all manure in Denmark from cattle, pigs and poultry is used for biogas production. The outcome of this analysis is shown in figure 3.4.

	Example 1: (0 million DKK extra tax pr year)	Example 2: (1500 million DKK extra tax pr. year)	Example 3: (750 million DKK extra tax pr. year)
Gross National Product (Million DKK/Year)	+ 1000	0	+ 500
Employment effects (Persons)	+ 5000	0	+ 2500
State finance (Million DKK/Year)	+ 200	+ 1200	+ 700
Balance of payment (Million DKK/Year)	+ 300	+ 900	+ 600

Figure 3.4: AAU study: Three examples of consequences of biogas scenario (50%)

The three examples are different in the way that example 2 includes 1500 million DKK in extra tax, in order to establish a situation, where the total buying power and production are constant. Example 3 has exactly the same biogas scenario, but with only 750 in extra tax. Example 1 has no extra tax at all. The three examples just show the different possibilities, the politicians have, when they have decided to support the biogas scenario(50%).

The positive socioeconomic effects are mainly caused by:

- Saved import due to decrease in oil and coal imports.
- Increased employment because of the high employment effects linked to building, maintaining and running biogas plant.
- Increased incomes and consequently increased taxes, which improve the state finance. This increased provenue to the state budget more than compensates the subsidies which have to be given to motivate the construction of biogas plants.

The resource and environmental effects are described in figure 3.5. Figure 3.5. shows that when relating the socioeconomic feasibility of biogas to the goals of Parliament, the biogas scenario (50%) gives a higher economic and environmental performance on all important areas. When including the employment effects, balance of payment effects and effects on the state finances, this scenario therefore is very feasible from a socioeconomic point of view.

The calculations of Risø were right seen in isolation. It was, and probably still is correct that biogas plants have not yet reached a stage, where they are economically feasible with the existing market prices. But seen from the viewpoint of the Government, and this is the relevant standpoint in this case, the above biogas scenario (50%) is socioeconomically feasible, as it pursues

and satisfies some essential governmental aims. The www - and Diamond-E analysis were used in order to establish the context in relation to which relevance should be measured. The Risø calculations were not wrong, but irrelevant in the specific calculation context.

	Biogas scenario (50%)	Reference: Oil for heat and coal for electricity.	Environmental advantage of biogas
Total fuel consumption (TJ/year)	16196	18720	
Fossil fuel consumption (TJ/year)	468	18720	18252
CO ₂ emission (1000 ton/year)	34	1494	1460
SO ₂ emission (ton/year)	470	5840	5370
NOx emission (ton/year)	2780	2783	-

Figure 3.5: AAU study: The resource and environmental effects of the biogas (50%) scenario.

Chapter 4

Public Regulation

The important thing is the context. Some kinds of public regulation are suitable in certain institutional setups and others are not. Quite often public regulation is discussed without taken in the context. In economic theory it is normally discussed whether tax and subsidies are better or worse than administrative means. Such discussions rarely include a detailed description of the specific social and institutional context, in which the public regulations are supposed to function. The society is described by use of macro-economic models, where organisations and institutions are constant over a long-term period. In such models Society is constituted by existing static energy organisations, static rules of financing, static agreements of electricity sale to the grid from decentralized cogeneration, static education systems etc.

The implementation of radical technological changes such as those described in chapter 1 depends on the public regulation also addressing the organisational and institutional circumstances. Very often this is forgotten. It is characteristic for the division of public regulation into economical or administrative measures that strategies for implementing organisational and institutional changes are not established. And such strategies are important when political objectives of reducing CO₂ emission are to be implemented at the lowest socioeconomic costs. Only the changes that will not change the existing organisations in a society with a constant institutional setup are considered.

In chapter 1 it was found that Public Regulation analysis should:

- analyse not only regulation by means of taxes and subsidies, but also regulation by developing new institutions around the market.
- be aware of the asymmetry of financial power between the old fossil fuel-based technologies, and the new energy conservation technologies. Public regulation measures may not require subsidies for the new technologies,

but just equal terms with regard to financial possibilities, by removing the capital advantages of the existing energy companies.

- be aware of the asymmetry of political power between the old fossil fuel-based technologies and the new energy conservation technologies. Quite often it is necessary to create organisations within research, price and monopoly control, advisory committees, and funding, which are totally independent of the established fossil fuel companies.

Based on the description of market economy and the character of technological change in chapter 1 this chapter will lead to a check list of public regulation measures suitable for implementing such new technologies.

1. Firstly the political phases of introducing new technologies are described, when such technologies meet resistance from the established organisations.
2. Then the kind of public regulation are described which are needed in order to develop the existing organisations and institutions.
3. Finally a check list of public regulation is given.

4.1 The Political Phases of Technological Change

Any radical technological change will meet resistance from the established organisations and institutional infrastructure of the market. This struggle between the existing and the new technologies tends to vary depending on the kind of new radical technology introduced. The introduction of natural gas in Denmark became a radical change in the sense that important new organisations were established. A new organisation was formed with a new product sold from few single-purpose companies to individual consumers. Thus, one more organisation could be added to the existing electricity and district heating companies. Of course the introduction of natural gas was met with resistance from the established organisations, but natural gas did not have to go through a number of phases in which certain technical specifications or the potential were put in doubt. Contrary to that a change into manifold energy systems based on differentiated solutions from many different and multipurpose organisations have quite different characteristics, and therefore invariably go through a number of different resistance phases from the existing organisations.

In the following a number of typical phases are described. The phases are numbered. Often new technologies will have to undergo all phases by the

numbers. It should, however, be emphasized that the phases may intervene and sometimes a technology, after passing phase 5, may be pushed backwards to phase 2 again etc.

Phase 1: The struggle of defining the problem.

Very often defining the problem contains the solution itself. This may be illustrated by a subject such as "electricity consumption for cooling". The problem may be defined as providing a given cooling capacity with given efficiency with the cheapest possible electricity. In this case the solution could be obtained by a power station with better efficiency. On the other hand the problem might just as well be defined as providing a certain cooling capacity at the lowest possible costs. In this case the solution could be found by a low energy refrigerator in combination with a smaller power station. Or the problem could be defined as providing consumers with fresh goods. Now the solution could be a smaller low energy refrigerator plus an even smaller power station plus shorter transportation of consumer goods. Or the problem could be expanded to include both fresh consumer goods and house heating at the lowest possible costs. Now the solution could be a low energy refrigerator plus decentralized cogeneration etc. Economical interests are linked to any definition of the problem. This definition is very important to the choice of solution and thereby the production system which will have the profits.

Phase 2: The struggle of getting at the agenda

Sometimes new technologies are excluded from the political agenda, which in an introductory phase is essential, because the public discussion is more or less the only place (virtual technology) where the brand new technologies exist in this phase. In Denmark such exclusion was carried out in the case of decentralized cogeneration based on natural gas for a period of almost 10 years. The technology was simply ignored in any technical report published by the established companies.

Phase 3: The struggle of being recognized as technically possible

In this phase the new technology will be met by the question of whether the technology or the technical systems can be established from a technical and/or practical point of view. In Denmark the wind turbine was met with this question until 1978, the biogas production plants and the electricity conservation until the early 1980ies, and decentralized cogeneration until 1990. As an example the established electricity companies tried to say that the energy system in the government energy plan "Energy 2000" from 1990 could not become reality due to purely technical reasons.

Phase 4: The struggle of being recognized as considerable

In this phase the new technology will be met by the statement: "OK, it is possible from a technical point of view, but the potential is so small that political reform work is not worth while". This was the case for decentralized cogeneration until 1989. In official reports made for the government by the established companies the technical potential of decentralized cogeneration was calculated to 450 MW at the highest. Today a much higher result has already been reached, but for a period the established companies managed to exclude this technology from the political agenda. Thus for a number of years decentralized cogeneration was not included in fuel saving energy strategies, because the potential did not matter much.

Phase 5: The struggle of being economically feasible

"The technology is not feasible from a socioeconomic point of view" is an argument which will often appear in the first 4 phases. This argument is sometimes correct, sometimes wrong, and sometimes it is impossible to answer. The argument will very often be emphasized after a technology has passed the first 4 phases. In Denmark major electricity savings in households and in industries have recently passed the first phases and for a couple of years they have been met with the argument that they are not feasible because of "high transaction costs". The savings, however, are feasible but because it is expensive to locate area for the savings, the whole project is considered not feasible. Decentralized cogeneration was considered not feasible until 1989, when this barrier was surmounted. For the time being decentralized biomass gasification is considered not feasible and therefore plans are that biomass should be incinerated in big power stations. The socioeconomic feasibility in the latter is not good either, but this solution has big companies in its support. It is obvious that only the new technologies have to pass the test of phase 5. Established technologies with established organisations do not have to pass the test. For example the decision of building another new coal-fired power station in North Jutland was not subject to any socioeconomic evaluation.

Phase 6: The struggle of the decision arena

Particularly in the case of a radical technological change the opportunities of new technologies are a function of the national energy policy. As described in chapter 1 the market is not "a free market" without barriers of penetration.

The implementation of new technologies will depend on certain changes in the institutions of the market. For example decentralized cogeneration did not really start before regulations were constituted for the sale of electricity to the public grid, and a "subsidy" of 10 øre/kWh was introduced. Several of the institutional changes necessary will have to be introduced at a national level. At this level Parliament will be a major decision making arena. It is often quite difficult to control this arena unless one can manage to influence the written material which form the basis on which the decisions are made. The struggle of influencing such material is difficult for many differentiated small scale technologies, because it is more difficult for them to have a common lobby organisation to influence committees set down by the energy authorities.

Phase 7: The struggle of implementation

By making the official Danish energy plan "Energy 21" Parliament recognized the need for a radical technology change at the strategic level. But such change needs follow-up by various institutional changes, which are quite complicated and therefore possible to impede at the tactical level. One way of doing this is to expand the well-established technologies (such as coal fired steam turbines in Denmark) by use of the well-established organisations (such as the power companies in Denmark). Another way of slowing down the introduction of new technologies is to conquer the implementation. "If such new technologies must be implemented, then let us do it. In that way we control the rate and the tempo". In the implementation phase the established organisations are typically very strong as they have access to money, know-how etc. In spite of this advantage a number of examples show that very often the established organisations have difficulties in implementing radical changes. In Denmark this came out clear in the windpower program carried out by the electrical power companies during the 1980ies. The power companies tried to build big wind turbines from the very start. The result of that program seemed only to be a demonstration of the problems concerned with windpower and not the solutions the technology might bring. Fortunately a number of individuals and small scale wind turbine industries developed the technology at the same time. They managed to prove the feasibility of windpower in production of electricity.

Phase 8: The struggle of surviving

A new technology may run through all the former 7 phases and then again slowly be squeezed out by the established organisations. Maybe windpower in Denmark is presently being exposed to such a pressure. Windpower has been unpopular on locations in which the power companies and the

authorities have enforced the establishment of wind farms against the will of local residents. Also, the insulation of houses may be squeezed out in the future. The substantial Danish expansion of district heating in combination with regulation rules resulting in a high percentage of fixed costs might lead to stop the implementation of heat savings.

4.2 The Development of Institutional Infrastructures

With political objectives that result in the need for new organisations within the energy sector there is a need to include in the discussions of public regulation the issue of institutional and organisational change. By this is meant either change of existing organisations or the establishment of new organisations. The situation makes it necessary to change views on public regulation. Radical changes in technology cannot be implemented solely by changes in a universe of static institutions and organisations. Public Regulation must address and develop the institutions themselves.

An institution can be defined as "*a set of circumstances or rules for transactions*" (Hernes 1972). Thus, such institutions determine the development of a number of given organisations in the market. The conception of institution may be better explained by adding the word infrastructure and by describing the following characteristics:

- Investments in institutional infrastructures have a longer time horizon than investments made by individual actors on the market.
- Investments in institutional infrastructures have a larger space than the investments of individual actors. The investments are meant for more than one actor.
- The costs of institutional infrastructures are paid for by others than the individual actor or organisation.

Institutional infrastructures can be anything from educational systems to hardware physical infrastructures such as roads or district heating systems. The institutional infrastructures are part of both established private and public organisations. They function as a kind of historical inertia formed by former major investments designed and influenced at the strategic level.

In an analysis of public regulation one may place oneself in one of the following categories:

- Both institutional infrastructure and established organisations may be considered constant.
- Institutional infrastructures may be considered variable while the established organisations are considered constant.

- Both institutional infrastructure and established organisations may be considered variable.

In the case of need for radical technological changes such as described in chapter 1, both institutional infrastructure and established organisations should be considered variable. Organisation and institutional developing public regulation must make sure that a development of new organisations and new institutions can evolve. But such institutional and organisational preconditions do not evolve in the market automatically. Normally strong interests linked to existing power companies will try to impede the development of any institutions which support competing technology. The political process therefore has to be independent of these companies, and strong enough to establish the new market conditions mentioned above.

The established companies do not have the innovation capability required. Often a technological change results in loss of market shares of the old companies. Therefore, the political process has to be independent of the existing organisations and strong enough to establish new rules that might diminish the market shares of the existing companies. This is a severe requirement. For instance, the EU has heavy problems with this requirement due to the lack of openness in the Commission regarding the members of advisory committees and to the lack of any efficient legislation regarding lobbyism. To further the political strength and independency needed, the following preconditions should be stabilized:

- Tariffs and costs in the established companies should be more transparent to the public. By "the public" we mean any citizen and not just another public commission.
- The abolition of links between established companies and the State and the municipal economy. The economy of individual politicians, the State and the municipalities should be totally independent of the economy of established companies.

The information process which takes place feeding the political process with regard to the potential of new technologies should be independent of the established power companies.

4.3 Check List for Public Regulation Analysis

In the case of implementation of radical technological changes the public regulation should address the following (See figure 4.1):

- (1) the energy system, i.e. energy production, distribution and consumptions; plants and companies, and all the circumstances and rules for transaction on the energy market,

- (II) the socio strategic process, i.e. the process to secure the ability of society to adjust major changes in the environment. This is a primarily parliamentary process in which the decision makers are Parliament and local authorities,
- (III) international relations, i.e. the external limits of design and implementation of national energy policies and strategies. In the case of Denmark such limitations and possibilities mainly come from the European Communities,
- (IV) technical development, i.e. the development of well-proved new technical solutions such as new burners, new types of renewable energy ect.

Within each of these areas public regulation should include change in administration, organisations and institutional infrastructure as possible means for achieving defined political objectives.

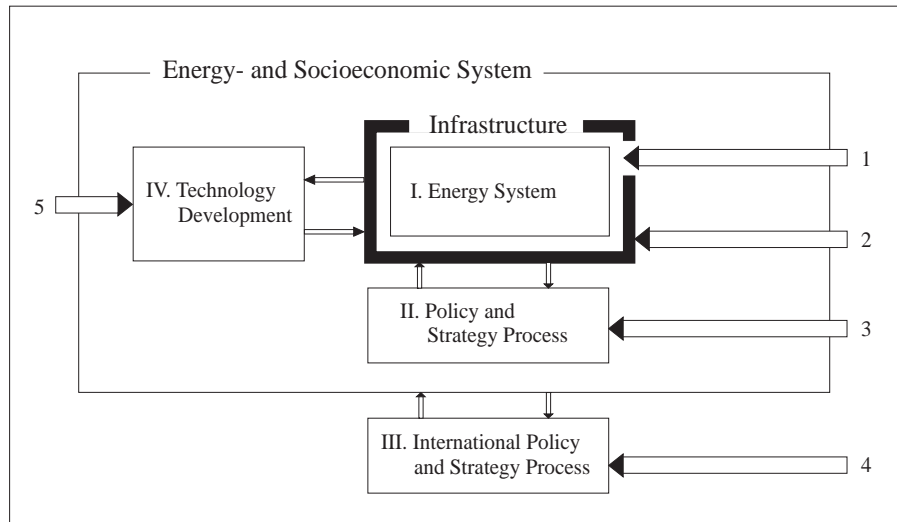


Figure 4.1: Public Regulation of Radical Technological Change in a Market Economy.

The analysis of public regulation can be discussed according to the following check list (See figure 4.1.):

Arrow 1: The establishment of economical rentability

The establishment of economical rentability may include

- 1) standard rules to secure buy and sales conditions,
- 2) financial reforms such as index loans and public guaranties,

3) taxes and subsidies etc.

Arrow 2: Organisational and institutional infrastructures

The establishment of a suitable organisational infrastructure may include either changes in established organisations or help to initiate new organisations perhaps combined with control of the development of existing organisations. The establishment of institutional infrastructures may include both the establishment of technical infrastructures such as the public electricity grid and the natural gas transmission pipe line system as well as the establishment of long-term rules and regulation of institutions for the definition of sales conditions etc.

Arrow 3: The strategic political process behind new reforms

The strategic process behind the establishment of new reforms (such as those mentioned above) may be influenced by the formation of committees who analyse and describe the material behind the political decisions. In Denmark, very often such committees consist of representatives for companies living by established technologies, and very often reports from such committees therefore tend to emphasize problems with new technologies (such as described in chapter 4.1) rather than promote them.

Arrow 4: Influencing international rules and regulations

Very often national policies and strategies are highly influenced by international rules and regulation. In the case of Denmark the developments of so-called "liberalisations" of the energy markets are initiated by the EU. Such international regulations will always be influenced by very intensive lobby possibilities from established technologies. And very often such lobby activities will have to be counteracted by either governments and/or lobby activities in favour of the new technologies.

Arrow 5: The development of new technologies

If houses are to be insulated, the ways of doing so must be available. Technical side effects must be avoided and skilled handcraft must be educated. If decentralized cogeneration is to be introduced new organisations must be able to buy the necessary equipment etc. The establishment of new technologies might include research, building of experimentation plants etc.

Chapter 5

Public Regulation cases from Denmark

By March 1997, EU decided to reduce the CO₂ emission by 10% in 2010. According to this decision Denmark has to reduce the CO₂ emission by 25%. The agreement between the EU countries is in accordance with the official Danish Energy Policy, which has had clear CO₂ reduction targets since 1990. Also, the Danish Energy Policy is based on a specific description of the technical means for implementing the reduction targets. Two important elements in the technical implementation are decentralized cogeneration and the conversion of electric heating. The public regulation of those two elements has already been implemented to some extent. Here the implementation will be described according to figure 4.1 in chapter four.

5.1 The Danish Energy System Since 1972

At the political level changing Danish governments have managed to formulate and hold on to specific objectives for the Danish energy policy in terms of reduction targets for CO₂ emission. But at the strategic level the representatives of the old technologies have made the implementation difficult.

Danish Energy Policy Objectives

Energy security and climate change responses are major objectives for energy policies in Denmark as well as in many other European countries. During the past 20 years these objectives have been expressed through a number of energy plans adopted by the Danish Parliament. During the period from 1972 to 1990 the major objective was to become less dependent on oil imports. Since 1990, the main objective for Danish energy policy has been to reduce the CO₂ emissions by 20% before the year 2005. This objective was expressed by the national energy plan *Energy 2000* (Ministry of Energy, 1990). Since then, the objective has been confirmed by the energy plans *Energy 2000 - Follow-up* (Ministry of Energy, 1993) and *Energy 21*

(Ministry of Environment and Energy, 1996). In March 1997, Denmark participated in the European Council decision to reduce CO₂ emission by 10% in 2010. According to this decision Denmark has to reduce CO₂ emission by 25% (European Council, 1997).

In the 1970s and 1980s the first objective of energy security was met partly by energy savings and partly by an increasing oil production and by replacing oil with other fuels, mainly coal and natural gas. Houses were insulated and central heating systems were converted from oil to natural gas or district heating based on coal-fired cogeneration. Power stations replaced oil with coal, and over a period of five years the Danish electricity production changed from a 90% use of oil to a 95% use of coal. In the same period Denmark began to produce oil and natural gas in the North Sea. At present, Denmark has a net export of oil and natural gas.

Already in the period before 1990 Danish energy policy has succeeded in meeting the second objective, i.e. the objective of climate change response. Firstly, insulation of houses and an extensive expansion in the use of cogeneration has led to decreased fuel consumption for domestic heating. It has been achieved during a period of 20 years of economic growth during which the number of houses has increased. Secondly, different types of renewable energy have been introduced, e.g. wind power, which is now producing approximately 5% of the Danish electricity supply.

The Danish energy policy has also had its failures. For example, the expansion of decentralized cogeneration was delayed for several years because the potential was considered too small to motivate development. And while large investments were made in insulation during the 1970s and 1980s none were made in electricity savings. This resulted in an increased fuel consumption for electricity production while the fuel consumption for domestic heating decreased.

Along with Parliament's introduction of the climate change response objective in 1990 it was also described how this objective could be reached by various types of strategies. According to the government's energy plan from 1990 *Energy 2000* the current technology of coal-fired power generation has to be replaced by new technologies, such as energy conservation, decentralised cogeneration and renewable energy. Since 1990, all strategies in Parliament's energy plans have been based on these principles of technology change, and consequently Parliament has decided

that Denmark must change its energy technologies radically - along the lines defined in chapter 1.

Some Actors on the Danish Energy Scene

The Danish energy scene can be understood as a struggle between the established organisations, which represent the old technologies, and grassroots movements etc., representing new technologies.

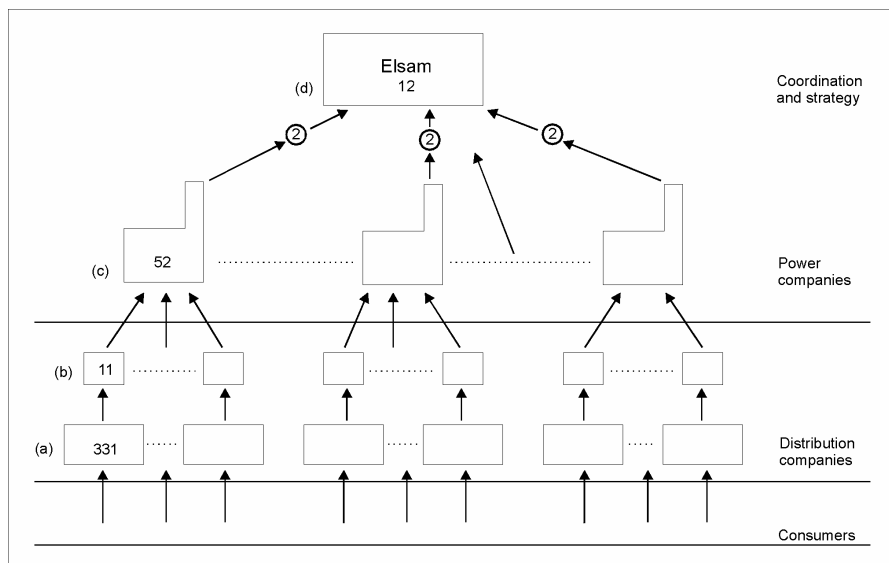


Figure 5.1: The organisation of the Danish electrical power system (The Jutland/Funen Case).

The Electricity System

The electrical power companies were very efficient in changing from oil to coal in the 1970ies, but have been resistant to new technologies such as renewable energy and decentralized cogeneration because of the following reasons. Many companies are consumer-owned with a hierarchical organisation illustrated by figure 5.1. The consumers elect their representatives in the distribution companies (a). These representatives elect their board of directors (b). The board of directors elect their representatives for their power plant company (c). The director and the deputy director from each power plant are automatically members of the power plant association for Jutland/Funen, ELSAM (d). ELSAM is the coordination unit and the organisation which elaborates the political strategy for the electricity system in Jutland/Funen. Today ELSAM is in the process of being divided into two independent companies, namely a production and a transmission company.

It is important to notice the following features:

- (1) The elected board of directors of ELSAM has a preference for large centralized power plants (at present coal plants). This is the case because the board consists of the elected director and deputy director in each of the 6 large coal-based power plants. There is no independent administration linked to the elected board of directors.
- (2) Furthermore the administrative directors of these companies have the right to meet (but not to vote) at the 4-6 committee meetings every year. There is no independent administration linked to the elected board of directors.
- (3) A set of indirect election procedures squeezes out any minority group, and new technology is always a minority at the initial stages of its development.
- (4) There is a high degree of openness with regard to accountancy information and tariff information. Every year information regarding these matters is published. That way any consumer can see what other consumer groups and consumers in other areas pay for electricity. This public control makes the Danish power companies rather cost-efficient. Denmark has the lowest electricity prices in the EU after Sweden and Finland.
- (5) The Danish electricity system is consumer-owned, and it is stated by law that any payment for electricity has to be recycled to the electricity consumers. One of the results of this system is that the Danish electricity system in reality has no debt. It can, for instance, lose market shares without risking any serious economic problems.

The above mentioned features ((1), (2) and (3)) result in an organisation which is very conservative concerning technology, and the conserved technology is a centralized coal-based system. Therefore it is no wonder, that this type of organisation has worked against the introduction of new technologies such as decentralized cogeneration plants continuously since 1975. These features ((4) and(5)) have as their result an organisation, which is rather cost efficient and governable due to relative openness and financial ability to survive changes. All these characteristics are important, when analysing this organisation as a part of a process of change. One might say: The Danish electricity organisation cannot change itself, but it can survive in a process of change.

The Natural Gas system

The Danish natural gas system is a rather new system, which expanded considerably in the late eighties and the early nineties. Its total sale on the Danish market was around 4.8 billion cubic metres of natural gas in 1997.

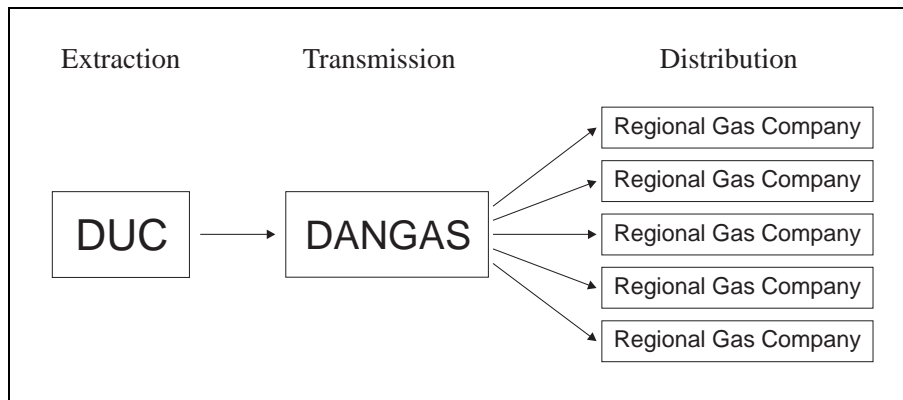


Figure 5.2: The organization of the Danish natural gas system

DUC (Danish Underground Consortium) extracts the natural gas from the gas deposits in the North Sea. It is owned by A.P.Møller, Shell and Texaco. Prices and costs are kept secret for the public, and the concession agreement between DUC and the Danish Government is also secret to the public.

DANGAS buys the natural gas from DUC and sells it to 5 regional natural gas distribution companies. DANGAS are owned by the Danish State, and have a board of 9 members: 3 from private companies, 3 from the employees in DANGAS and 3 from the Danish Central administration. Minutes from meetings in the Board, and communication between DANGAS and the Ministry of Environment and Energy are not accessible for the public.

The five regional natural gas distribution companies, which are owned by the municipalities, buy the natural gas from DANGAS, and sell it to the consumers. It must be emphasised that the Municipalities at the same time have responsibilities as energy planning authority.

A short characterization of the Danish natural gas system is:

- It is a rather new system, which still has a *high financial debt*. Especially the 5 regional gas companies cannot easily cope economically with an energy policy which would have decreasing gas markets as a result.
- It is a system, where there is a comparatively very *low degree of openness* towards the public. It is therefore very difficult to establish a

public discussion regarding the necessary public regulation of the gas companies.

- The Municipalities (and the State) have a *double role* as public regulator and owner of the natural gas system. A result of this is that the state and the municipalities are motivated to establish political conditions, which favour the natural gas project and disfavour competitors of the natural gas system.
- There are no organisational and economic links between the natural gas companies and the electricity companies.

This organisation has been rather efficient in the phases, where market expansion was the primary target, as the Municipalities and the State are extremely motivated to establish conditions, which support the expansion of the gas market.

The motivation for expansion may be described as follows: If the gas market expands, the public owned gas companies will have no deficit of payments, and it will be unnecessary to support the companies with extra payments from the taxpayers. Therefore the tax will not increase, and the taxpayers will reelect their politicians at the next election. This motivation would seem rather healthy from an economic point of view. Nevertheless, it has two main disadvantages seen from a public regulation point of view:

Firstly the politicians can be captured and held as a sort of economic hostages by the gas companies, which will demand favourable conditions even after being consolidated in the market. The politicians might be in a situation, where they, due to the low level of openness in the natural gas organisation, don't have the information needed for an efficient control of their companies.

Secondly Denmark is presently entering a phase where energy conservation, and the utilization of biomass resources are increasingly important aims of the energy policy. We donot need expansion but energy conservation, or market contraction, and we have an organisation which is designed for expansion. That is a very serious problem when designing a system of public regulation, which is feasible in the future.

What can be learned from the Danish experience?

- (1) It has been favourable to the Danish energy policy, that the natural gas companies have been relatively independent of the electricity companies. Consequently, the natural gas distribution companies have collaborated with the electricity companies in their fight against

decentralized cogeneration. The natural gas distribution companies rather have had an interest in the development of a gas market for decentralized cogeneration.

- (2) Almost nothing has been done in order to implement energy efficiency programmes, since the natural gas project was started.
- (3) The utilization of biomass resources in the natural gas areas has been hampered by the natural gas project.

The problems in (2) and (3) are generated by mixing the economy of the "policy making" organisations, the state and the municipalities, with the economy of the natural gas companies. Because of this mixture, the state and the municipalities have lost/weakened their political freedom to perform their most important task, namely to establish an open public discussion of the design and implementation of a long term policy/strategy. Furthermore it has become politically difficult to change the policy because of a system, where the public has very limited access to the information flows between the natural companies internally, as well as between these companies and the public administration authorities. So if an energy system is supposed to maintain its long term innovative capability, it is important to avoid mixing the economy of the energy supply companies with the "policy making" organisation, the state and the municipalities. At the same time the innovative ideas of the public can only enter the scene, if there is a very high degree of openness of information built into the energy system.

The Central Administration

To a large extent the central administration in the Ministry of Energy has been influenced by the electrical power companies in the period 1975-1989. This influence is a part of a corporate public regulation culture. Meetings between the administrative directors of the power companies, natural gas companies and the directors of the Ministry of Energy were institutionalized under the term "coffee meetings". They were of considerable importance for the policy of the central administration. This is systematically combined with a tradition of establishing advisory committees mainly consisting of employees from the power companies and the central administration. It is also supported by an administration that does not have sufficient resources to examine specific technical questions within the area of electricity supply. Consequently such questions are often handed over to the employees of the power companies, and these employees are not in a position to give objective answers.

In 1989 a new Minister of Energy broke this tradition by having his administration work out a new energy plan "Energy 2000", without giving specific

preference to the viewpoints of the power companies. At present the central administration is in a process of managing between a tradition of regulation by negotiating solely with the large power companies, and a need to introduce new cooperative procedures, where a number of proponents for the decentralized new green technologies take part in the planning process. The new energy plan *Energy 21* continues the energy policy of *Energy 2000*, and describes how it is possible, by means of new decentralized green technologies to halve the emission of greenhouse gasses. But so far no decisive steps have been taken to alter the administrative procedures characterized by negotiations solely with the existing fossil fuel power companies.

Parliament

The Danish parliament is able to organize the introduction of new technologies - even when this is against the wishes of the power companies:

- (a) Minority political views are represented in Parliament, but not in the power companies. If a political party gets more than 2% of the votes, it gets representation in Parliament. Consequently, Parliament has many political parties, at present eight. This political pluralism in Parliament makes it difficult to conquer all the political parties. Some of the minor parties have no strong links to the power plant industry or the trade union interests linked to this industry. They are independent parties. Therefore, new ideas can enter the political debate.
- (b) Normally there is a very delicate balance between the right wing and the left wing parties in Parliament, and this sometimes makes it possible for the above mentioned independent political parties to get political influence. The Minister of Energy in 1989 came from one of these small parties, the Radical Liberal Party.
- (c) There is a certain openness in the administrative procedures. According to law correspondence between the public administration and others is open to the public. This means that any person has the right to see this correspondence.

The grass-roots organizations

The movement against nuclear power played a very important role during the years 1977-1984, and was a scene of discussions, meetings, seminars, etc. Here many people got their introduction to and knowledge of energy questions. Simultaneously the organization for renewable energy played an important role. Among others, these organisations had close connections to universities and members of Parliament, and as a result specific political

reforms, proposed by the grass-roots organisations were implemented by Parliament. The characteristics of the movements are:

- (a) That they have been "unauthorized" educational scenes.
- (b) That many people who got their training within the energy field from these organizations, are now employed in new businesses dealing with conservation, cogeneration and renewable energy or employed in administration or the media. In these organizations they now represent persistent forces influencing the energy policy in their firms and in the public debate.

Energy researches, universities, etc.

In the period from 1975 and onwards critical reports have been published from the universities, advocating technological openness, making the introduction of energy conservation, cogeneration and renewable energy possible. The universities have free research funds amounting to 40% of the salary of each employed teacher. This gives a rather high degree of research independence. The researchers are not totally dependant on funds coming from external funds. Furthermore a Steering Committee for Renewable Energy was founded in the eighties, with an annual research budget of 6 million \$. The members of this committee were independent of the existing fossil fuel companies, and were proponents of the new technologies. A rather large amount of independent research funds for renewable energy purposes made it possible to establish well-documented arguments to match the arguments of the established power companies.

5.2 The case of Decentralized Cogeneration

Decentralized cogeneration is one important element of the implementation of the Danish energy policy objectives of CO₂ emission reduction. As it is well known, cogeneration decreases the consumption of fossil fuels for heat and power by 20 - 40%, when compared with separate production of heat and power. Naturally the exact figure depends on the specific conditions. At the same time cogeneration is a technology that can be used as infrastructure for the implementation of increased use of wind power, biomass and hydrogen-based systems in a later phase.

During the period 1990-1995 the DCHP (Decentralized Combined Heat and Power) technology had a "take-off" in Denmark. From the beginning of 1990 to mid-1995 the installed DCHP plant capacity raised from 60 MW to 1250 MW, which is about 15% of the total power capacity. In the

Jutland/Funen area the DCHP plants and wind power delivered 27% of the electricity in 1996 versus 1% in 1987, and 4% in 1991.

This "take-off" was induced by means of the introduction of a set of institutional reforms in the late eighties and the early nineties facilitating the introduction of DCHP plants:

- Index-regulated low interest loans in combination with municipal guarantees were introduced in the mid-eighties.
- In 1988 a specific (and publicly accessible) set of rules for the pricing of natural gas for heating and electricity was laid down.
- Regarding the sale of electricity from auto producers to the public grid, negotiated standardized rules based on a long term marginal cost was introduced in 1988. In December 1995 this principle was put in the Statute Book.
- A set of open and common rules and administration procedures regarding the payment for the enforcement of the distribution network were introduced in 1991.
- A governmental subsidy, 0.0167 US\$/kWh cogeneration electricity sold to the public net, was introduced in 1993.

The development of these institutional reforms was a result of a long and complicated political process with lots of conflicts. In the following this case will be described according to the theory of chapter 4:

- (a) The economy of Decentralized Heat and Power production and its dependence on a set of politically appointed institutional reforms (Arrow 1).
- (b) The Establishment of new organisations to invest in decentralized cogeneration (Arrow 2)
- (c) The history and character of the political conflicts which led to these reforms (Arrow 3).
- (d) The ongoing struggle against EU-directives to keep the Danish priority of decentralized cogeneration (Arrow 4).
- (e) The development that secured the existence of a well proved and well functioning decentralized cogeneration technology (Arrow 5).

The Establishment of economical rentability (Arrow 1)

Since 1990 more than 200 DCHP plants have been established in Denmark. 30 of the plants (64 MW electrical capacity) are based on biomass as fuel and the remaining around 200 (1180 MW electrical capacity) on natural gas. The size of the plants vary from 0.2 MW to 60 MW electrical capacity. A typical plant has between 0.5 and 5 MW electrical capacity. In order to

understand this development, the case of Sønderholm Cogeneration Plant will be scrutinized: Sønderholm Cogeneration plant has an electrical capacity of 1 MW, and a heat capacity of 1.8 MW installed. The plant started production in the beginning of 1992, and ever since it has produced without problems.

Investment	Million US\$.
Cogeneration Plant (Gas engine incl. hot water storage)	1.73
District heating pipe line system	1.27
House installations	0.60
Total	3.62

Figure 5.3: Investments, Sønderholm Cogeneration plant. 1 US dollar = 6 DKK.

Investment and financing

The total investments amounted to 3.62 million US\$ (See figure 5.3) similar to an investment per consumer of approximately 14,000 US\$. The plant is a cooperative plant owned by 259 consumers, mainly private households. These consumers represent 84% of the households in the village of Sønderholm. The investment was financed by external credit and each household only had to make a symbolic payment of approximately 15 US\$ to become a member of the cooperative.

The investment of 3.62 million US\$ is financed with 2.5% per annum index regulated loans. The index regulation is linked to the consumer price index. Such index regulated low interest loans were made available in the financial market in the mid-eighties. And in 1989 a law was introduced, saying that the municipality is obliged to give a public guarantee for the loan, which means that if the consumers cannot pay the yearly instalment, the taxpayers will have to pay. In reality this guarantee has no subsidy element, as the consumers are juridically linked to the cogeneration cooperative, and in case of bad economy would be obliged to pay high heating bills.

If we compare the Sønderholm financing conditions to the financial conditions of the established electricity system, it is important to be aware of the fact that the latter have a very high degree of consolidation, and that there is no taxation on the large capital of this system. I.e. that the built-in interest on

the expansion of this system is lower than 2.5% p.a. Therefore, the amount of subsidies in relation to the traditional power system is negative. In the case of Sønderholm, the 3.62 million US\$ investment has been financed in such a way, that the annual payment in 1993 and 1994 was 0.26 million US\$.

Sale of electricity to the public grid

The Sønderholm DCHP plant produces about 3.54 million kWh every year. In 1994 this equalled a payment of 0.2 million US\$, or an average price of 0.073 US \$/kWh. This price level is composed of:

- (a) payment from the public grid,
- (b) conditions for delivery to the public grid, and
- (c) payment from the Government for low CO₂ energy production.

Rules for standardized payment from the public grid were introduced in 1988 after a tough political fight/debate, where the power companies tried to lower the payment as much as possible. The rules are based on the principle of *a long term marginal costs* and include a payment for decreased need for transmission networks in a power system with many decentralized power production units. It was also assured, that the owners of a decentralized combined heat and power plant (DCHP) should have the right to sell electricity to the public grid at a price based on the principle of a long term avoided costs in the public electricity system. The reference system is a large coal fired power plant, and the transmission system linked to this is a centralized method of electricity production. Included in the price is the payment for reserve capacity for situations where the Sønderholm DCHP plant is out of production.

In 1995 the power companies refused to follow these rules which were then put in the Statute Book by Parliament in December 1995. In spring 1996 this law was accepted by the European Union. The implementation of this principle has resulted in the following prices for electricity sold by the Sønderholm cogeneration plant to the public grid (See figure 5.4).

Name	Time definition	Sønderholm production	Sales prices
		Million kWh/year	US\$/kWh

High load	Monday-Friday -Winter 730-1200 and 17-1830. -Summer 730-1200	1.24	0.083
Middle load	Monday-Friday -Winter 630-730, 1200-1700 and 1830-2100 -Summer 630-730 1200-2100	1.34	0.060
Low load	The remaining time	0.96	0.023

Figure 5.4: Sales prices for electricity sold to the public grid

The terms of sale are very simple and non-bureaucratic. In 1991, after a political fight with the power companies, agreement was reached on a standardized set of rules of the payment for establishment of sufficient transmission capacity in the electricity grid. There is no specific payment for reserve capacity.

In addition to the above-mentioned prices there is a 0.0167 US\$/kWh payment: The so-called "CO₂ 10 øre" that was introduced in 1993 as a part of the national energy policy. This payment was given to electricity produced at decentralized cogeneration plants, based on natural gas as fuel, as a reward for low CO₂ energy production. This "CO₂ 10 øre" was only given to consumer owned decentralized cogeneration plants. Not to the plants owned by the electricity companies. The subsidy in the case of Sønderholm amounts to 60,000 US\$/year.

Sale of heating to the consumers

In 1994 the Sønderholm cogeneration plant produced 4.9 million kWh heat sold to the consumer for 411,295 US\$ or in other words at an average price of 0.0833 US\$/kWh. This price includes payment for the amortization of the investments in each house. An investment of 2,317 US\$ in average per household. The marginal price in 1994 was 0.065 US\$/kWh. It should be mentioned that in comparison the price per kWh light fuel oil in 1994 was at the same level. Seen from the consumers' point of view, this type of heating is not cheaper than its alternative, which is light fuel oil, but the consumers benefit from not having to maintain and reinvest in a private fuel furnace storage system. Many households were close to a point where they had to invest in new private systems. This was avoided by paying 16.7 US\$ to the cogeneration cooperative.

Purchase of natural gas from the gas companies

Sønderholm cogeneration cooperative in 1994 purchased 997,711 m³ natural gas, for 0,318 million US\$. The average price was 0.32 US\$/m³ gas. In Denmark there is a taxation on fossil fuel utilization for heating purposes. Electricity has a kWh electricity tax, but not a fuel tax. Consequently gas for heating purposes is more expensive for Sønderholm, than gas for electricity purposes. In 1994 Sønderholm paid around 0.44 US\$/m³ gas for heating purposes, and 0.15 US\$/m³ gas for electricity production.

The principle of dividing between heating and electricity purposes has been heavily discussed in Denmark, and the result should be seen as a consequence of a political decision more than a technical calculation. The main principle is that a calculation is made of how much gas would have been used to supply the given amount of heating from an ordinary heat production unit. The marginal extra amount of gas used for the cogeneration plant is defined as gas for electricity production. In the case of Sønderholm 627,413 m³ was defined as gas for heating (0.44 US\$/m³), and 370,298 m³ (0.15 US\$/m³) was defined as gas for electricity production.

This solution is due to the fact that in 1988 a specific (and publicly open) set of rules for the pricing of natural gas for heating and electricity was laid down. It should be noted that these rules are not relatively favourable for natural gas-based cogeneration. In fact the large coal-based cogeneration units in the big cities still have by far the lower total fossil fuel taxation, compared to the decentralized cogeneration units. From a taxation point of view the large units are in principle operating as power producing units with a marginal use of fossil fuel for heat production. Under these rules Sønderholm would have been able to buy about double the amount of natural gas to the low price, if it had been a coal-based cogeneration unit in a big city. This is just to mention that the new technology at this point has no relative advantage seen in relation to the conventional large coal-based power plants. In fact the decentralized plants here still have a negative subsidy, seen in relation to large coal-burning cogeneration plants of 70 - 80,000 US\$ per year.

Conclusion regarding the institutional preconditions

Figure 5.5 shows that in the year 1995 there was a small deficit, but in the previous year there was a small surplus. At present the economy is in balance at a heat price that is competitive to the price of the alternative: Light fuel oil.

Expense category	Expenses million US\$.	Income category	Income million US\$.
Natural gas heat	0,27	“CO ₂ 10 øre”	0,06
Nat. gas. elect.	0,05	Sale electricity	0,2
Working expenses	0,11	Sale heat	0,41
Amortization	0,26		
Total expenses	0,69	Total income	0,67

Figure 5.5: Financial balance of the Sønderholm DCHP plant 31 June 1994-31 June 1995

The Establishment of organisational infrastructure (Arrow 2)

As described in chapter 5.1 the established electric companies showed no interest in building decentralized cogeneration units. On the contrary the expansion of this technology was seen as a threat to the possibilities of getting permission for building new coal fired power stations. Therefore, new organisations had to evolve in order to introduce this technology.

In Denmark the establishment of consumers owned cooperatives is an old tradition which is widely spread all over the country. The power companies are consumer owned, district heating systems are mostly consumer owned, many agricultural organisations are consumer owned, etc. And in many towns and villages consumer owned district heating companies already existed when the expansion of decentralized cogeneration started. But this was not the case in all places. In some towns - such as for example Sønderholm - new consumerowned companies had to be formed.

In such places the establishment of cogeneration was typically initiated by a ginger group of 5-10 persons. Sometimes they were formed by existing local citizens groups, and sometimes this was initiated by the natural gas companies or consultancies ect. Also, in Sønderholm a ginger group of five persons was formed.

Furthermore it is a lesson from the Danish development in general that in the long run houses with district heating linked to cogeneration will have considerably lower prices, than houses using individual oil-based heating systems. Nevertheless, this price argument was never used by the local cogeneration ginger group. They used to say that they could not promise that the heat would be cheaper than systems based on individual oil-burning.

Nevertheless this ginger group, consisting of five persons, was able to convince 84% of the households, that cogeneration was a good idea.

The precondition for this solution was the existence of an active local ginger group, which was willing and able to analyse technical alternatives, negotiate with the electricity companies and arrange public meetings with the consumers within the region. Also it was possible to work out a solution, where the consumers had to raise less funds, than if they did not join the cooperative, they only had to pay 16.7 US\$ to become members. Their alternative would have been to raise a couple of thousand US\$ in order to maintain their own private systems. It was very cheap to become a member.

The Strategic Political process behind the reforms (Arrow 3)

It must be remembered, that cogeneration is well known in Denmark; there have been large cogeneration plants in towns with more than 100,000 inhabitants since the 1930s. Before the Second World War there were also many decentralized cogeneration plants based on diesel as fuel. In the following the focus is set solely on the political process from 1973 and onwards, which led to the development of DCHPs in the nineties. This development has the following characteristics:

Dansk energipolitik 1976 (Danish Ministry of Trade, 1976) i.e. *Danish Energy Policy 1976* was the first Danish energy plan after the energy crisis in 1973. In this plan DCHP plants were excluded because they would impede an economic utilization of nuclear power-based electricity production. It was recognized that the potential of DCHP was considerable, but at the same time it was decided that this potential should not be further examined. Economic comparisons of nuclear power and fossil fuel alternatives were conducted between large coal fired plants and large nuclear plants. In that way the nuclear power technology, which in the seventies was wanted by the government and the power companies, was compared with the second best fossil fuel technology. The best technology, cogeneration, was not included in the comparisons.

The government and the power companies tried to keep the DCHP technology off the political agenda, but they did not succeed, as different independent energy plans were elaborated, concluding that decentralized cogeneration plants could play an important role in the Danish energy system as an alternative to nuclear power. A group of university researchers participated in the public debate by elaborating an alternative energy plan in 1976 (Hvelplund, 1976). In this plan a considerable electricity production

came from natural gas-based DCHPs. Nevertheless, in information pamphlets from the power companies, DCHPs based on natural gas were not even mentioned as a technological possibility in 1979. The publication from ELSAM called *Kort fortalt om kraft/varme* i.e. *Cogeneration in brief* mentioned coal-based co-generation in towns down to a size of 10,000 inhabitants. There was no mention about the possibility of introducing DCHP based on natural gas.

The *Energiplan 1981* (Danish Ministry of Energy, 1981) was the second official energy plan. It relied either on large coal based or large nuclear power plants. The DCHP technology was described as having negligible potential in the energy system. The official policy and the policy of the power companies continued to be that of keeping DCHPs off the political agenda. A group of university researchers wrote *Energi for fremtiden*, i.e. *Energy for the Future* as an alternative to *Energiplan 1981*. Here DCHP plants were introduced in towns with a size of down to 200 inhabitants amounting to a generating capacity of around 2000 MW.

In 1984 the Danish parliament decided to abolish nuclear power from the energy plans, and the Ministry of Energy established an advisory committee, that was to examine the possibilities for DCHP. This group had 13 members from the central administration, the power companies and the natural gas companies.

At the same time a natural gas-based DCHP pilot plant was built by the power companies in a village called Ullerslev. The first results from this pilot plant were very pessimistic. Among other problems there was an engine stop for 3 months in 1985. The power companies expressed deep pessimism regarding the technical and economic performance of this plant.

In 1987 a final report from the above-mentioned advisory committee estimated the maximum potential for DCHP in Denmark to be 450 MW electrical capacity. The total electricity production from such plants was estimated to be only 6% of the electricity supply. The message to the politicians was, that DCHP was interesting, but of minor interest for the total energy system. This message (450 MW DCHP capacity) was included as official energy policy until 1989.

Also in 1987 there was a public discussion regarding the payment of the electricity sold from DCHP plants to the public grid. As a result of this public discussion, where the power companies tried to keep the price down

as much as possible, fixed rules for payments were established, based on the principle of a long term avoided cost. The reference system was a 350 MW coal-based power plant.

In 1988 the authorities still calculated with a price between 1,266 and 1,583 US\$/kW per installed kW electrical capacity DCHP plants. This had the effect that in the public debate, cogeneration continued to be regarded as a very expensive alternative to the large coal based power plants. In 1988 the official policy still had it that decentralized cogeneration could only supply around 450 MW electrical capacity.

In 1990 a 3.5 MW electricity and 5.6 MW heat cogeneration plant were founded in a small town called Dronninglund, mainly because Dronninglund had a coal fired furnace, which should be closed according to heat plan procedures. The price per installed MW electrical capacity was 833 US\$, or even lower than the kW price of a large coal fired power plant.

At the same time a new Minister of Energy, J. Bilgrav Nielsen, member of a small rather green liberal party, had been appointed. He was an experienced politician and concerned about the ecological problems linked to the energy productions. He organized the elaboration of a new energy plan *Energy 2000*. This plan had as its goals a 20% reduction of the CO₂ emission and a 15% reduction of the energy consumption within the period 1988-2005. In this plan a DCHP plant capacity of 1500 MW was planned for the year 2000.

In 1995 the power companies refused to continue to pay a price based on the principle of a long term marginal costs for the electricity bought from DCHPs. After fruitless negotiations with the power companies, the Minister of Environment and Energy decided to propose a law enforcing the power companies to pay according to the long term marginal cost principle.

This law was passed by Parliament in December 1995, and was notified in the European Union in May 1996. In 1996 a new electricity law was passed by Parliament, giving electricity from DCHPs and renewable energy sources first priority in the Danish electricity system.

Influencing International Rules and Regulation (Arrow 4)

In February 1997 a new EU directive on electricity trade was accepted by the EU Council of Ministers. The declared aim of this directive is to establish more competition between the power companies at the same time as environmental goals are pursued. The directive among others aims has

opening the electricity market by ensuring that consumers are allowed to buy from different producers in the market to an increasing degree. The directive will be implemented during a period of 6 years, starting from February 1999.

Concurrently with the implementation of this directive, there is a tendency in Northern Europe to establish an overcapacity with regard to power capacity. Together with the above-mentioned directive this might result in a situation with periods of electricity market prices equalling the short term marginal costs plus a profit. This might result in prices which in periods could stay at 4-5 US cents pr. kWh. At the same time the large power companies have an interest in pushing the new decentralized cogeneration and renewable technologies off the market.

As mentioned before, the Danish cogeneration units by law get a payment for electricity sold to the public grid, which equals the long term marginal costs at a large coal fired power plant. In 1995 and 1996 the question arose, to what extent it was possible to defend the Danish energy policy, especially with regard to cogeneration and renewable energy. The danger was that the companies behind these "new" technologies could not survive in a market environment, where the external environmental costs were not included in the market prices, and where the market prices in periods would be close to the short term marginal costs, due to a situation with overcapacity.

As a consequence of this discussion a Danish "liberalization" law was introduced and accepted by the Danish parliament in mid 1996. This law as good as copied the content of the coming EU directive mentioned above, and represents an opening of the Danish electricity market, so that consumers with an annual consumption of more than 100 GWh are allowed to buy electricity where they want to. At the same time the Danish law gives preference to renewable energy and cogeneration, so that these "green" technologies are protected against direct competition from the large fossil fuel power plants. The law states that the Danish electricity distribution companies and the Danish consumers are obliged to buy each their proportion of the electricity produced in renewable energy and cogeneration units.

After a longer period of analysis and discussion between the Danish negotiators and the EU, the EU accepted the content of the Danish "liberalization" law in mid 1997. Therefore this law is now in effect. It seems clear that new technologies organised by comparatively new and small organisations cannot be exposed to "free" competition with the old

power companies which have huge accumulated capital, and at the time overcapacity. It is therefore important to establish market constructions, which both establish competition in order to keep costs down, and protection of newcomers and their green technologies. It was necessary that the Danish government worked actively in order to establish this protection of the “green technologies”, and in this case it seems as if this work succeeded.

The development of new technologies (Arrow 5)

The first natural gas DCHP pilot plant was built in the early eighties by power and natural gas companies, which had not really any interest in the development of such a technology. It was placed in the village of Ullerslev on the island of Fyn and was always called the Ullerslev plant. The first results of the Ullerslev plant were very pessimistic, and the plant itself was very expensive. Therefore the power and natural gas companies expressed deep pessimism regarding the technical and economical performance of this plant and of such technology in general. For several years this pessimism was used wherever decentralized cogeneration was proposed. For example the city council of Aalborg rejected this technology because of the prices of heat in Ullerslev.

For almost 10 years this technology was regarded expensive and not stable until two new stations were built in Northern Jutland in 1990 (Dronninglund and Nørager). Those two stations were based on technological experiences in Germany and the Netherlands, where many decentralized cogeneration units had been put into production without the problems of Ullerslev. Cogeneration units were then imported and installed in Denmark. The special Danish energy taxes on fuels for heat production and the Danish tradition for heat savings initiated that Danish companies developed special heat equipment for the imported engines in order to secure no waste of heat.

Concluding remarks

The case of decentralized cogeneration is an example of how a new technology has to run through a number of political phases before it can be implemented. The following classical methods of resistance against a new technology can be mentioned:

The early introduction phase (1975-1982):

Here the "it does not exist" argument was used. The representatives of the “old technologies” tried to exclude the new technology from the political agenda. Decentralized cogeneration was simply ignored in any technical report published by the companies. This strategy had considerable success

until about 1980. This can be regarded as a typical first phase opposition strategy.

The late introduction and pilot plant phase (1982-1989):

First the "it does not work" argument was used. The technical reliability of decentralized cogeneration was underestimated. This was exemplified in the mid-eighties with the Ullerslev pilot plant administrated by the power companies. Then the "it is too expensive" argument was used. The economy was underestimated. This was done with success until 1990, when the first DCHP plant was built at a price 40% lower than the official "planning price" in 1989. Finally the "maybe it exists, works and is economical, but it is only of minor importance" argument was used. The potential was underestimated. This strategy was successful until 1989. The way of doing it was to conquer the political process and assure that governmental advisory committee only had members from the central administration and the power companies.

Implementation phase:

In the implementation phase the "it does not work in an energy system" argument was used. Technical problems linked to the adjustment of the new technology to the total electricity system was exaggerated. This was, and is done by means of the newly established "Integrated Resource Planning" procedures where it is argued that the new technology, DCHPs, lead to problems with excess electricity during the winter.

To a large extent the way of resisting the new technology has been to conquer parts of the political planning process. Amongst others by supplying members to official advisory committees, which prevented unbiased information from entering the decision scene of Parliament and by getting a monopoly on the newly established "Integrated Resource Planning" procedures.

It may be concluded, that proponents of a specific technology, in this case coal fired power plants, should not be the only members of governmental advisory committees or have monopolies on integrated resource planning procedures. The advisory committees should also have members who are proponents for the new technologies, and who are independent of the established technologies. Integrated resource planning procedures should include organisations which are proponents of DCHPs, renewable energy and energy conservation technologies. If such precautions are not taken, the

information reaching Parliament will be biased, and unfeasible for sound political decisions.

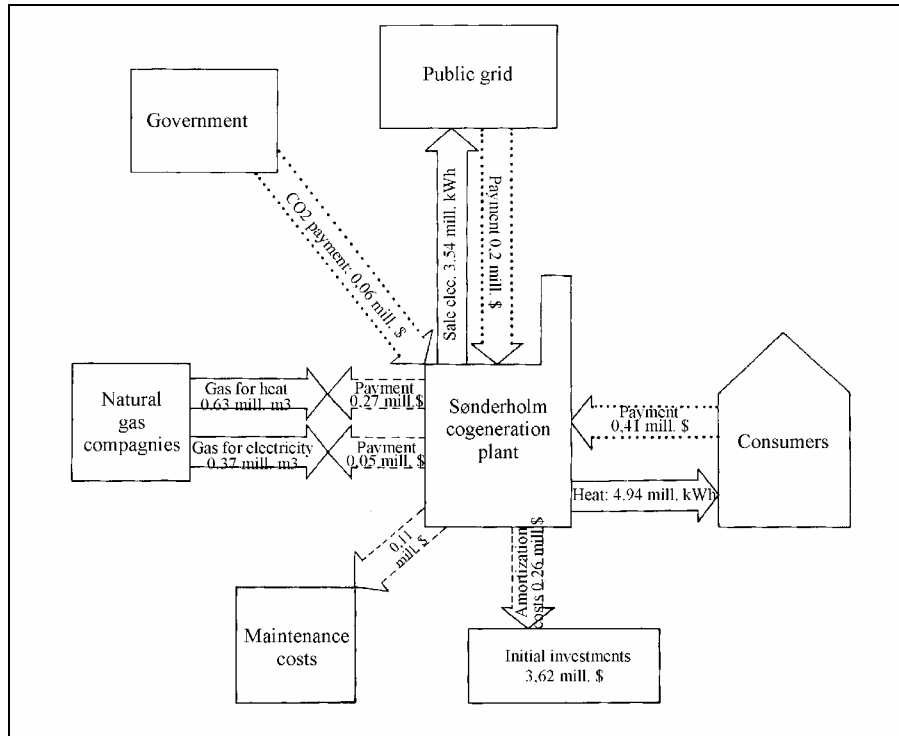


Figure 5.6: The economy of Søndersholm Cogeneration Plant

The total picture of the establishment of economical rentability of Søndersholm cogeneration plant is illustrated in figure 5.6. The figure shows that cogeneration plants are extremely vulnerable to financial conditions at four levels:

- (I) The prices of purchase for natural gas,
- (II) the prices for heating sold,
- (III) the prices for sold electricity, and
- (IV) the financial conditions for amortization of the loans.

At all levels bad institutional conditions may stop the growth of the cogeneration. The established institutional conditions are shown in the circles. Every condition has been necessary for the successful development of the cogeneration in Denmark. The economy of the cogeneration plant has now reached a level, where it can compete with the alternative: individual heating systems based on light fuel oil.

In addition to this the Danish tradition for consumer owned cooperatives-, and the active ginger group was necessary. The active ginger group was necessary because Sønderholm was among the first small cogeneration plants which also needed investment in a water pipe distribution system (1.27 million US\$). Now that the technology has become common the need for an active ginger group has diminished.

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995
Standard gas prices	÷	+	+	+	+	+	+	+	+
Long-term marginal costs	÷	+	+	+	+	+	+	+	+
Index loans	÷	÷	+	+	+	+	+	+	+
Public guarantee	÷	÷	+	+	+	+	+	+	+
Standard grid payment	÷	÷	÷	÷	+	+	+	+	+
CO ₂ subsidy	÷	÷	÷	÷	÷	÷	+	+	+
etc.	+	+	+	+	+	+	+	+	+

Figure 5.7: Growth in DCHP capacity, and the establishment of the financial institutional preconditions at the implementation level

Figure 5.7 is a summary of the establishment of a number of institutional preconditions at the implementation level for the Danish development of DCHP capacity since 1987.

Furthermore it has to be recognized that a set of non-financial preconditions at the implementation level also have to be present. Among the preconditions we will sum up the following:

- In the initial phases it is a big advantage that there is an infrastructure of district heating systems distributed all over the country. This was the case in Denmark, and these consumer-owned district heating cooperatives represent the backbone of the Danish decentralized cogeneration development. These systems are easier to implement, than systems like Sønderholm, where it is necessary to invest 1.27 million US\$ in pipelines for distribution of hot water.
- In Denmark there is an institutional public heat planning procedure which, by political decision, in 1990 enforced coal-burning district heating systems to find a substitute for coal as a fuel. As these systems

had to change fuel, they were looking for new technological possibilities. The DCHP technology was at hand, and therefore it was implemented in the former coal based district heating cooperatives.

- Active district heating cooperatives with a rather active democratic decision procedure have made it possible to make decisions regarding the introduction of DCHP systems.
- A high tax on coal, oil, gas, and electricity makes heat rather expensive. This increases the public interest for issues of heating.

The "breakthrough" for DCHP was initiated despite the resistance from the central administration and the electrical power companies. The initiative evolved from the public debate established by grass-roots groups, researchers at universities and Members of Parliament. Future energy policy must realize, that innovation comes from firms, groups of people and individuals who are independent of the existing fossil fuel supply companies.

In general it may be concluded that the specific Danish conditions in the power companies, in the central administration, in Parliament and in the grass-roots movements made it possible to introduce reforms against the will of the power companies and initially also against the will of the central administration.

The situation of the energy scene does not seem to have changed with respect to the resistance to change coming from the power companies. Therefore the specific Danish conclusion is that public regulation has to give an important role to groups and people outside the influence of the large fossil fuel supply companies.

5.3 The Case of Conversion of Electric Heating

It is planned that the Danish energy policy objective of CO₂ emission reduction be reached by the introduction of a wide range of technological changes. Decentralized cogeneration is one element, and a switch from electric heating to central heating is another small but an important element. In 1992, around 152,000, out of approximately 3 million, Danish households were heated by electric heating as the main source. The net heat demands were estimated to 8,6 PJ/year which were approximately 1,4 % of the total energy consumption. But since electricity production in Denmark is based on coal-fired power stations the electric heating needed 2,8% of the primary energy uses and resulted in 3,8% of the total CO₂ emission.

	Heat demand	Grid loss	Heat product.	Prod. efficiency	Fuel consumpt	CO ₂ emission
	GJ/year	%	GJ/year	%	GJ/year	ton/year
Electric heating (Based on coal)	56	10	62	40	154	14,6
Natural gas (Residential burner)	56	-	56	80	70	4,0
District heating (Partly cogeneration)	56	25	70	133	53	4,0
Oil (Residential burner)	56	-	56	75	75	5,5
Straw/Wood and solar collector	56	-	45	70	64	0,0

Figure 5.8: Fuel consumption and CO₂ emission from electric heating compared with relevant alternative technologies

In figure 5.8 electric heating is compared with a number of relevant alternative house heating technologies. The comparison is made for an average, electrically heated household with a heat demand of 56 GJ/year equal to approximately 15.500 kWh/year. Fuel consumptions are calculated with the shown grid losses and production efficiencies which are typical for Danish heating equipment. And CO₂ emission is calculated on the basis of the following emission factors: coal, 95 kg/GJ; gas oil, 74 kg/GJ and natural gas, 56.9 kg/GJ (Ministry of the Environment, 1994).

In the table electric heating is compared with:

- natural gas in residential burners, which is a relevant alternative for approximately 39% of the electrically heated houses located in areas within the Danish natural gas grid;
- district heating which is relevant for 23% of the houses within district heating areas;
- and residential burners using either gas oil or straw/wood, which is relevant for the remaining 38% of the houses located outside both natural gas and district heating areas. All of these technologies may be supplemented with solar collectors which typically produce approximately 20% of the house heating (hot water during summer time). This possibility is shown for the case of straw/wood burners. In the case of district heating a mixture representing the average Danish district heating system in 1995 is assumed. In this year approximately 72% of the heat was produced in cogeneration, and the mixture of fuel was more or less an even division between coal and natural gas.

Figure 5.8 shows how both fuel consumption and CO₂ emission are much higher for electric heating than for any of the shown alternative technologies. This is primarily due to the electricity being produced from coal. If the electricity was produced from wind power, hydro power or nuclear power, the CO₂ emission would have been zero. Meanwhile it must be emphasized that coal is the relevant alternative in Denmark where 84% of the electricity production in 1995 was based on coal. It also counts for the fifteen EU countries as a whole since more than 30% of the European electricity production is based on coal.

	Buildings	Heat demand	Fuel consumption	CO ₂ emission	Saved electricity capacity
	Number	TJ/year	PJ/year	Thousand ton/year	MW
Electric heating	151,847	8,572	23.57	2,239	-
Alternative					
-Natural gas	59,165	3,280	4.10	233	300
-District heating	34,528	2,056	1.95	148	190
-oil/wood + solar	58,154	3,236	4.02	160	290
Sum	151,847	8,572	10.07	541	780
Difference	-	-	13.5	1,698	780

Figure 5.9: Potential fuel savings and CO₂ reductions from a 100% conversion of electric heating.

In figure 5.9 the result of the implementation of a 100% conversion from electric heating in Denmark is calculated. In areas without natural gas and district heating a 50% conversion to oil burners and a 50% conversion to straw/wood burners supplemented with solar collectors is assumed. As seen in figure 5.9 the fuel savings and the reduction in CO₂ emission are substantial. The fuel consumption is cut down by 57% and the CO₂ emission is cut down by 76%. And it should be emphasized that the end-use house heating is exactly the same.

Compared with 1995, the conversion from electric heating has a potential of reducing the Danish CO₂ emission by almost 3% from 58.7 to 57,0 million tons/year. At the same time a capacity of 780 MW electric power may be saved.

The establishment of economical rentability (Arrow 1)

The public regulation of the conversion of electric heating is a multi-instrumental regulation. It consists of both general taxes, standard and

specific subsidies, governmental information campaigns and local administrative free help and follow-up.

Green energy taxes

The conversion is already helped considerably by high energy taxes in Denmark in general, and in particular when the government decided on a green tax reform in 1993. According to this reform, taxes on electricity for electric heating are increased every year in the period from 1993 (0,335 DKK/kWh) to 1998 (0,495 DKK/kWh). Also, coal and oil are taxed.

Standard subsidies for renewable energy

Denmark has had subsidies for renewable energy for many years. The principles of these subsidies are set to help renewable technologies in an introduction period until the technologies have been developed so much that subsidies are no longer needed. Typically the subsidies have covered 30% of the construction costs. Anno 1997 status is the following: the subsidy to wind power has ceased since this technology is now feasible; the subsidy to solar collectors and biomass is approximately 20% (depending on the efficiency) and the subsidy to heat pumps is 15%.

Subsidies specifically for conversion of electric heating

In June 1995, Parliament decided to grant a subsidy specifically for the conversion of electric heating. This subsidy is given to the installation of a new central heating system and the amount is 5000 DKK plus 60 DKK/m² heated areal. Moreover, an environmental bonus is granted if the conversion is into a heat pump or renewable energy such as a biomass burner or a small heat producing wind turbine. Additionally, a bonus is granted if the burner is supplemented with a solar collector.

The establishment of organisational infrastructures (Arrow 2)

Compared with the expansion of production capacity the conversion of electric heating is a good example of the need for organisational change. As described in chapter 1 the construction of a new coal fired power station may be handled by power companies and consultancy companies, while the conversion of electric heating needs the active involvement of a number of various households and industries at consumer level. In Denmark those “new investors” were partly addressed by an information campaign and partly by the follow-up of local energy advisory offices.

A general information campaign

In January 1996, the Danish Energy Agency mailed a letter to each individual household in the areas without district heating and natural gas. The letter informed the households of the reasons why the government wanted this policy of fuels for heating and of technical alternatives and the possibilities of subsidies.

Free advice from 16 local energy offices

The Danish Energy Agency also made an agreement with the corporation of energy offices in Denmark, which encompasses a number of private member organisations based on the promotion of renewable energy and environment. This organisation has built up a number of offices in which the citizens can seek information on renewable energy. Typically the offices have a network of local craftsmen who can instal renewable energy. In the above mentioned information letter from the Energy Agency the households were told to contact one of the sixteen offices situated around the country to have free additional information and help to fill in forms to apply for subsidies.

The strategic political process behind new reforms (Arrow 3)

In the case of the conversion of electric heating the design of public regulation must be seen in the light of a number of various barriers. The public regulation must address many private households and industries with a very small awareness on electricity consumption.

Thus, this is an example of a radical technological change such as described in chapter 1. Moreover, the following barriers must be dealt with:

- Electric heating has very low residential construction costs, while the alternatives include a very expensive central heating system together with heavy investments in wood- or natural gas burners. Electric heating has high running costs compared with the alternatives, but still the conversion needs a very high residential investment to be paid here and now.
- Many people feel that the solution of electric heating was recommended to them by the government, when they built their houses. This is not quite true, but for a period after the first oil crisis electric heating was considered a better solution than residential oil burners, because the power stations had replaced oil with coal. The main reason for installing electric heating systems in many new houses in the 1970s was the low investment costs. Still, this solution was approved by many municipalities.
- From the residents' point of view the solution of electric heating is clean and extremely easy to maintain. There is no oil or wood or dirty machinery in the houses. And there is no need for maintenance.

- Typically there is no room for a burner and fuelstorage as many houses were equipped with electric heating or they have been adapted to it and used the space for something else. This means that the conversion will result in less space.

Altogether, the conversion of electric heating is facing serious barriers. However, these barriers are most serious in areas without district heating and natural gas. In district heating areas the conversion costs are relatively low, the demand for space is low, and the technology is relatively clean and easy to maintain. The conversion in areas of natural gas is a bit more difficult but still more uncomplicated than conversion in the rest of the areas. Moreover, the alternative technologies (natural gas burners and district heating) are present and well organised in district heating and gas companies, and the conversion is more feasible in these areas.

Therefore, the conversion from electric heating in areas of district heating and natural gas (but not in the other areas) was part of the plan, when the Danish Government formed *Energy 2000 - Follow up* in 1993. However, this plan ran into difficulties arising from the interest of the old technologies.

After the decision on the *Energy 2000 - Follow up* the Danish Energy Agency formed a group of actors including the utilities to design the implementation. One of the major issues of discussion was who should benefit from the saved capacity cost of the power stations. The power stations in Denmark are owned by the electricity consumers and have all been paid for as a part of the electricity prices during the past many years. Consequently, there is hardly any net debt in the electricity sector in Denmark. Furthermore, the electricity companies are allowed to raise electricity prices in advance in order to finance future power stations. And such new stations were about to be built. Therefore, the Danish Energy Agency argued that the electricity companies should repay an amount equal to the saved capacity costs to the households that had converted and in this way saved capacity costs.

The utilities protested strongly against this policy. They had no interest in converting electric heating as they would lose customers and they would lose arguments for permission to construct new power stations. The latter was probably the strongest concern. Precisely at that time one of the two big power company corporations in Denmark (ELSAM) had just had severe difficulties in finding arguments for two new power stations and the other big corporation (Elkraft) was just in the process of applying for another new station in Copenhagen.

The discussion went on for a long time without any result. Therefore the government changed implementation strategy when the latest energy plan *Energy 21* was drawn up in 1996. It was decided to start the conversion in the areas without district heating and natural gas and to finance the investments partly by a new fund for electric savings within households and public buildings. This fund was formed owing to a law passed in 1996 along with *Energy 21* and the fund was financed by a small tax on every kWh electricity sold. It is still the plan to continue with the conversion later on, also in areas with natural gas and district heating.

Influencing international rules and regulations (Arrow 4)

So far the Danish policy has not been directly influenced by international rules and regulations.

The development of new technologies (Arrow 5)

One alternative to electrical heating in areas outside district heating and natural gas is conversion to traditional individual oil boilers. This technology is well-proved and would not have called for specific technology development initiatives. But other alternatives are better suitable seen in the light of the Danish objectives of CO₂ reductions. Such alternatives are solar collectors and wood stoves, which technologies have been developed during a long period of time with special technology development initiatives.

Concluding Remarks

The Danish Energy Agency mailed 60,000 letters and approximately 6,000 households responded, of those 1294 had converted by the middle of 1997 while a number of other households are in the process of converting. In November 1996, the first 832 applications for subsidies were analysed (Energi- og Miljødata, 1996). Many different households were represented, but the typical house has the following characteristics:

- Detached house or farm building
- Built around 1910
- Heated area of approximately 165 m²
- Electricity consumption of 110 kWh/m² equal to 18.000 - 19.000 kWh/year
- Well insulated and with two layers of panes in the windows
- Electric heating is supplemented by a fireplace or a wood burning stove

The households mainly chose wood burners (74%) or oil burners (22%), only very few chose the heat pump and 22% chose to supplement the burner with a solar collector.

There are central records of the applications for subsidies, but those records do not include all the construction costs in detail. Based on an interview with one of the local energy offices that assist the households in the conversion the following may be said (Bender, 1997): investments in solar collectors and wood burners are very homogeneous. The costs are almost always 32,000 DKK for solar collectors and 55,000 DKK for wood burners (excluding VAT) which include installation and a chimney, etc. Central heating systems do cost between 10,000 and 65,000 DKK with an average of 32,000 DKK. The very large variation is due to differences in size, self-installation and tolerance of whether the pipes should be hidden in the walls or not. The cost of oil burners also varies a great deal. This is due to the fact that old burners are very easy to find because many households have just joined district heating systems, and consequently a lot of burners are available. Moreover, some households have a chimney for the existing fireplace and therefore investments in oil burners are typically very low. The average is here estimated to 15,000 DKK.

In figure 5.10 the total investments of the first 1294 conversion cases are calculated to 104 million DKK. In the same table it is calculated that sooner or later this investment should entail savings of an investment in some 6.6 MW coal fired power stations equal to 53 million DKK. Therefore, the net investment may be calculated at 51 million DKK. Based on the investigation of imports and employment consequences of different energy technologies in Denmark mentioned in chapter 2 those effects have also been calculated. Figure 5.10 shows that the net effects on imports are very small (7 million DKK), whereas the job creation has been as big as 149 additional jobs.

	Share	Units	Costs pr. unit	Costs	Import share	Imports	jobs/inv.	Jobs
	Per cent	Number	DKK pr. unit	Million DKK	Per cent	Million DKK	Man year pr. million	Man year
Central heating								
Oil burner	100	1294	28.000	36	11	4	2.8	101
Wood burner	22	285	15.000	4	18	8	2.7	11
Solar Collector	74	957	55.000	53	25	13	2.0	106
Heat Pump	22	285	32.000	9	22	2	2.2	20
-----	4	52	30.000	2	13	0	2.8	6
Sum				----- 104		----- 27		----- 244
Power station		6.6 MW	8.000	- 53	37	- 20	1,8	- 95
Difference				51		7		149

Figure 5.10: Constructions Costs, Imports and Jobs from the first 1294 conversion cases

The estimations of the running cost in figure 5.11 show that even though the total costs will raise imports will be saved in the future and some additional permanent 10 jobs have been created. The net import during construction (7 million DKK) is paid back over a period of 10 years (684,000 DKK/year), and after this period the net effect on the balance of payment will be positive. Furthermore, a minor rise in coal prices will have a considerably positive effect on the reimbursement period.

If the electric heating conversion is continued in the areas outside natural gas and district heating the 150 jobs already created will be able to raise to an amount of 430 permanent jobs directed from the running costs of the burners and the fuels. Additional jobs may be created within the areas of natural gas and district heating. Maybe the most important feature is that such positive employment effects can be created together with a CO₂ reduction and without having negative net effects on the balance of payment.

	Running costs	Fuels	Fuel costs	Costs	Import share	Imports	Jobs/inv.	Jobs
	% of investm.	TJ/- year	DKK/- GJ	1000 DKK/y	Per cent	Million DKK	Man year pr. million.	Man year
Oil		20	44	880	85	748	0.3	0.3
Wood		73	45	3285	21	690	2.1	7.0
Coal		3	13	39	90	35	0.2	0.0
Burners	4			2280	15	342	2.5	5.7
Solar + centr.heat	1			450	15	68	2.5	1.1
-----				-----		-----		-----
Sum				6934		1883		14.1
Coal		199		2587	90	2328	0.2	0.5
Power station	3		13	1590	15	239	2.5	4.0
-----				-----		-----		-----
Sum				4177		2567		4.5
Difference				2757		- 684		9.6

Figure 5.11: Running Costs, Imports and Jobs from the first 1294 conversion cases.

The case of electric heating conversion in Denmark illustrates a number of general problems, when radical technological changes are needed in order to implement political objectives of CO₂ reduction. Also the case gives an example of how public regulation can deal with those problems.

Firstly, it must be realized that the implementation of CO₂ reduction policies is characterized by a change in technology that calls not only for minor technical modifications, but also for large organisational changes, which will

often comprise the establishment of completely new organisations. Secondly, the existing institutional setup is strongly influenced by the existing organisations linked closely to the old technologies that will no longer be needed in the near future.

Therefore, implementation of the new technologies is a challenge to public regulation. On the one hand it must be expected that it will meet resistance from the old technologies. On the other, it must initiate establishment of new institutional setups. In the case of conversion of electric heating in Denmark these barriers have so far been overcome partly by introducing a mixture of numerous differentiated and multipurpose public regulation instruments, and partly by changing strategy in terms of implementing “least-feasible” conversions first in order to avoid conflicts with the old technologies.

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National and international environmental objectives call for new technologies, new organisations and institutions within the energy area. In such a situation, “Feasibility Studies and Public Regulation” must include a detailed description of the relationship between the present economic, social and institutional situation and the situation in which the new technologies are supposed to function in the future.

This book outlines a systematic methodology for “Feasibility Studies and Public Regulation” in a situation, where technological and institutional changes are needed.

The method is based on the experience of implementing ambitious economic, social and environmental objectives in the Danish Energy Policy. A number of examples from Denmark is included .

In the present form the book addresses the subject in a general manner. For educational purposes it has to be combined with case material. It has been written for a training programme for Energy Experts in the Baltic States, the PROCEED programme, and is used in combination with case material developed in each country. The PROCEED pro-gramme is financed by the Nordic Council of Ministers.