Appendix 4.2 –Deliverable D2

Project no. 502487

Project acronym: POPA-CTDA

Project title:
Policy pathways to promote the development and adoption of cleaner technologies

Instrument: STREP

Thematic Priority 8.1, Policy-oriented research (SSP), FP6-2002-SSP-1

Deliverable number D2
Energy Sector Background Study

Due date of deliverable: May 30, 2004
Actual submission date: April 29, 2004

Start date of project: January 1^{st}, 2004 Duration: 24 months

Organisation name of lead contractor for this deliverable: Göteborg University

Revision [draft]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	R

TABLE OF CONTENT

1. INTRODUCTION

The energy sector can be defined in many ways. Since energy conversion is a prerequisite for most industrial and household activities the delimitation of the energy sector is somewhat arbitrary. In this project we will include electricity and heat production as well as the use of heat and electricity in buildings; a very important energy end-use sector not covered by any other sub-projects within the POPA-project.

Energy conversion is at the heart of the environmental issue and perhaps the most fundamental cornerstone of the industrial society. Reaching a sustainable development is to a large degree a question of managing a transformation of the energy system.

In Europe, some environmental effects of energy conversion have been halted. End of pipe type solutions are now decreasing emissions of acidifying and polluting substances in spite of increased energy demand. However, this is not the case for emissions of carbon dioxide, the main cause of anthropogenic global warming. The growth of the world population and economic growth in developing as well as industrialised countries will continue to increase the demand for energy services. At the same time, the carbon dioxide emissions inherently linked to current fossil fuel energy technologies need to be reduced substantially over the century to ”prevent dangerous anthropogenic interference with the climate system” (UNFCCC, 1992). As a consequence, there will be a tremendous need for development and large-scale diffusion of a range of radically new technologies for supply, storage, transport and efficient use of energy.

To reduce the environmental impact of energy conversion a variety of policy instruments have been implemented at the European Union level as well as nationally and locally. Policy instruments range from economy wide environmental taxes and tradable emission permits to policies targeted at promoting specific technologies. The result is mixed. In many cases policies have been too weak to overcome the many technical, economic and institutional barriers in for example the electricity and building sectors. In some cases, policies have resulted in rapid change. As a result the diffusion of for example various renewable energy technologies differs greatly among member states.

In this background report we will briefly discuss the most important environmental issues related to the energy sector and give an overview of policy developments in Europe. We will select two case studies, each comprising a set of environmental friendly technologies, which will be further investigated in the next part of the project. The barriers that need to be overcome to increase adoption of these technologies are outlined and finally, we briefly describe the development of the selected technologies and their sectors.

2. ENVIRONMENTAL ISSUES

Environmental degradation originating from energy generation is mutually coupled with increased world population and global economical growth. Consequences are evident on all geographical scales, ranging from global warming to regional and local air degradation, acidification and extensive use of natural resources affecting human health, flora and fauna, structures etc. Alongside a raised awareness of these predicaments, the need to transform the energy system has been increasingly acknowledged in the political debate, science literature, NGO’s and society in general. The European Union may in the strive towards a sustainable development take on a leading role by influencing the international policy framework, developing and diffusing environmental technologies, aiding third world countries and challenge indigenous environmental issues.

In this report we will focus on global warming, air pollution and acidification as being main environmental concerns relating to energy generation in a European perspective. Even though left out, additional environmental effects such as land degradation, thermal pollution (mainly from energy plants cooling water), depletion of the ozone layer (to some extent trough the secondary pollutant N_2O) and extractions and transportations of resources do affect social and environmental welfare and are in no way negligible.

2.1 Global warming

Mainly as a consequence of an extensive use of fossil fuels the earth's climate is changing and, irrespective of future actions, it will continue to do so for a long time. This was confirmed in the Third Assessment Report of the United Nations Intergovernmental Panel on Climate Change. A global increased temperature of 0.4-0.8 °C during the latest decade, melting Artic sea ices and glaciers are well-documented and present effects. (IPCC, 2001a)

Due to the complexity of the earth's climate systems, quantified relations between increased global temperature and various effects on regional weather, rising sea levels, effects on flora and fauna etc. are inherently difficult to estimate. Several interrelated atmospheric processes (synergies) are still either unknown or incompletely understood. However, it is a well-known fact that any planet with an atmosphere will experience a warming of the planets surface. Due to atmospheric gases absorbing both incoming solar energy and outgoing radiations from the planetary surface and atmosphere, a greenhouse-like environment is established. In the earth's climate system, primarily H_2O and CO_2 regulate the equilibrium of ingoing and outgoing radiation. The Industrial revolution brought by increased emissions of CO_2, resulting in raised CO_2-concentrations in the atmosphere ever since, and consequently a change in the net flow of radiation causing an increase of the earth's surface temperature. From the pre-industrial level of 280 ppm, current CO_2-concentrations are about 370 ppm and are believed reach 540 to 970 ppm in 2100, depending on socio-economic assumptions. Such a development is expected to lead to an increased global temperature of 1.4 to 5.8 °C (IPCC, 2001a).

Several scenarios, based on climate change foresights have been elaborated, many of them dramatic in their description: *"food shortage, decreased availability of fresh water and disrupted access to energy supplies"* (Schwartz and Randall, 2003), *"more extreme weather, submerged costal areas and small islands, and catastrophic cascades in the food chain"* (IPCC, 2001a) or *"…increased deaths from heat stress…"* (WEA, 2000). Recently, in an attempt to denote the magnitude of climate change, the European Commissioner Margot Wallström pronounced that *"climate change is one of the decisive challenges that our generation has to tackle"*. Regardless of which future consequences a climate change will bring, the plausible environmental impacts are all to devastating to ignore.

Fossil fuel based energy technologies dominate the global energy system; fossil fuels (coal, oil and gas) contributed 80% to world energy supply in 2001 (IEA, 2003). The combustion of fossil fuels is responsible for the lion's share of the anthropogenic net supply of CO_2 to the atmosphere. With a world population reaching approximately 9 billion in the middle of this century and a continued economical growth, global energy demand is expected to rise considerably. To satisfy this increased demand, and at the same time stabilising CO_2 on a level sufficient enough to "prevent dangerous anthropogenic interference with the climate system" (UNFCCC, 1992) will call for a transformation of the current energy system.

The Kyoto protocol is an effort to bring greenhouse gas (GHG) emissions 5% below the levels of 1990s. This is an important effort of decreasing anthropogenic influence on the climate but should, however, only be regarded as a first step towards future more stringent reduction targets. The protocol has yet to become ratified[1]; even though, the EU has implemented the undertakings for the union into European legislation.

2.2 Air pollution and acidification

In addition to global warming, the conversion of energy gives rise to air pollution and acidification. These effects cause harm to human health, degrade crops lands, forests and lakes and damage buildings and parts of our cultural heritage.

Emissions from energy conversion can be categorized into six main types: particulate matter (PM), sulphur dioxide (SO_2), nitrogen oxides (NO_x), hydrocarbons (HC), carbon monoxide (CO) and carbon dioxide (CO_2). CO_2 is a green house gas (GHG) and is main contributor to the global warming; SO_2 and NO_x contribute to both acidification and air pollution, while PM, CO and HC primarily contribute to air pollution. Ground-level ozone is formed in reactions involving both NO_x and HC. Ambient PM, including sulphates, nitrates and organic aerosols accounts for about 95% of costs of air pollution[2] originating from the energy, transport and industry sectors (Delucchi *et al*, 2001). These are estimated to cause 60000 deaths annually in European big-city areas (EEA, 2003) and even more in lung-related illnesses, asthmatics and allergies.

Air pollution is foremost a problem in urban regions where there is a high intensity in traffic, energy facilities and industrial activities gathered in a relative small area. Main contributors to urban area PM-emissions in Europe are coal combustions in energy power plants and diesel fuelled road transportations. Acidification, on the other hand, is mainly a distress for forests and lakes affecting flora and fauna, but also damaging structures containing limestone, cement and concrete. Deposition of acids originating from sulphur and nitrogen emissions has caused serious degradation of lakes and forests throughout Europe.

Several policy efforts to reduce concentrations of air pollutants have been taken during the recent decade in the European Union. Mainly through developing target values for ambient air quality in “air quality daughter directives”, introduction of national emission ceilings (NEC), identifying cost-effective reductions in targeted areas (Auto Oil I and II), introducing specific measures to limit emission and raise product standard (IPPC) and, most recently, the implementation of the Clean Air for Europe-programme (CAFE) and the Convention on Long-Range Transboundary Air Pollution (CLRTAP). However, despite that recent trends indicate decrease in both PM and ground-level ozone concentrations in the EU-15 countries, targeted values set in CLRTAP and NEC seems unlikely to be reached without further efforts. A greater success has been achieved in the reduction of SO_x and NO_x concentrations. It has been estimated that more than 90% of ecosystem areas in Europe are protected from further acidification. Cleaner fuels and a shift from coal to natural gas in electricity production, the use of cleaner fossil fuels in transportation and catalytic converters are the prime sources behind this achievement. (EEA, 2003)

---

[1] Russia has a casting vote since the US declared withdraw from the protocol. The protocol will enter into force once 55 countries have ratified it and 55% of the industrialized world carbon dioxide emissions are incorporated in these countries.

[2] These compounds are so-called *primary* pollutants, but a significant share of the associated costs relates to damage caused by *secondary* pollutants, i.e. substances formed in chemical reaction involving primary pollutants. Acids formed by SO_2 and NO_x, ground-level ozone formed by NO_x and volatile organic compounds (VOC) are example of such secondary pollutants.

3. POLICY DEVELOPMENTS

On the basis of promoting the use of *clean* or *environmental-friendly* technologies through policy instruments, there is generally speaking a distinction between either remove barriers for clean technology options (e.g. disadvantageous market failures, regulations and legislation) or create barriers for "dirty" ones (taxes, emission limitations, remove subsidies etc). It has become widely accepted that market-based instruments, i.e. taxes, subsidies, trade systems is a cost-effective way of reducing emissions. However, the available policy instruments reach far beyond economics. Aspects related to institutions, behavioural patterns, norms, knowledge and information can be tackled in multiple ways. Policy design also need to consider the time frame, the geographical scope, allocated resources and the choice between targeting one technology, a group of technologies, a certain sector (transportation, production, electricity generation etc) or the whole economy. At the EU level, the disparity between the member states, i.e. differences with regards to environmental issues in focus, economic and industrial capabilities, political and institutional setups and social acceptance for environmental technologies, have to be tackled in some manner.

Several policies that promote the development and adoption of environmental technologies have or are on the verge of being implemented, such as the Sixth Framework Programme, Integrated Pollution Prevention and Control (IPPC) and the Environmental Technologies Action Plan (ETAP), which often are directly or indirectly based on the Kyoto-protocol bindings. A survey of policies promoting the development and diffusion of technologies for cleaner energy supply and more efficient use of energy follows. The survey comprises instruments affecting visions, information and knowledge generation and diffusion and the selection of technologies on markets.

3.1 Visions and political guidelines

In a political context, the settlement of guidelines (e.g. indicative targets for emission reductions) is a method for the European commission to communicate political objectives and visions to governments, institutions and the business world in general. These are often discussed and communicated via Green and White papers and may, further down the line, affect the legislative and regulative settings.

Green and White papers

In order to cope with the undertakings in the Kyoto protocol (the EU are obligated to reduce carbon emissions with 8% below the levels of 1990) and climate change in general, the European Commission has launched several strategies in dedicated White papers. By the means of indicating political guidelines and course of actions, often through stating reduction targets etc., they have a strong influence on the governmental work in the member states.

Following the debate of the green paper *"Energy for the future: Renewable sources for energy"* (EU, 1996), statements were set in the subsequent white paper (EU, 1997) aiming at increasing the share of renewable energy technologies (RETs) in the European energy sector. The prime target was to increase the share to 12% by 2010, twice the levels of 1996, for the energy sector as a whole. An additional target of a 23.5% share of RETs was set for the electricity sector. These targets were further complemented with sub-targets for photovoltaics, wind power and bio energy (1,000,000 photovoltaic systems, 10,000 MW of large wind farms, 10,000 MW of biomass installations and integration of renewable energies in 100 Communities).

Later on, the Commission proposed a national share of RETs based on the percentage of each country's consumption of electricity (EU, 2000). The year after, it was proclaimed that further reduction targets for GHGs are necessary, beyond the commitments under the Kyoto-protocol: an annual average decrease of 1% up to 2020 would increase the possibilities of tackling climatic change.

These visions have been increasingly accepted among the EU member states (Morthorst, 2003), which in turn has lead to an easier implementation of the Kyoto protocol bindings into European legislation. The European Parliament and Council recently decided to convert the targets to become legally binding for the EU member states, despite the fact that the US declared a withdraw from the protocol.

3.2 Information and knowledge

The generation and transfer of knowledge are essential in the development of new technologies. Initiating R&D-projects, the formation of networks and adapting the educational system are central, not only for the diffusion of information, but also to increase legitimacy, raise public awareness and encourage new actors to enter the field. Such initiatives are common on the European level as well as on national and regional levels.

Environmental Technologies Action Plan (ETAP)

A key issue in decoupling environmental degradation from economical growth, officially recognized by the European Council in 2003, is to promote the development and diffusion of clean or environmental technologies, which is the underlying principle for ETAP. The environmental, economical and social benefits (i.e. sustainable development) of such a promotion were put forth in both the Lisbon strategy, the 2001 Göteborg European Council and in the 2002 Barcelona European Council. As a concretisation, the Environmental Technologies Action Plan (ETAP) was implemented in the early 2004.

ETAP could be viewed upon as an effort to provide governments with policy guidelines. Main objectives in the action plan are to *remove barriers for the development and diffusion of environmental technologies*, to *ensure that the EU will take a leading role in developing and applying such technologies*, and to *mobilize all stakeholders in support of these objectives* (EU, 2004). The technological approach is broad; it is stated that there is potential of promoting environmental technologies in all economic sectors, but no "one size fits all" solution is likely to be found. Instead, 11 "priority actions" (PA) are delineated in four main areas: (i) getting from research to markets; (ii) improving market conditions; (iii) acting globally and (iv) moving forward.

There is a strong emphasis on achieving the PA's mainly through existing policy efforts; e.g. the Sixth and Seventh Framework Programme will play an important role in the first main area due to the focus on research and development. Increased financial resources to R&D projects, coordination of all ready existing R&D projects, establishing technology platforms and establishing networks for testing, performance verification and standardisation are listed as priority actions. Thus, this area focuses a great deal on product development and generation and diffusion of technological centred knowledge. However, the mentioned approach of selecting "promising technologies" may be risky. There is a distinction, policy-wise, between "fostering" specific technologies and originate new technologies. The former implies a confidence of "picking winners" through selective R&D-projects and funding etc., while the latter is an open approach assuring wide experimentation on different technological designs. Selecting wrong technologies in an early state may cause premature lock in (Sandén and Azar,

2004) and, thereby, hamper future environmental challenges. A successful R&D policy manages to balance the fostering of promising options with the creation of completely new.

Improving market conditions is suggested to be achieved through developing performance targets for various technologies, distribute risk among actors, review state aid guidelines, environmentally harmful subsidies and public procurement, raise business and consumer awareness and provide targeted training. ETAP put less emphasis on the creation and strengthen of actors and network of actors that can drive the development of a technology. In recent literature the role of such prime movers and advocacy coalitions has been high-lightened. According to Jacobsson and Bergek (2003), the formation of strong advocacy coalitions with the prime purpose of influencing the institutional set-up, is a key task for an evolving industry. The involvement of prime movers serve four important tasks: they raise awareness, undertake investments, provide legitimacy and diffuse the new technology (Jacobsson and Johnson, 2000).

In the third area, "acting globally", the potential and possible impact of promoting sustainable development on a global level, particularly in developing countries, is recognised. Promoting responsible investments and use of environmental technologies in developing countries and countries in economic transition is identified as a priority action. Influencing international trade via the international institutional framework and further liberalisation of multi- and bilateral agreements in favour of environmental products and services are pointed out as important issues.

Intelligent Energy – Europe

Developed out of the green paper *"Security of Energy Supply"*, the white paper *"European Transport Policy"* and additional related community legislation is the *"Intelligent Energy – Europe"* (EIE-programme), initiated in 2003 and will last until 2006. The programme is a "non-technological" action to promote energy efficiency and support the use of RETs through, partly, focusing on targets stated in recent community policies. The approach is multi-facetted and divided into four fields:

- *SAVE* is directed to energy efficiency and the use of RETs in primarily the industry and building sectors,
- *ALTENER* will promote the use of RETs in the production of electricity, especially decentralised systems,
- *STEER* supports initiatives directed to all energy aspects of transportation but foremost those relating to efficiency measures and renewable energy fuels, and
- *COOPENER* is a support for initiatives promoting RETs and energy efficiency in developing countries.

This programme is non-technological in the sense of that, generally, actions will be of "promotional" character and not support any costs associated to investments in RETs.

3.3 Markets

Marked-based policies are here split up into two main categories: economy wide, directed at the economy as a whole, and sector and technology specific policies. Taxations and trading schemes are typical examples of the former, while the latter are distinguished into those directed at efficiency measures (end-use of energy) and those directed to supply of energy. This division reflects the characteristics of existing policy instruments used to regulate the energy system.

3.3.1 Economy wide

Carbon taxation

External costs (*externalities*) of energy supply could be addressed through taxation on emissions; in the case of climate changes: on carbon emissions. Although experiences are limited, there is evidence suggesting its effectiveness. The effects of carbon taxation are, primarily, threefold: increases competitiveness of carbon neutral technologies, increases incentives for energy efficiency through raised energy prices and increases incentives for actors to develop advanced technologies for supply, conversion and end-use of energy (Sandén and Azar, 2004).

Energy taxation has been used in Sweden since 1950s, even though the arguments at that time mainly concerned finance of the social welfare and not environmental aspects, but have later on been complemented with specific taxation on carbon emissions. The Swedish system is, however, quite complex with several exception and reduction regulations. The electricity sector is, for example, excepted form all energy and carbon taxation and the industry sector has several tax-reductions. These exempts have mainly been introduced in efforts of withholding international competitiveness (STEM, 2003), but do as well indicate the complexity of implementing carbon taxations as a consequence of being economy-wide. The Swedish Environmental Protection Agency has reviewed the Swedish carbon taxes as *"…has helped reduce carbon emissions in line with Swedish environmental policy"* (SEPA, 1997).

EU-wide carbon taxation has been discussed frequently during the 1990s, but no agreements could be made. Instead, the European Commission suggested in 1997 a minimum level of national taxation on energy services, which should be raised incrementally during a six year period. Even this proposal got declined by a majority of the member states. Denmark, Finland, Germany, Italy, the Netherlands, Sweden and the United Kingdom had until 2003 implemented national carbon and energy taxations.

It is believed that a carbon tax rate of around 70 USD/ton C could be sufficient enough to reach the Kyoto-targets (see IPCC, 2001b; Persson and Azar, 2002). Whereas this tax rate would help reaching near-term environmental goals, a level exceeding 1000 USD/ton C would probably be necessary to make, for example, photovoltaics competitive on the most grid-markets. (Sandén and Azar, 2004) Thus, finding the right levels of taxation is crucial in order to achieve stipulated environmental objectives.

Carbon emission trading scheme in the EU

In order to cope with the undertakings in the Kyoto protocol, the EU reduction target has been distributed into national shares throughout the member states. Thus, each member state has either right to increase emissions or is obliged to reduce emissions relative the levels of 1990. To ensure this in a cost-effective manner, the implementation of tradable permits for carbon emissions is highly anticipated. In principle, reductions will be carried out where it is least costly.

National reduction targets are now being refined to quotas for each industry and energy facility and translated into emission permits. These will be tradable on a national and international market, where a net exporter of permits will be allowed to increase carbon emission beyond the national targets and vice versa for a net importer. In addition, a penalty will have to be paid for industries which emissions exceed the permits.

During 2003, the European Parliament and Council reached an agreement to implement the scheme in full force at the beginning of 2005. The scheme will be applied to the most significant GHG emitting sources that have been identified in the IPPC directive (see below). Thus far only carbon dioxide emissions are covered by the scheme.

Actors within this scheme mainly have three options in order to fulfil reduction obligations: either to purchase permits that will cover the emissions, increase efficiency or install new technology. Marginal costs of reduction will determine the choice of action. Estimated effects on the energy system will vary depending on the use of *flexible mechanisms* and to which degree trade will be constrained or not. In principle, an unconstrained market (low price on permits) will in the short term ensure a cost-effective reduction of carbon emissions through either the purchase of permits or "end-of-pipe" solutions (i.e. install filter technologies, optimising industrial processes etc.). A constrained trade (supplementary) may, on the other hand, induce incentives to enhance energy efficiency and invest in new technologies and, thereby, support the development of RETs. This could prove crucial in a long-term struggle against climate changes even though this technology fostering aspect could possibly be better dealt with by more technology specific policies (Sandén and Azar 2004).

3.3.2 Sector and technology specific - efficiency

Policies that promote the adoption of more energy efficient technologies have mainly been of the type that set minimum performance criteria. We will here give two examples, from the building sector and the industry sector.

Energy Performance in Buildings

In the *"Energy Performance in Buildings"* directive (EU, 2001), which went in to force in the beginning of 2003, the European Commission has recognised the building sector as being the sector with the greatest potential of decreasing energy consumption through efficiency measures. Hence, this directive has a somewhat different approach, equally emphasising energy efficiency measures (decrease energy use via change in behavioural patterns, e.g. shutting off lamps) and technological change. Through the introduction of performance targets and a certification system for buildings, the energy efficiency is expected to increase and, thereby, reduce emission of GHGs and, additionally, lower the need of importing energy to the EU. Five main tasks are put forward in the directive, which all should within a three year period be implemented to national legislation of the member states: (i) develop common methods for calculating the energy performance of buildings, (ii) introduce minimum requirements for energy performance of new and (iii) restoration of existing buildings, (iv) introduce a certification system for buildings and (v) enforce regular control of heat boilers and air condition systems.

Integrated Pollution Prevention and Control (IPPC)

Even though emissions originating from point sources throughout the EU have decreased in the latest decade, industrial processes still accounts for a significant share of overall emissions. Greenhouse gases, volatile organic compounds (VOC), acidifying substances and wastes are widespread residuals of industrial activities. The integration of the IPPC-directive (adopted in 1996) into European legislation is an exertion through environmental technologies enhances environmental performance of European industries. It is regarded as a key for the promotion of sustainable production patterns.

All industrial facilities covered by the directive are obligated to obtain permits from authorities in the EU countries. These permits consider all environmental aspects of the facility, i.e. emissions to air, water and land, generation of waste, use of raw materials, energy efficiency, noise, prevention of accidents, risk management etc. Industrial plants must fulfil technological standards set by the European IPPC Bureau based on "best available techniques" (BAT) defined in so-called BREFs (BAT Reference Document), to obtain such a permit. The member states have exclusive responsibility for the implementation, and had until the end of October 1999 to adjust national legislation in line with the directive. Very few managed to fulfil this deadline, and even in 2002 neither the United Kingdom (North Ireland), Greece, Spain or Luxemburg had implemented complete national legislation[3]. Plants installed after 1999 and modifications of existing ones, which were estimated to have considerable environmental impacts, were all obligated to fulfil the requirements. In many cases, the costs associated with BAT are considerable high, and in an effort to avoid too high impact on the European job-market, existing installations were granted with an eleven year long transition period, counted from 1996.

During the legislation process, several shortcomings have arisen: definition of sector specific BATs, requirement targets for obtaining permit, monitoring and identifying emissions etc. Lack of skilled personnel, knowledge regarding operating and managing BATs, unawareness regarding business investment cycles and firm competitiveness and legitimacy of environmental technologies have all blocked the implementation process of the directive. Hence, forming networks for knowledge transition and raised awareness concerning environmental and economical benefits of BATs is a prime task in a successful completion of the IPPC-directive.

3.3.3 Sector and technology specific - supply

There is a great variety in policies that have been implemented to increase the market for RETs. First, there are direct economic support from authorities such as procurement, investment subsidies, tax redemption and soft loans. Secondly, authorities can facilitate that consumers' willingness to pay more for green energy can be used to create markets through environmental labelling and green electricity stock exchanges. And finally, there are market mechanisms that transfer the extra cost of new technologies to all consumers through a small increase of the general energy prices. The former two are important in early phases of development. To create markets of a larger size the, latter are probably more effective. In the electricity sector two ways to design such a policy have been tested. Market shares for RETs can be guaranteed, as is the case with renewable portfolio standards and tradable green certificates, or prices for electricity from RETs can be guaranteed through fixed tariffs, as is the case with the German feed-in-law. These two options are discussed in the following sections.

Guaranteed market shares: Green certificates

Following the recent trends in Europe of liberalisation of national electricity markets, there has emerged a need of market-based policies for promoting diffusion of green electricity. In an effort to increase the development of economically competitive RET for electricity generation, green certificate schemes have been implemented in several EU member states (The Netherlands, Denmark, Sweden, UK, Belgium, Italy and Austria). From an EU point of view, these national efforts are indeed followed with great interest in comparison with the ongoing German feed-in-law with fixed tariffs, since there are plans on implementing a common union-wide system.

---

[3] In 2003, all but Luxemburg had completed the legislation. A case against Luxemburg is still pending at the EG Council of Justice.

The underlying principle of green certificates is to let market forces determine the additional costs for electricity generated from RET. Producer receives a certificate for every unit (e.g. kWh) of generated green electricity which, in turn, can be sold to distributors or consumers. In Sweden, end-consumers are obligated to purchase a certain share of total electricity consumption as green electricity and, hence, a demand of RET is guaranteed relative the size of the share. Producers of green electricity will gain income from both the sales of certificates and sales of electricity on the spot market; thus providing subsidies financed of end-consumers (in the Swedish model). The benefit is expected to be achieved through an increased competition between renewable technologies, which in turn will increase development, competitiveness and, therefore, diffusion.

Doubts have been put forward against the benefits of a green certificate system. The main concern is regarding the possibilities of governing technology development and diffusion through a governmentally controlled diffusion curve; i.e. the end-consumer quota is supposed to be increased annually by a fixed rate elaborated by central instances (Jacobsson, 2002). Furthermore, RETs close to commercialisation will most likely be favoured over others as a result of the induced competition. There is a risk that only minor incentives will exist to invest in emerging technologies, which may be crucial in achieving long term goals, and that they, consequently, could be locked out (Sandén and Azar, 2004).

Guaranteed electricity prices: Feed-in-law

The German *Electricity Feed-in Law* (EFL), implemented in 1991, obligated utilities to purchase electricity produced from RETs at fixed prices, based on a percentage value on average consumers prices of electricity: 90% on wind and solar power, 80% on small-scale bio and hydro power (<0.5MW) and 65% on bio and hydro power with capacity between 0.5 and 5 MW. This law proved very beneficial for specifically wind power where the tariffs paid from the utilities, in combination with other supporting schemes (as the 100/250 MW programme), resulted in high accumulated payments.

In 2000, EFL was replaced by the *Renewable Electricity Law* (REL) where the obligation to pay tariffs had been moved from utilities to operators of the grid. The prime objective was to double the contribution of RETs, from the levels of 2000, to 2010 (equalling a share of around 6%), in the German electricity sector. Though, in order to increase competition and, thereby, reduce costs of power from RETs, the tariffs paid to new installations decreased annually by a 1% for bio power, 1.5% for wind power and 5% for photovoltaics. All new RET installations were guaranteed these tariffs during a 20 year period. Photovoltaics have, since the implementation of this law, grown significantly and the industry as a whole been strengthened through increased specialisation in, for example, module manufacturing and adaptation of buildings (Jacobsson *et al*., 2004).

Similar systems with fixed tariffs for the supply of photovoltaics can be found in Spain and Austria as well. The system is self-financing it that aspect that additional costs are paid by consumers or operators in contrast to being governmental supported. In the case of photovoltaics, the initial market is small enough to keep the affects of additional costs on electricity prices negligible for end-consumers. Along with a growing market, the premium set tariffs can be reduced and, thereby, keeping electricity prices low (Sandén, 2004).

4. SELECTION OF TECHNOLOGIES AND CASE STUDIES

The need to transform the current global energy system in order to deal with future climate changes has already been pointed out in this report. In the energy sector, this will mainly be achieved through technological changes where the development and diffusion of RETs will be crucial. In addition, measures promoting a higher efficiency in the end-use of energy will play an important role as well. These assertions will serve as a foundation during the selection of the case studies to be carried out in WP2.

The selection criteria will be gradually narrowed to a selection of two case studies. Thereafter, the two case studies will be specified in more detail.

4.1 Guidelines in the selection process

As stated in ETAP (see chapter 3), the promotion of environmental technologies in the EU *"aims at harness their* (environmental technologies) *full potential to reduce pressure on our natural resources, improve the quality of life of European citizens and stimulate economic growth"*. Hence, all three dimensions of sustainable development are in focus in the promotion of environmental technologies. Notwithstanding the potential impact emerging energy technologies may have in social and economic areas the main driver for change in the field of energy conversion is the aim to reduce the environmental impact.

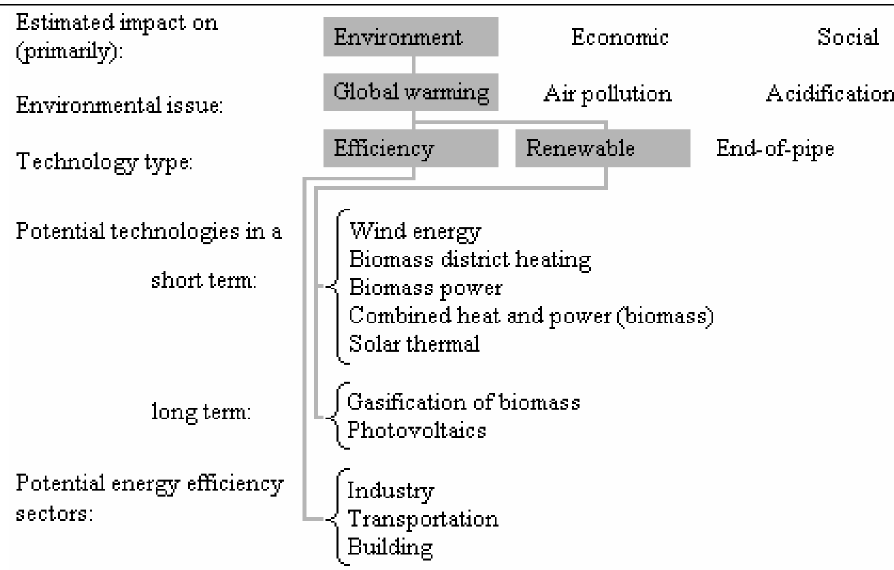

Figure 1. A schematic overview of the guidelines used in the process of selecting the two case studies.

The three main environmental issues coupled with energy supply (discussed in the "Environmental issues" chapter) are identified as global warming, air pollution and acidification. Of these three, there are no doubt the former are at the centre of attention in both the European and global political agenda. For this reason, the potential impact to achieve the Kyoto-targets and deal with global warming in the longer term is prioritised in the selection process, i.e. the ability to reduce GHG-emissions.

Reductions of GHGs emissions could mainly be achieved through either increasing the share of RET in the energy system, increase energy efficiency or install end-of-pipe technologies in energy supplying facilities. The latter implies a minimum of change to the current energy system, where, for example, CO_2 could be captured from fossil fuels and stored, away from the atmosphere. The potential of CO_2 capture and storage technologies (CCS) as a contributor to global CO_2-reduction has been increasingly acknowledged, but several key issues still remains to be solved before a large-scale application could be applied. According to Azar *et al* (2003), a significant contribution of decarbonisation of fossil fuels to the global energy system could be realised somewhere at 2040-2050. On the other hand, carbon sequestration may further strengthen the lock-in to fossil fuels (Unruh, 2002) at the expense of RETs. Further, a decision to adopt technologies that are radically different from entrenched technologies is from many points of view more difficult than making decisions about incremental changes (see chapter 5). In this respect RETs are of more interest in this study than end-of-pipe technologies and will constitute the first case study.

Energy efficiency is generally regarded as one of the important options to reduce GHGs, improve the security of energy supply and, in the long run, to attain a sustainable energy system (Metz *et al.*, 2001). Efficiency in end-use applications of energy could be enhanced through both the use of new technology and through change in behavioural patterns. An annual improvement rate of 2% of energy efficiency is considered achievable, though the current rates seldom exceed 1% (Blok, 2004). Due to the efficiency potentials and the end-user perspective, end-use energy efficiency measures will represent the second case study.

4.2 Case study I, selection of RETs

In addition to the guidelines elaborated above, some additional statements regarding the selection of RETs will be made.

Considering the time frame of the Kyoto-bindings, technologies estimated to have an impact on the energy system in a short term (less than 10 years) are considered to be of prime interest. However, as stated by Sandén and Azar (2004), more advanced technologies will have to be developed in order to face future more stringent reduction targets. Therefore, additional RETs will be chosen that are promising in a longer term.

Electricity generation from wind, biomass and solar energy fulfil the guidelines elaborated. Technologies related to these energy sources will be selected to constitute the first case study. Additional arguments strengthen this choice. Wind power, biomass and photovoltaics

- are identified as key technologies for achieving the 12% renewable energy target for 2010 in the *"Energy for the future: Renewable sources of energy"*;
- involve a broad range of actor types, ranging from small private firms to medium and large sized utilities;
- are relevant options in both the current EU-member states and the accession countries;
- are adopted at very different rates in different European countries;
- have a huge potential in comparison to current use and could form the backbone of a future sustainable electricity supply system and
- represent a variety with regards to the level of technological maturity and adoption.

4.3 Case study II, selection of energy efficiency sector

The contribution to the overall energy demand has been an important aspect in the selection of the building sector to constitute the second case study. In the EU approximately 40% of the total energy demand stems from the building sector (EU, 2001) and, hence, the single largest user of energy. This demand has had an upward going trend and according to OECD this trend seems to be consistent (OECD, 2001). Focusing on residential buildings, most of this demand, more precisely 57%, is used for space heating. In the "Directive on energy performance of buildings" (EU, 2001) a saving potential of 22% compared to today's consumption levels of energy used for heating, hot water, air-conditioning or lighting, is estimated and can be realised by 2010. Apart from its major contribution to the energy demand the building sector has also been chosen due to:

- energy efficiency potentials are significant in both the EU-15 countries and the accession countries, even though in varying magnitudes;
- the large amount and variety of actors such as contractors for installation of energy services, construction firms and real-estate owners;
- the longevity of buildings cause decisions taken in the construction process of today crucial in shaping the future energy demand;
- the high discrepancy between owners and users has an impact on the incentives for investments in energy efficiency.

Note that even though no specific technologies have been selected within this case (it is the end-use of energy that is at prime focus), such a selection may be necessary in a later stage of the project. The choice will then be with regards to which type of buildings (i.e. residential, industry or public buildings) and the choice between renovation of the existing stock or the construction of new.

5. BARRIERS AND DRIVERS

A fundamental barrier for new environmental technologies is costs. However, the simplistic argument that RETs and energy efficient buildings are not adopted (or even should not be adopted) because of the high costs needs to be scrutinised. First, one major reason for new technologies being more expensive in terms of price/performance in comparison to incumbent technologies, is that they have not yet undergone a processes of increasing scale and learning economies with increased adoption. Second, additional technical and institutional barriers do have a significant impact to the development and diffusion of environmental technologies These aspects are stressed in the *innovation system* approach, suggesting that innovation is a non-linear process in which firms interacts with organisations (e.g. research institutes, customers, authorities, financial organisations) and institutions (e.g. regulations, culture). Hence, barriers to diffusion of innovations are found not only in the form of market failures but are also due lack of technical compatibility and institutional failures, all denoted by the broader concept of *systemic failures*. In the case of the building industry investments costs are emphasized in confront to life cycle costs and high actual discount rates hinder the savings achieved to be fully appreciated, creating a gap between the most energy-efficient options available and those in use. This phenomenon is often named as the “efficiency gap”.

Main barriers to the diffusion of RETs and energy efficiency measures are described in the following sections, categorised into *market failures*, *market barriers*, *technological barriers and infrastructural failures* and *institutional barriers*.

Table 1. Barriers influencing the development and diffusion of RETs categorised in three main areas.

Categories	Barriers	Examples in the energy and building sectors
Economy – market failures	*Unpriced external costs*	Under priced fossil fuels
	Insufficient and incorrect information	Minimising first costs of buildings instead of life cycle costs (inhibits energy efficiency measures)
	Distorted fiscal and regulatory policies (taxes, subsidies, R&D etc.)	Unequal governmental support and taxation between fossil fuels and RETs
market barriers	*Short-term business investment cycles*	Investors minimises first costs instead of life cycle costs (inhibits radical innovation and

		energy efficiency measures)
	Economic uncertainty	Uncertain pay-offs to new technologies favours incumbent ones (e.g. fossil fuels)
Technology barriers and infrastructural failures	*Product uncertainty*	Uncertain robustness/performance of new technologies favours incumbent ones (e.g. fossil fuels)
	Infrastructural failures	Limited or no access to grids (inhibits the adoption remote wind and solar power)
	Lack of complementary products and services	Expensive service and maintenance costs of RETs
Institutional failures – hard	*Legislation*	None-progressive legislation fails to induce insensitive to invest in RETs
	Regulation	Lack of long-term governmental visions for RETs, inaccessible building permits, grid regulations
soft	*Social values*	Legitimacy issues for RET construction sites
	Culture and tradition	The general public biasing RETs

5.1 Economy – market failures

Under perfect market conditions, energy services are provided at lowest costs. There is, however, considerable evidence showing that lowest energy investment costs are constrained, implying that market failures exist (Worrel *et al*., 2001).

Unpriced external costs include a wide range of negative impacts related to the extraction, production and distribution of fuels and power. Fossil fuels using current conversion technologies generate numerous negative externalities including global warming, air, water and land pollution and uneven distribution of oil resources. Energy sources with negative environmental and social impacts could be stated to be currently under priced, resulting in under-investments in RETs and a higher consumption rate of fossil fuels than what is socially optimal. Negative externalities can be internalised through policy intervention as carbon taxation and carbon trading.

Insufficient and incorrect information relates to the fact that information can be difficult and expensive to obtain, while market efficiency requires free and perfect information. Consumers of electricity and heating in the residential sector, for example, seldom face the individual end-use costs on the bill, resulting in a lack of incentives to invest in energy efficiency measures. This is a classical illustration of split incentives where the actor responsible for efficiency investments can not collect the savings. Imperfect information also relates to underlying principles of decision-making, where initial investment costs often are decisive and easier to estimate than life-cycle calculations. In the building sector, this is a reason why builders minimises first costs assuming a higher purchase value with installed efficiency technologies will not be as attractive in the eyes of customers. The contractual nature of the building industry in many countries emphasises this aspect, since each contractor will be more focused on minimizing its own costs and thus increasing its profit instead of taking into account the total costs during the life time of the building.

Distorted fiscal and regulatory policies may favour certain technologies in terms of skew subsidies and regulatory systems and, thereby, inhibit the use of both energy efficient technologies and RETs. Governmental support favouring incumbent technologies, e.g. failing in regulating a non-competitive market, affects the “free choice” of consumers to purchase services provided by new technologies (Johnson and Jacobsson, 2001). Monopolies may as well be a result of regulatory systems biasing new technologies in favour of incumbents. The supply of products and services is consequently distorted and technological options reduced, which is considered harmful for an economy (Brown, 2001). This is historically the case of the energy sector, where fossil fuels have been benefited from both unequal governmental support and taxation.

5.2 Economy – market barriers

By market barriers we here denote economic obstacles of a different kind than the traditional market failures (Jaffe and Stavin, 1994).

New technologies suffer an economic disadvantage not because they are inherently more expensive but because they are new. Namely, positive feedback mechanisms leading to "processes of increasing returns" (*economies of scale* and *learning by doing/using*) are key issues in enhancing competitiveness. Production costs per unit output decreases as a result of fixed costs being spread over increasing production volumes; producers learn how to enhance production processes and, together with increased costumer feedback, product performance improves as well. Thus, it is a Catch-22 situation. The new technology is locked out of the market because of the high cost, and the cost can not decrease because it is locked out of the market. (Arthur, 1988)

Switching to environmental technologies is often coupled with high initial costs and uncertain pay-offs, the perceived economic risk bias economical unproven technologies. Anchored in possibility of loosing capital investments and reduction of firm competitiveness, investments in such are therefore restrained. This is especially evident in a business climate where investors seek short-term pay-offs to investments. When the global society faces long-term climate changes, this is a serious concern for the development and diffusion of environmental technologies.

The residential building sector is characterized by a large number of small actors. One of the consequences is that the "economy of scale" will be harder to achieve and that less capital can be put into achieving knowledge and information about new building technologies. It will also limit the access to capital and, as small actors are considered to be less reliable on the financial market, they receive higher rates of return. The same problem is faced by the individual customer who, due to the high capital costs connected with housing, will have fewer opportunities to "learn by buying" and thus have smaller chances to achieve information through past actions.

The specific nature of the industry will also have an impact on the diffusion of new technologies or new design processes. According to a study of made in the UK the construction industry is characterized by fragmentation and the buildings process involves a large number of actors from the client to contractors and suppliers. Subcontracting, temporary coalition between firms and risk transfer are typical features of construction projects. The contractual nature of the sector leads to short sighted price pressure, little communication between the parties and threats of litigation. The latter attribute leads often to an over sizing of service equipment increasing the energy usage of the facility. The timely limitations are often more pressing then the financial ones. These properties combined with a linear, sequential design process inhibit the possibility to achieve a well functioning green building. (Sorrell, 2003)

5.3 Technological barriers and infrastructural failures

New technologies have to verify certain qualities and characteristics in order to prove its viability, often in comparison with incumbent well-known and legitimated technologies. Until doubts have been removed through, for example, the emergence of a dominant design and wide-spread diffusion, product uncertainties may inhibit adoption and withhold potential investors. The early phase of the wind power industry was characterised of frequent experimentation on different design concept: horizontal- and vertical-axis turbines, different number of blades and turbines of shifting sizes (5 kW to 3 MW) to various degree of success (Bergek and Jacobsson, 2003). Not until mid-1990s the three bladed, vertical-axis designs emerged as a "winner", which had proved both effectiveness in terms of cost and performance and reliability as well. Performance issues often get solved through increased adoption. The more the technology is used, the more is learned about it and thus enhancing development and improvements (Arthur, 1988).

To which extent a new technology will fit into the old system is a key issue in how well the technology will be accepted (Frankel, 1955). Both in terms of fitting into an infrastructure as well as the presence of complementary products and services (spare parts, qualified maintenance skills etc.). Hydrogen power vehicles will, for example, need to have a well-developed distribution system of hydrogen and adapted refilling stations. Roof-mounted photovoltaics are dependent of both the gradient and direction of the roof, which thus may lock-out potential adopters as this seldom has been a requirement in ordinary house designs. New technologies may therefore suffer disadvantages depending on what level of infrastructural change is necessary for an adaptation. To some extent RD&D-programmes could address both product uncertainty and demonstrate a technology in an infrastructural setting.

5.4 Institutional failures

Recently, there has been a growing emphasis in the academic literature of barriers relating to institutional failures in addition to strictly economic ones (e.g. Carlsson and Jacobsson, 1997; Smith, 1999; Edquist et al., 1998). In some literature, there is a distinction made between "hard" institutional failures, relating to failures in the regulative framework and the general legal system, and "soft" failures being in social institutions as political and social culture (Smith, 1999). Hard institutions are created to serve functions in society, whereas the soft ones emerge in a more spontaneous manner.

Hard institutional failures could easily be confused with the market failure concerning a distorted governmental support, but here refer to formal institutional mechanisms that may hinder innovation. Technical standards, labour law, risk management, health and safety regulations could obstruct implementation of new technologies as well as general legal systems relating to contracts and employment, and intellectual property rights (patent and copyright law) (Smith, 1999). The Dutch wind industry was, for example, restrained in its diffusion due to the difficulty to obtain building permits for the facilities. In Sweden, the wind industry failed to develop a self-sustained market through, partly, misguided governmental support. Sweden invested more governmental funding than, for example, Germany and the Netherlands, during the early 1980s, but only on large turbines. Due to public legitimacy issues, there were no demand for such large-scale turbines and the national industry later more or less collapsed[4].

Soft institutional failures are found within a wider context, where political culture and social values may inhibit diffusion (Smith, 1999). These frame the scene where business is carried out through the shaping of public policy objectives and the macroeconomic policy environment, i.e. the legitimacy a technology has in the eyes of different actors and society in general, social norms and culture and, thus, the implicit willingness to invest, share resources (knowledge, monetary etc.). Altogether, these institutions outline a set of implicit rules (or a paradigm) for innovation and diffusion (Dosi 1982, Bijker 1995), which may, indeed, both

[4] Two decades later, such large-scale turbines (>1MW) have become the "dominant design" in the wind power industry.

stimulate and hinder the transition of environmental technologies. Wind power as a renewable technology is widely accepted, but even though faces legitimacy issues when selecting the local construction sites. In the eyes of the public, residences "should" look in a given way, which may exclude the sight of photovoltaic installations on the roof etc.

6. SECTOR DEVELOPMENT

6.1 Case study I

6.1.1 Future investment needs

The demand for electricity in EU is growing, albeit at a lower pace than in the 1960s and 1970s that showed annual growth rates of 8% and 4%, respectively. The rate slowed down to 2.6% in the 1980s and 1.8% in the 1990s. The growth in demand in the 1960s was mainly satisfied with oil-fuelled power plants (figure 2). The next to decades were dominated by growth of nuclear and coal power. In the 1990s, natural gas power grew at the expense of coal. RETs (excluding hydro) have shown a steady growth but still contribute marginally to electricity production (less than 3.6% in 2002).

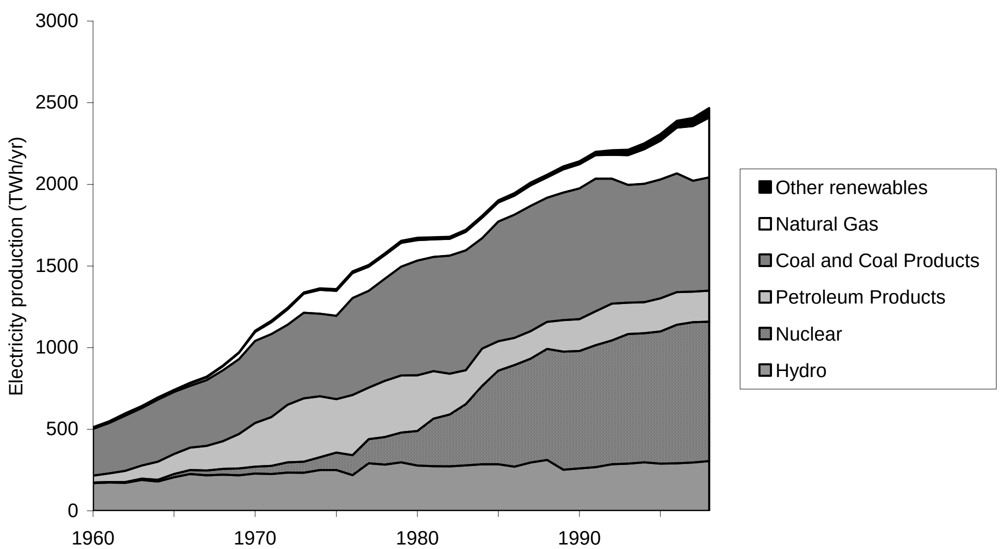

Figure 2. Electricity production in EU-15 1960-1998. (Source: Data from IEA 2001)

The need for new investments in the electricity sector is large even without considerations of stringent targets for CO_2-reduction since old power plants need to be replaced. In a scenario made by Kjärstad and Johnsson (2004) it is assumed that all existing fossil based power plants will be phased out in 2043.[5] Assuming some decommissioning of nuclear plants and a growth in electricity demand of 1.4% per year, a large gap emerges. This has to be filled with new advanced fossil technologies or renewables or be reduced in size by accelerated

[5] These scenarios are based on assumptions that fossil based technologies will be phased out due to age (on their 41st year) and the rate whereby nuclear power will be phased out is based on national policies (Kjärstad and Johnsson, 2004).

implementation of more efficient end-use. Their estimates show that in order to meet the future electricity demand, total investments of around € 750 billion are required over the next four decades. Note that these figures do not include future investment needs in the accession countries, which will further increase this need.

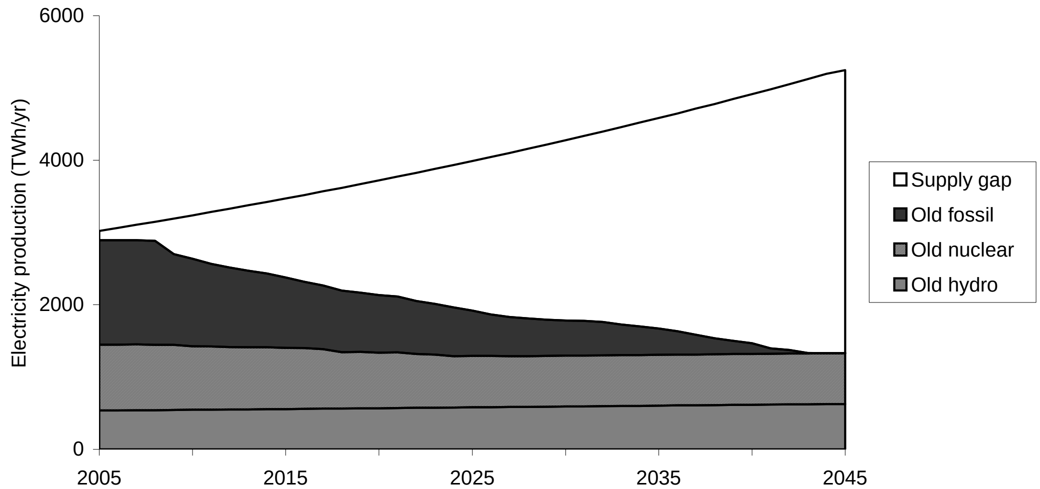

Figure 3. Scenario for future European (EU-15, Czech Republic, Norway, Poland and Switzerland) electricity production, indicating the need for new investments.

6.1.2 Liberalisation of national electricity markets

The old system with municipal utilities and national electricity producers has over the last two decades been challenged by the tide of market liberalisation. Liberalisation and various forms of feed-in-laws have opened up for new actors on the electricity markets. However, in many countries the markets are still dominated by a few actors and despite efforts to liberalise national electricity markets (through the implementation of *"Liberalisation of Electricity Markets"* 96/92/EC), there are several examples of monopolies in the EU-member states. But there is a vast disparity among the member states. Greece, France, Belgium, Netherlands, Luxemburg, Portugal, Spain and Sweden currently have 10 or less companies represented on the national electricity markets, while, for example, Denmark, Italy and Austria have more than 1000. Even though the great numbers of participants in the Austrian and the Italian markets, the three largest electricity producers still accounts for 65% and 83%, respectively of the national markets. Liberalisation has in some cases resulted in takeovers and mergers and thus to increased market concentration.

The recent growth of natural gas fired power plants at the expense of coal power is partly a result of the liberalisation of the electricity markets in many European countries. In the new investment environment smaller units implying smaller risk and larger flexibility is generally favoured. This could favour renewables. On the other hand liberalisation could also make the producers more oriented towards short-term profits instead of long term supply security. This could slow down investments in less mature renewables.

6.1.3 Diffusion of RETs

In 2002, the share of RETs in the energy sector had increased to 5.5% from 4.8% in 1990. In the electricity sector, only a marginal increase of RETs had been achieved, from 13.1 % in 1990 to 13.7% in 2002. These figures could be compared to the indicative targets stated in white paper on renewable energy sources (see chapter 3) of 12% renewables in the energy sector and 22% RETs in the electricity sector by 2010.

Of electricity produced from RETs, the largest share originates from hydro power (0.305 TWh of a total output of 0.403 TWh), while wind, photovoltaics and biomass have relative shares of 9.2%, 0.064% and 10.9% respectively. As indicated in figure 4., the average growth rates of photovoltaics and wind power is very high (above 30% per year) while electricity from biomass grows at a more moderate speed. However, national growth rates in Europe, in particular for solid biomass show great variety. In the Netherlands biomass has grown by 85% during the period 1996-2001, whereas countries such as Austria and Portugal, both with a relative large share of biomass (3.0% and 2.4% respectively), have had growth rates below 2%. Biomass based technologies are naturally preferred in countries with considerable amounts of forests such as Finland and Sweden, but have, for example, in the Netherlands been increasingly adopted partly as a result of progressive political support. Finland, Sweden and Spain together constitute more than half of the electricity produced from solid biomass in the EU. The European community as a whole has an annual growth rate of electricity from solid biomass well above the average of the remaining part of OECD countries (indicated with big bold and grey squares in figure 4).

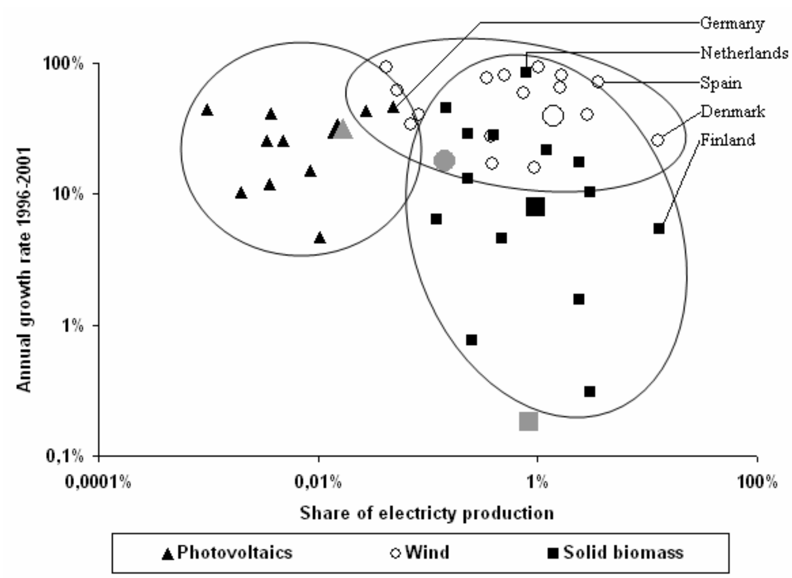

Figure 4. Annual growth rates and relative shares of national electricity production from photovoltaics, wind and solid biomass in the EU member states. Note that large bold and grey symbols indicate average values for the EU (bold) and the remaining OECD countries (grey) for respective technology.

Wind power in the EU has grown by 40% annually, where especially Denmark, Germany and Spain constitute a significant share of the total electricity production. A majority of the EU member states have an annual growth rate over 10%, but the national shares varies by a factor of 100, from approximately 0.1% and up to more than 10% in Denmark. The Danish wind power were to a large extent developed by small communities, often farmers organised in small groups wishing to develop their own renewable energy systems. Later, a governmental support through subsidies and a feed-in law positioned Denmark as a world leader in the wind power industry. German wind power has developed in a similar way, but with an even stronger support from national and regional policies. An early federal market stimulation and R&D-programme, initiated in 1989, in combination with the *Electricity Feed-in Law* (EFL) pushed the German wind industry to the fastest expanding in the world during the 1990s (Bergek and Jacobsson, 2003).

Photovoltaics are currently only a marginal contributor to the electricity production in the EU. However, growth rates during the period of 1996-2001 are fully comparable with those of the wind industry. In the period of 1999-2002 Germany increased the installed capacity of photovoltaics by a factor of three, and produced in 2002 about 70% of the electricity form photovoltaics in the EU. The *"100.000 PV roofs"*-programme and the above mentioned EFL, have been the prime institutional drivers for the German expansion (Jacobsson *et al*., 2004).

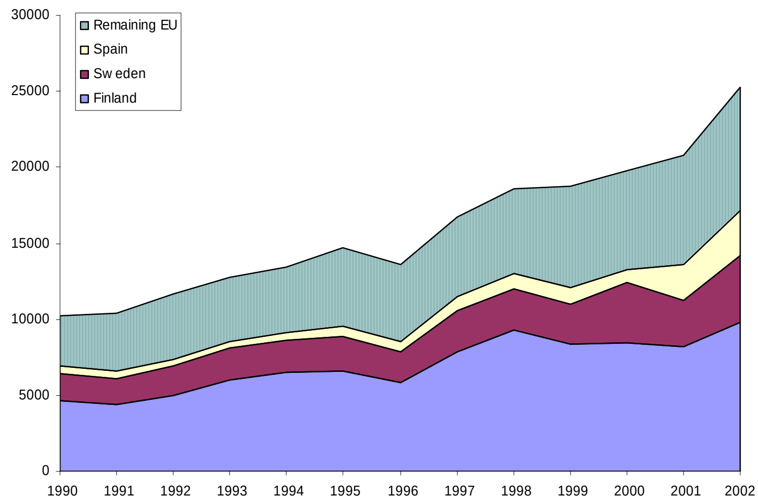

Figure 5. Electricity production from solid biomass in the EU during 1990-2002, showing the three main contributors and the remaining EU (GWh/year).
Source: data from IEA 2001

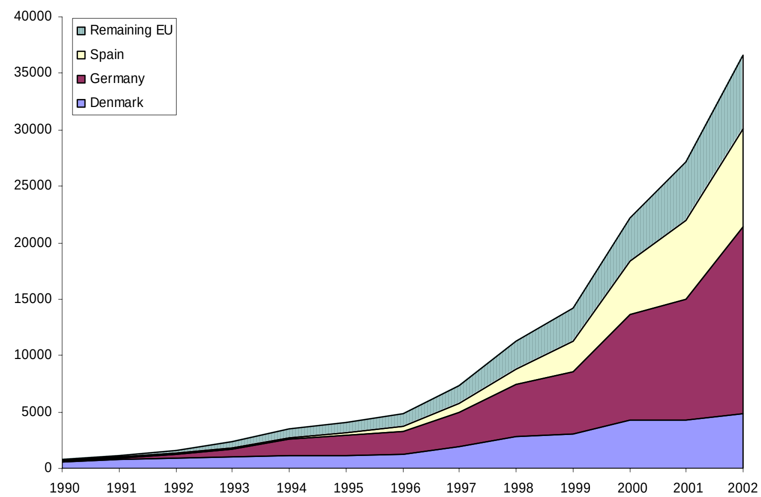

Figure 6. Electricity production from Wind Power in the EU during 1990-2002, showing the three main contributors and the remaining EU (GWh/year).
Source: Data from IEA 2001

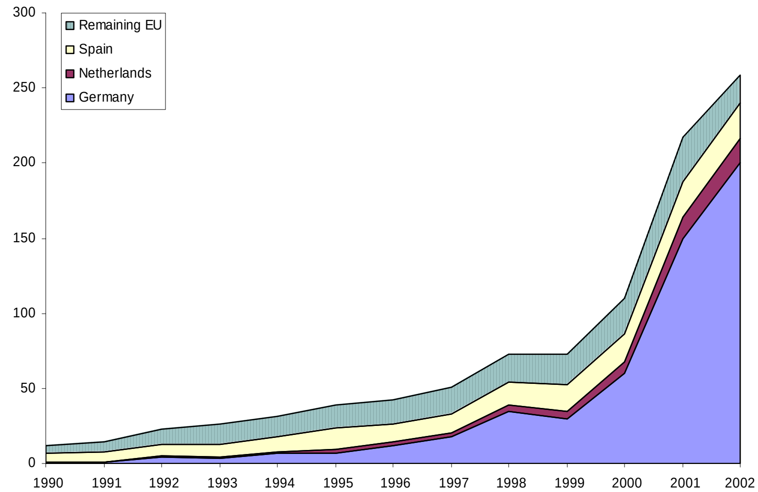

Figure 7. Electricity production from Photovoltaics in the EU during 1990-2002, showing the three main contributors and the remaining of EU (GWh/year).
Source: data from IEA 2001

6.1.4 Policy influence on technical development and costs

Production and operation costs of photovoltaics and wind farms have been greatly reduced over the last decades. Economies of scale as well as learning by doing, using and thinking have played important roles, often pushed by national policies. Wind power in Denmark were in the 1970s driven by several governmentally financed RD&D-programmes, which lead to a frequent experimentation and, eventually, to a global dominant design concept of an up-wind, three bladed, stall-regulated, grid-connected machine with a horizontal axle. Ever since then, only incremental changes to this design concept have been made. Two influential programmes supporting technological development were induced during the 1980s: the Energy Research Programme (EFP) and the Renewable Energy Development Programme (UVE), both focusing on developing large and small-scale wind farms. In addition, the Danish government supported a technological platform for testing and certifying wind farms, which improved reliability for the wind turbine technology. During this period, production costs of wind turbines produced by Danish manufactures dropped from 10909 DKK/kW in 1981 to 5563 DKK/kW in 2000. (Neij *et al.*, 2003)

While R&D policy influence the choice of design, improve reliability, production and operation costs, market policies may induce market formations, support market expansion, provide learning opportunities in production and use and, thereby, reduce costs of producing wind farms and generating electricity (Neij *et al.*, 2003).

In Germany, several market based instruments have been implemented and successfully reduced costs and prices of photovoltaics, initially often on a local level and, when proved successful, initiated on federal scale. Perhaps most powerful is the EFL (see section 3.3.3), which, inspired by a local model, guarantees producers 57.4 euro cents per kWh of electricity produced from new photovoltaics installations over a period of 20 years. The guaranteed price is reduced with 5% annually for new installations, in order to create incentives for cost reductions and enhance competitiveness. However, high costs are still a great barrier for the diffusion of photovoltaics, but since the experience curve is quite steep (Neij, 1997), the prospects for reaching competitive costs by stimulating adoption are good (Sandén, 2004).

6.2 Case study II

In previous chapters we have denoted that the residential sector has a significant share of the energy demand and that approximately half of this demand can be attributed to heating of buildings. Two countries will here be presented in an effort to describe current development and situation regarding energy efficiency in the building sector: Sweden and the United Kingdom. An overview of policies to address reductions of CO_2 emissions from new and existing buildings will also be presented.

6.2.1 The Swedish case

Studying the development of energy efficiency in Swedish residential buildings one can observe improvements throughout the seventies and early eighties. In the nineties the trend levelled out and almost no further improvements were achieved. This, despite the fact that in the late seventies the best available technology, represented by low energy buildings, used less than a third of the energy of average new buildings. These are marked as crosses in figures 8 and 9, illustrating the development of energy intensity (kWh/m2) in one-two dwelling houses and multi dwelling houses, both in the existing stock and in new buildings. The efficiency improvements that have occurred have balanced out the increased activity of the sector but have not managed to reduce substantially the energy demand for heating. It must also be pointed out that the trend observed is the delivered energy and that part of the improvement can be attributed to the fact that energy losses within the building were moved to conversion and distribution outside of the building, when the choice of energy carrier was altered. Thus the primary energy use increased instead.

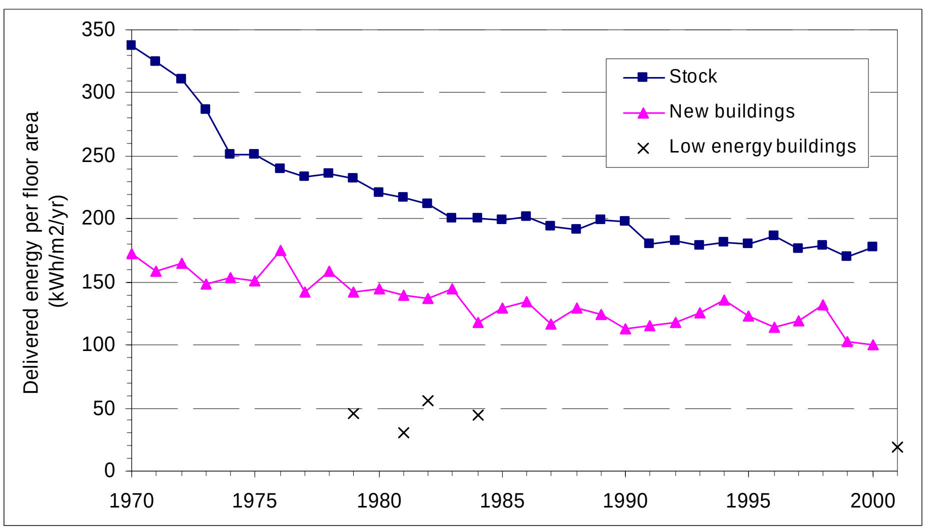

Figure 8. The development of delivered energy use for heating per floor area of one and two dwelling buildings. The stock represents all heated floor area in a certain year. The curve for new buildings shows the energy use in the year of completion. Examples of low energy buildings are included to illustrate the gap to Best Available Technology (BAT): Färgelanda 1979 (Eek, 1987), Uppsala 1981 (Wolgast, 1981), Malmö 1982 (Elmroth & Granberg, 1987), Tuggelite 1984 (Eek, 1987) and Lindås 2001 (Ruud et al., 2002).

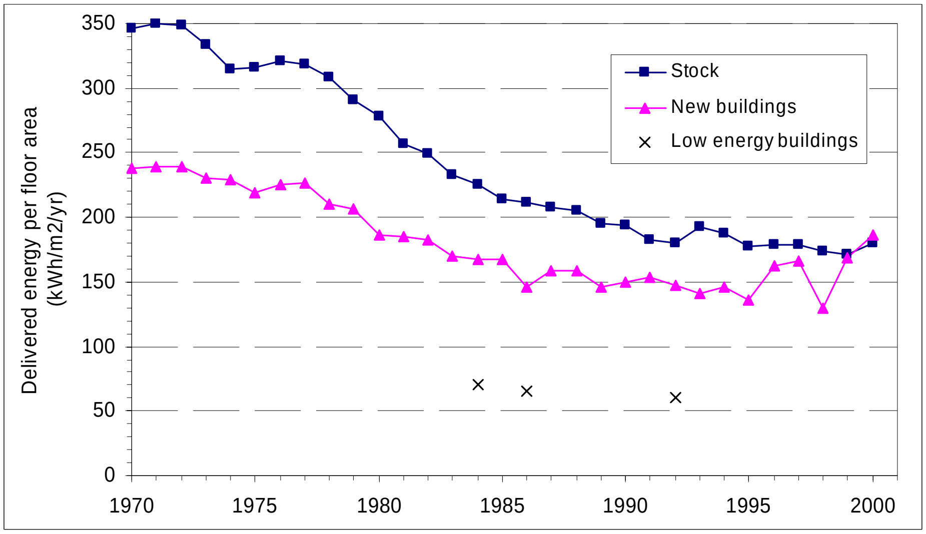

Figure 9. The development of delivered energy use for heating per floor area of multi-dwelling buildings. The stock represents all heated floor area in a certain year. The curve for new buildings shows the energy use in the year of completion. Examples of low energy buildings are included to illustrate the gap to Best Available Technology (BAT): Stockholm 1984 (Eriksson, 1993), Göteborg 1986 (Gustén, 1992) and Uppsala 1992 (Askensten, 1996).

The development can mostly be explained through the changes in energy prices. Between 1970 and 1985 the price of oil increased abruptly: 350 percent compared to the consumer price index. During this period the energy supply of the residential sector was dominated by oil and thus the increased prices created incentives for energy efficiency and fuel substitution. In parallel, the Swedish nuclear program was initiated and kept the electricity prices low in comparison to raising oil prices. Consequently, oil was substituted to the cheaper electricity and, thereby, reduced carbon emissions but also increased pay-back times energy efficiency investments.

There are also non economic factors that influence the rate of energy efficiency in buildings such as the relationship between the contractors and the building companies. In Sweden today the typical contractor for a multi-dwelling building is a small housing co-operative with little knowledge in building techniques, law and property management. Their weak position in comparison to the building company leaves all the control of the building process to the later. This is a typical demonstration of how asymmetrical information can impede the smooth functioning of a market for energy efficiency. An example of split incentives is the fact that multi-dwelling residents do not pay their own heating expenses and will therefore not try to alter their behaviour.

The influence of building standards on energy efficiency has been small, mainly due to the fact that these have been too lenient and no effort has been necessary to meet them.
The standard that came into force 1977 (SBN 75) constituted a strengthening of the insulation requirements but no major results were observed, largely due to an overestimation of the energy use in buildings from the seventies.

A requirement for heat exchanging was enforced in 1980 leading to a decrease of delivered energy intensity, but the increase in energy prices that occurred in parallel could also have had an influence. These requirements were lifted in 1995, in BBR 94, for buildings heated with less than 50 percent fossil fuels, including district heating, a common energy carrier in multi-dwelling buildings. This could be one of the reasons for the increased energy intensity in new multi-dwelling buildings in the late nineties.

6.2.2 The United Kingdom case

The domestic energy in the United Kingdom has had a slight increase between 1970 and 2000. Lighting and the usage of appliances has increased the most, but also space heating has had an upward trend, as can be seen in figure 3. Space heating stands for 58% of the domestic energy usage and 50% of the carbon emissions.

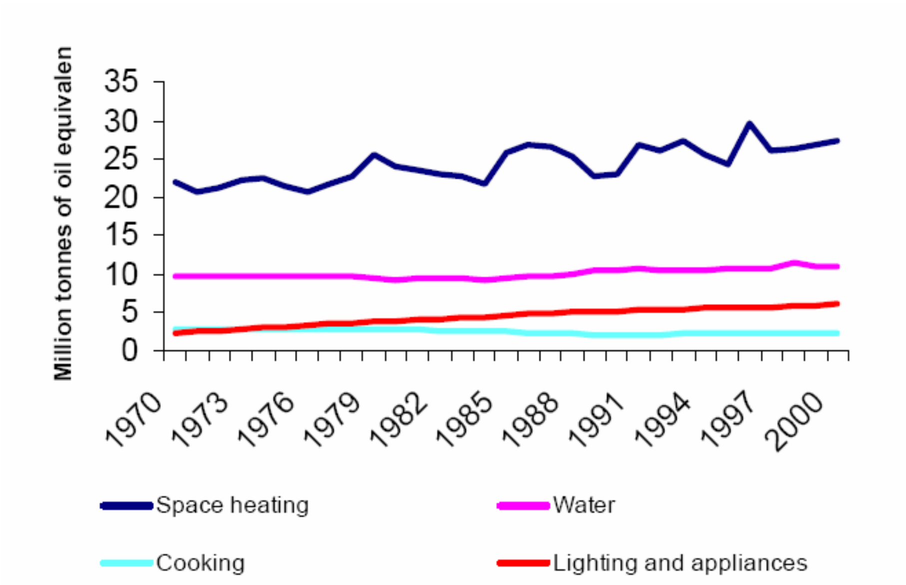

Figure 10. Domestic energy consumption by end use, 1970-2000.
Source: HM Treasury, UK

One of the principal national schemes for energy efficiency is the Home Energy Efficiency Scheme (HEES) and was first put into operation in 1991 and its first phase ended in 2000. By 1999 3 million households had received grants for energy efficient measures. The main purpose of this scheme was to reduce fuel poverty (when household spend more than 10% of their income on domestic fuels), by cutting energy costs while keeping a constant service level. A similar scheme is the Warm front Scheme, whose aim is to increas comfort levels for low-income groups. Grants are offered for insulation and heating measures. A new HEES was started in April 2000 and will end in 2004. The new HEES is projected to save 0,2 MtC per year by 2010.

Building regulations for England and Wales (Part L) have been revised in Octeber 2001 and the changes came into effect in April 2002. This implies that the energy efficiency standards for any work on new buildings or existing stock has increased. The estimated savings from this stricter regulations are 0,8 million tonnes of carbon emissions by 2010.
An economical instrument to enhance energy efficiency is the VAT reductions on certain energy saving materials. Insulation materials, draught stripping, hot water and central heating system controls are covered.

Despite these efforts and the savings predict from these measures there is still a gap (about 2 MtC) that needs to be filled to achieve the goals set by the Climate Change Programme, implying that new policies are needed to reach the 5 MtC saving by 2010.

7. REFERENCES

Arthur, B. W., (1988): “Competing technologies: an overview.” Technical change and economic theory. G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete. Pinter Publishers, London. 590-607.

Askensten, Å., (1996): VVS-Forum 5 1996, 22-23.

Azar, C., Lindgren, K. and Andersson, B. A., (2003): “Global energy scenarios meeting strigent CO_2 constraints – cost-effective fuel choices in the transportation sector.” *Energy Policy*, **31**, 961-976.

Bergek, A. and Jacobsson, S., (2003): “The Emergence of a Growth Industry: A Comparative Analysis of the German, Dutch and Swedish Wind Turbine Industries.” In: Metcalfe, S. & Cantner, U. (red): Change, Transformation and Development. Physica/Springer, Hiedelberg.

Bijker, W. E., (1995): “Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change.” The MIT Press. Cambridge, Massachusetts.

Blok, K., (2004): “Enhanced policies for the improvement of electricity efficiencies.” *Energy Policy*, In press.

Brown, (2001): “Market failures and barriers as a basis for clean energy policies.” *Energy Policy*, **29**, 1197-1207.

Carlsson, B. and Jacobsson, S., (1997): “In search of useful public policies: key lessons and issues for policy makers.” In: Carlsson, B. (Ed), Technological Systems and Industrial Dynamics. Kluwer Academic Publishers, Dordrecht.

Delucchi, M. A. *et al*., (2001): “The Health and Visibility Cost of Air Pollution: a Comparison of Estimation Methods.” *Journal of Environmental Management*, **64**, 139-152.

Dosi, G., (1982): “Technological paradigms and technological trajectories.” *Research Policy*, **11**, 147-62.

Edquist, C., Hommen, L., Johnson, B., Lemola, T., Malerba, F., Reiss, C., Smith, K., (1998): “The ISE Policy Satement – the Innovation Policy Implications of the ‘Innovation Systems and European Integration’.” Research project funded by the TSER programme (DG XII). Linköping University, Linköping.

EEA, (2003): *Europe’s environment: the third assessment*. European Environment Agency, Copenhagen.

Eek, H., (1987): “Passive solar heating in a Scandinavian climate - three housing projects with a low energy consumption.” Swedish Council for Building Research, Stockholm.

Ekins, P., Russell, A., Hargreaves, C., (2002): “Reducing Carbon Emissions through Improved Household Energy Efficiency in the UK.” *Journal of Environmental Policy & Planning*, **4**, 41-65.

Elmroth, A., Granberg, G., (1987): “*SPARSAM – fem energisnåla småhus med glasveranda och värmepump*.” In Swedish. R47:1987, Swedish Council for Building Research, Stockholm.

Eriksson, S-O., (1993): “*Stockholmsprojektet – energibehov i flerbostadshus med solvägg, tung stomme och värmepump*.” In Swedish. R44:1993, Swedish Council for Building Research, Stockholm.

EU, (1996): *Energy for the Future: Renewable Sources of Energy, Green Paper for a Community Strategy*. COM(96) 576.

EU, (1997): *Energy for the Future: Renewable Sources of Energy, White Paper for a Community Strategy and Action Plan*. COM(97) 599 final.

EU, (2000): *DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the promotion of electricity from renewable energy sources in the internal electricity market*. COM(2000) 884 final.

EU, (2001): *DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the energy performance of buildings*. COM(2001) 226 final.

EU, (2004): *Stimulating Technologies for Sustainable Development: An Environmental technologies Action Plan for the European Union*. COM(2004) 38 final.

Frankel, M., (1955): “Obsolescence and technological change in a maturing economy.” *American economic review*, **45**, 296-319.

Gustén, J., (1992): “*Hybridsolvärmehus i Göteborg*.” In Swedish. Internrapport I37:1992, Department of Building Services Engineering, Chalmers University of Technology, Göteborg.

HM Treasury, (2003): “*Economic instruments to improve household energy efficiency: consultation document on specific measures*.” HM Treasury, London.

IEA, (2003): *Key World Energy Statistics*. International Energy Agency, Paris.

IPCC, (2001a): *Climate Change 2001 - The scientific basis. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change*. Houghton et al. (eds.), University Press, Cambridge.

IPPC, (2001b): *Climate Change 2001 - Mitigation. Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change*. Houghton et al. (eds.), University Press, Cambridge.

Jacobsson, S., (2002): “Att omvandla energisystemet – reflektioner kring ”Handel med certifikat. Ett nytt sätt att främja el från förnyelsebara energikällor”, SOU [2001:77].” *Ekonomisk Debatt 2002*, **3**, 265-270.

Jacobsson, S. and Bergek, A., (2003): "Transforming the Energy System: The Evolution of Technological Systems in Renewable Energy Technology.” Department of Industrial Dynamics, Chalmers University of Technology, Göteborg, Sweden.

Jacobsson, S. and Johnson, A., (2000): “The Diffusion of Renewable Energy Technology: An Analytical Framework and Key Issues for Research.” *Energy Policy*, **28**, 625-640.

Jacobsson, S., Sandén, B. A., Bångens, L., (2004): “Transforming the energy system—the evolution of the German technological system for solar cells.” *Technology Analysis and Strategic Management*, **16**, 3–30.

Jaffe, A.B., Stavins, R.N., (1994): “The energy-efficiency gap. What does it mean?” *Energy Policy*, **22**, 804–810.

Johnson, A. & Jacobsson, S., (2001): “Inducement and Blocking Mechanisms in the Development of a New Industry: the Case of Renewable Energy Technologies in Sweden.” In: Coombs, R., Green, K., Walsh, V. & Richards, A. (red): *Technology and the Market: Demand, Users and Innovation*. Edward Elgar, Chelthenham/Northhampton.

Kjärstad, J., and Johnsson, F., (2004): Chalmers Power Plant Database (Chalmers PP db), 2004.

Metz, B., Davidson, O., Swart, R., Pan, J., (2001): *Climate change 2001 - mitigation*. IPCC 3rd Assessment Report, Cambridge University Press, Cambridge.

Morthorst, P.E., (2003): “National environmental targets and international emission reduction instruments.” *Energy Policy*, **31**, 73-83.

Niej, L., Dannemand Andersen, P., Durstewitz, M., Helby, P., Hoppe-Kilpper, M., Morthorst, P. E., (2003): “Experience Curves: A Tool for Energy Policy Assessment.” IMES/EESS Report No. 40 Department of Technology and Society, Environmental and Energy System Studies, Lund University, Sweden.

Nässén, J., Holmberg, J., (2004): “Energy efficiency – a forgotten goal in the Swedish building sector?” *Energy Policy*, Article in Press

OECD, (2001): *Environmental Outlook.* OECD, Paris.

OECD, (2003): *Environmentally Sustainable Buildings - Challenges and Policies.* OECD, Paris.

Persson, T. & Azar, C., (2002): “The cost of meeting the Kyoto protocol – dealing with the carbon surplus in Russia and the Ukraine.” Submitted for publication.

Ruud, S. H., Lundin, L., Nielsen, J. R., Sandberg, M., (2002): ”Jämn temperatur i småhus utan värmesystem.” In Swedish. *Energimagasinet* 6/02, 32-34.

Sandén, B. A., (2004): “The economic and institutional rationale of PV subsidies.” *Solar Energy*, In press.

Sandén, B. A. and Azar, C., (2004): “Near-term technology policies for long-term climate targets.” Submitted for publication in *Energy Policy*.

Schwartz and Randall, (2003): “An Abrupt Climate Change Scenario and Its Implications for United States National Security.” Pentagon Report.

Smith, K., (1999): “Innovation as a systemic phenomenon: rethinking the role of policy.” In: Bryant, K., Wells, A. (Eds), A New Economic Paradigm? Innovation-Based Evolutionary Systems. Commonwealth of Australia, Department of Industry, Science and Resources, Science and Technology Policy Branch, Canberra, 10-47.

Sorrell, S., (2003): “Making the link: climate policy and the reform of the UK construction industry.” *Energy Policy*, **31**, 865-878.

SEPA, (1997): *Environmental Taxes in Sweden - Economic Instruments of Environmental Policy.* Swedish Environmental Protection Agency, Stockholm.

STEM, (2003): *Styrmedel Inom Klimatpolitiken – modellberäkningar samt problemorienterade beskrivningar och analyser.* Swedish National Energy Administration, Eskilstuna, Sweden. (in Swedish).

UNFCCC, (1992): *United Nations Framework Convention on Climate Change*. URL: http://unfccc.int/

Unruh, G. C. (2002): “Escaping carbon lock-in.” *Energy Policy*, **30**, 317-325.

WEA, (2000): *Energy and the Challenge of Sustainability*. UNDP, New York.

Wolgast, (1981): *Energimagasinet* 1/81, 32-34

Worrel, E., van Berkel, R., Fengqi, Z., Menke, C., Schaeffer, R., Williams, R. O., (2000): ”Technology transfer of energy efficient technologies in industry: a review of trends and policy issues.” *Energy Policy*, **29**, 29-43.