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# Deliverable WP3 : Design of policy measures supporting the development and adoption of cleaner technologies

## Case Study "Electricity from Renewable Energy Sources"


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## Executive summary

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# 1 Introduction

There are few signs pointing to that modern society in the foreseeable future will demand less of products and services than it currently is. Quite the opposite; consumption and extensive resource usage are still key-characteristics of the western economy, and developing countries as China and India is rapidly marching along the same path. Even though the international community has succeeded in constructing agreements and directives on, for example, reducing greenhouse gas emissions, biodiversity and ecosystem conservation and freshwater management, the struggle against environmental degradation has just begun and will certainly call for additional substantial measures. The dissemination of 'new' clean technologies is a vital step in this direction and is highlighted in the European Community's Lisbon Strategy as essential to become "*the most competitive and dynamic knowledge-based economies in the world capable of sustainable economic growth with more and better jobs and greater social cohesion*" (EU, 2000). Thus, clean technologies are not only acknowledged for their environmental performance, but of great interest to encourage social and economic welfare as well, i.e. the three pillars of sustainable development.

The European Commission has through the launching of the rather ambitious Environmental Technologies Action Plan (ETAP) committed to the wide-spread of clean technologies in all the sectors of society. This programme encourage a numerous of actions designed 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 *"mobilise all stakeholders in support of these objectives"* (EU, 2004).

As a measure within the framework of ETAP, this project is designed to identify *policy pathways to the promotion and development of clean technology development* (POPA-CTDA) in the sectors of industry, transport, agriculture and energy. The underlying method is based on behavioural theory (Montavlo, 2001) that with a questionnaire survey (work package 2) put the developers and users of technology in focus to determine the various barriers and drivers to the uptake of new technology. Results of the questionnaire data is used in a wider discussion together with reviews of current literature and additional data collected during interviews. This case study deals with the European energy sector and is carried out for electricity generated from renewable energy technologies (RET), in particular wind, bio and solar power, as case study. These three technologies are all believed to play a crucial role in changing the energy system of today to a more sustainable one with decreased dependency on import of energy and reduced emissions of greenhouse gases.

The report begins with a general overview chapter briefly describing renewable energy out of a global perspective followed by a technology description and the current market situation. The following chapters will elaborate on the current state of supporting systems for RET, both on the EU and national level, and, there after, a presentation of the significant barriers and drivers found during the questionnaire study. This information is then considered in a scrutiny of optional policy instruments to address the barriers and, finally, a list of plausible policy instruments is presented with additional recommendations to the next steps of support to RET in the future.

# 2 Overview of the technologies under study

Currently driven by all three pillars of sustainability, in addition to the ‘traditional’ environmental one, RETs are increasingly looked upon as commercially competitive alternative to fossil based energy technologies. Use of renewable energy is growing on the global market - not only in niche applications as e.g. remote installations but on the broader energy/electricity markets as well. The share of renewable energy of global primary energy supply (TPES) is about 11.3%, which of the vast majority is combustible bio resources (about 10.8%) and about 0.5% being wind, solar and geothermal.[1] On the European energy market, RETs accounts for approximately 5% of TPES.

Renewable energy has a strong domestic market appeal and potential employment creation - more than 14 million jobs have been created world wide - but they can also drive export of technology and services to meet the growing international need for ‘green’ energy. Hence, it is no surprise that the qualities of renewable energy are more and more recognised on the political arena. Renewable energy has received important backing from the Kyoto protocol and UN Climate Conferences, the IEA Ministers have declared that they “intend for renewables to play an increasing role” in the energy sector and in 1997 the EU Commission launched a dedicated white paper on renewable energy[2] aiming at increasing the share of renewable energy to 12% by 2010 in the European energy sector.

Outside the OECD countries, over 1.6 billion people in the developing world are still without modern energy services as lightning, fresh water and heating/cooling. Renewable energy provides a relatively low-cost alternative to meet lack of such services in remote and developing regions, and have potential of contributing to local economic development, expanding industrial capacity, increasing agricultural productivity and, thereby, enhancing export capabilities.

The benefits to the global community is plentiful from a large-scale adoption of RETs but, despite significant reductions of costs, both capital and operational, and support from the political scene through various policy objectives, supporting schemes etc., the big break through to the mainstream is yet to come.

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[1] Key World Energy Statistics (2005, IEA)
[2] “Energy for the Future: Renewable Sources of Energy”, COM(97)599

## 2.1 Technology and economics

### 2.1.1 Solid biomass

There are numerous different ways to utilise solid biomass as fuel in an energy conversion process. Most commonly for electricity production is a direct-fired system to produce steam that, via a turbine, powers a generator. The technologies (combustion and power generation) constituting such a system are well-known and developed. The energy efficiency is limited by temperature and pressure of the steam (which, in turn, is dependent on fuel type, fuel quality, components and plant size). Size of bio energy combustion plants are typically in the range of 20-50 MW, which, compared to most traditional coal-fired plants (often in the range of 100-1500 MW), is relatively small scale generation. In practice, the energy efficiency is limited in small plants due to economic trade-offs: energy efficiency improvements tend to have difficulties paying off them selves. There are technologies to boost efficiency above 40%, but most plants are approximately around 20-30%. Co-firing of biomass in a coal plant is both a low-cost and energy efficient process; biomass may substitute a portion of the coal fuel in an existing conventional coal plant and thereby benefit from the large scale production with efficiency somewhere in the range of 33-37%.

Another high-efficiency option is a combined heat and power process (CHP) that puts to use heat, which usually is a by-product often released to the air; the overall fuel efficiency may be as high as 75%, or even higher. Plants localisation is though limited to be fairly close to end-users of heat[3]. Produced electricity is, however, easy to distribute to either dedicated industrial applications, local distribution or sold on the electricity market.

As mentioned above, biomass combustion technologies are well-known and proven. Large-scale utilisation of biomass is rather a question of having (local) access to sufficient bio-resources[4]. Associated costs of biomass generation is mainly dependent on the size and type of combustion technology, system investments needed (changing fuel in existing plants or invest in new), annual electrical output and the cost of biomass fuel supply. Waste products from forestry or agricultural industry or municipal wastes are common options as fuel and,

[3] The losses of heat distribution in pipe-lines limit the use of CHP to either high dense populated areas (district heating) or as a direct input to an industrial facility.

[4] Top three biomass using countries in the EU-15 is Finland, Sweden and Spain respectively; all having large national bio resources in terms of forests, agriculture etc.

compared to wind and solar energy, possible to storage. Hence, bio power is suitable for base-load duties in an energy system.

While biomass power is $CO_2$-neutral, all combustion emits harmful gasses and particulates to a varying degree depending on, among others, fuel type and quality. There are various end-of-pipe technologies to reduce these.

### *2.1.2 Wind power*

Schematically speaking, wind mill consist of the following principal components: a rotor, generator, directional system, protection system and a tower, which of neither is in essence a ‘new’ technology per se. Most of the components, as materials for blades, generators, gear boxes, bearings etc., have, even though in slightly different shapes, been developed and tried out in other industrial applications. Recent developments in the wind power industry are, no doubt, towards larger wind mills and off-shore installations. Every new generation has become larger than its proceeding one measured in either rated capacity or rotor diameter; installed capacity per wind mill has increased with almost a factor 100 since the early 1980s (e.g. ‘first generation’ of Danish wind mills were equipped with either a 15 kW or a 30 kW generator)[5] and the diameter on blades has increased approximately ten fold (from 10 m to around 100 m). The average capacity of wind mills has e.g. in Germany increased from 473 kW in 1995 to 1395 kW in 2002. Following this trend, average energy output has increased from about 400 kWh per $m^2$ and year to close to 900.[6] Generation costs have fallen with approximately a factor ten in Denmark (from about DKK 1.1/kWh at 1981 to DKK 0.4/kWh at 1995) and investment costs by 35% in Germany during the period of 1990-1999. Hitherto, cost reduction has been achieved through the up-scale of turbine sizes, but economies of scale and additional learning effects will prove important as well in the future with increasing production volumes. Further technology related cost reductions can be expected through the use of flexible blades, flexible hubs and variable speed-generators that lead to lower weight and lower machine costs. The number of components in a wind mill may also be reduced and a certain development of stronger materials and better internal damping is to be expected.

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[5] Parallel to this trend, there is also a growing market for small-sized systems directed to, primarily, development countries and remote installations where capital costs are kept to a minimum.

[6] Considering that the ‘fuel’ of wind power is free, the energy efficiency in itself is not of prime concern. Instead, the productivity which affects costs of generation is.

Albeit the up-scale of wind mills have some growing pains appear in sub-components as gear boxes, bearings, servo mechanisms etc., the greatest technological challenges is perhaps not inherent in the technology itself. Rather, in the integration to the supporting infrastructure, i.e. the grid. The issue is two fold. Firstly, on the short-term, wind power is based on natural forces and cannot dispatch power on demand; the power production varies greatly over time. Such fluctuations affects the quality of the grid network, but may be countered by variable-speed turbines, electrical flow controls and supplemental generation. However, a more long term issue is coupled with the affects on both regional and national grid networks when the total installed capacity of wind power (intermittent power) exceeds a certain level. In Denmark and some regional networks in Spain and northern Germany with penetration rates above 15 % have already been having some issues with the grid reliability. Exactly what local conditions that determine what level of wind power will cause trouble to the network is rather unknown and need more research to increase the knowledge.

Actual energy output from wind mills is obviously dependent on local wind conditions. In an optimisation process, localisation of mills is as important as technological advances. Hence, there is an increasing interest of off-shore installations; which, despite of expensive installations, services etc., have potentials of generating high profits. Off-shore wind farms are essentially a derivation of on-shore technology but tend to have larger turbine sizes. Hitherto installation developments are focused on shallow waters with bottom mounted structures. Mono-piles driven down into the seabed does currently provide the most economic and technologically feasible method.

### *2.1.3 Photovoltaic*

Photovoltaic (PV) technology is used in as far raging applications as providing satellites, households and pocket calculators with electricity, and can be used either as stand alone units or connected directly to the grid. The flexibility is derived from the modularity of the PV technology, which can be used in virtually any size and scale, even integrated directly into building materials for housings etc. Photovoltaic cells are interconnected and encapsulated in a transparent material, most often glass, and placed on a backing material to form a solar PV module. The typical installation capacity for a module designed to energy applications is in the range of 50-200 W. It is possible to connect any amount of modules, either in series or parallel, to provide the desired electrical output depending on situation. The PV technology is very reliable with a failure rate of one in 10000 per year, and an expected life time of about

20-30 years. Sub-components as inverter (converts electricity from DC to AC) and batteries have to be replaced more regularly.

The big breakthrough for large scale grid-connected power production is yet to come. PV modules available on the market today have an overall efficiency varying between 6-15% and are predominated by crystalline silicon (c-Si) cells (85% market share in 2002). They have a proven reliability and (relatively other PV technologies) high efficiency, but requires a comparable large amount of materials and a need for purity that drives costs of modules up. The dominance of crystalline silicon cells is expected to last in the coming years and not to be challenged until the thin-film cells, which are anticipated to be far less expensive, to develop in the medium to long term.

PV technology, no doubt, has a huge potential to play a dominant role in future global energy system - the total energy of incoming sun radiation is in the approximate size of 10000 times the global energy demand. Current generation costs per kWh are, however, roughly 10 times above competing energy technologies. Present learning curves indicate, however, a cost reduction of PV cells of about 20% (18-23%)[7] for every doubling of volume produced. Mass-production and continued R&D efforts are expected to significantly reduce investment costs, which are high, compared to other RETs. While capital costs to a large extent determine costs of generated kWh, the energy output of an installation is an important cost factor as well. It is, naturally, dependent on the amount of available energy (in addition to the energy efficiency of the PV module), i.e. sun radiation, and thereby the geographical location.

## 2.2 The RET market

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 and Spain currently have 10 or less companies represented on the

[7] Andersson and Jacobsson, 2000

national electricity markets, while, for example, Denmark, Italy and Austria have more than 1000 each. 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 EU member states. 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.

### 2.2.1 General development of the European electricity sector

The demand for electricity in EU is growing, albeit at a lower pace compared to the levels of 1960s and 1970s, which showed annual growth rates of 8% and 4%, respectively. The rate fell to 2.6% in the 1980s and further to 1.8% in the 1990s. The growth in energy demand during the 1960s was mainly satisfied with oil-fuelled power plants (figure 1). The next two 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 do still only contribute marginally to the total electricity production (less than 3.6% in 2002).

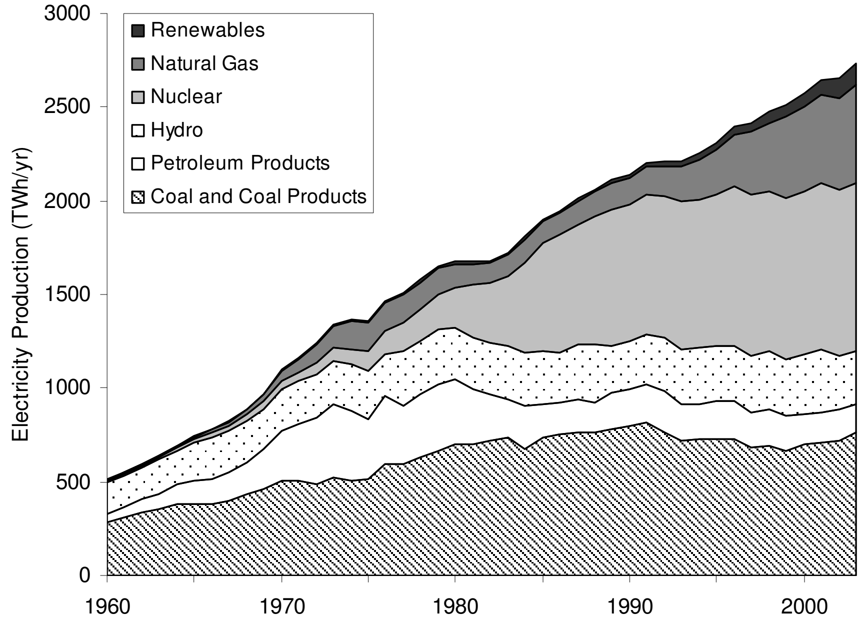


**Figure 1.** Electricity production in EU-15 1960-2003. Source: Data from IEA 2006

During 2003, investments in new generation capacity equalled to about 9000 MW in EU-25, which of 7000 MW was from renewable energy sources (see figure 2.). About two thirds of the growth in RETs originates from new installations, wind power in particular, in Germany, Spain and UK. In the same period, investments in fossil energy technology equalled approximately 330 MW and 1600 MW in 'others' (mostly hydro).

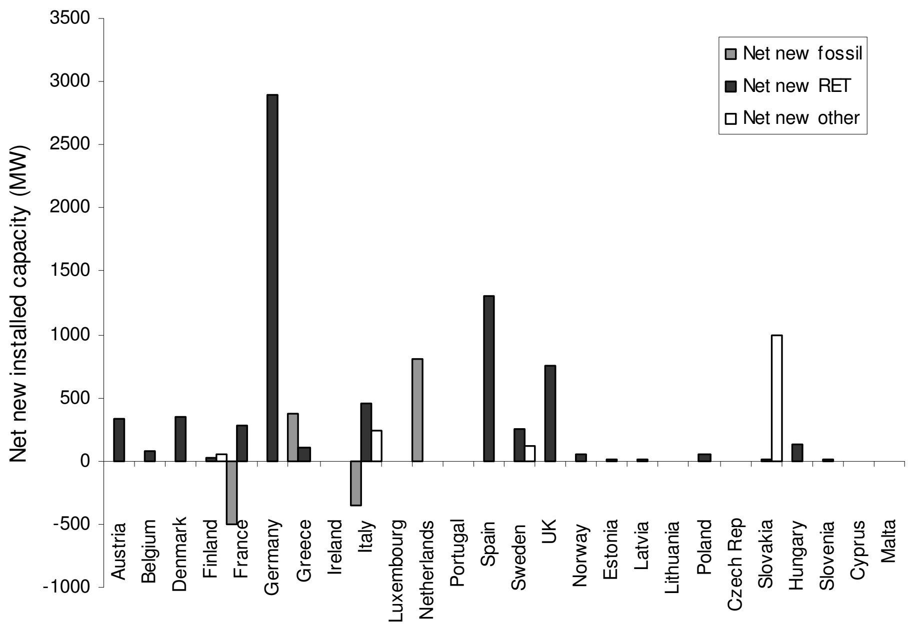


**Figure 2.** Net addition to new European (EU-25) electricity generation capacity in 2003, comparing the contributions from fossil, RETs and other sources respectively.

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.[8] Assuming a certain degree of decommissioning of nuclear plants and a growth in electricity demand of 1.4% per year, a large gap emerges between demand and supply. This has to be filled with new advanced fossil technologies or renewables or be reduced in size by accelerated 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.

[8] 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).

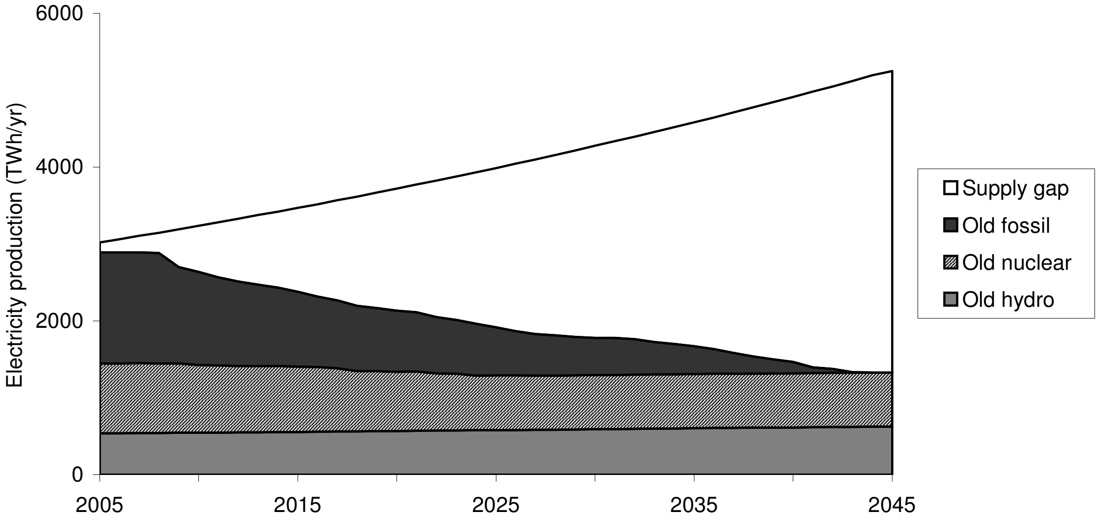


**Figure 3.** Scenario for future European (EU-15, Czech Republic, Norway, Poland and Switzerland) electricity production, indicating the need for new investments. (Kjärstad and Johnsson, 2004)

### *2.2.2 Diffusion of RETs*

In the period of 1990-2002, the share of RETs in the European energy sector increased from 4.8% to 5.5%. Specifically in the electricity sector, during the same period only a marginal increase of RETs was 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 biomass, wind and photovoltaic have relative shares of 10.9%, 9.2% and 0.064% respectively. As indicated in figure 4., the average growth rates of photovoltaic and wind power is very high (above 30% per year) while electricity from biomass grows at a more moderate speed.

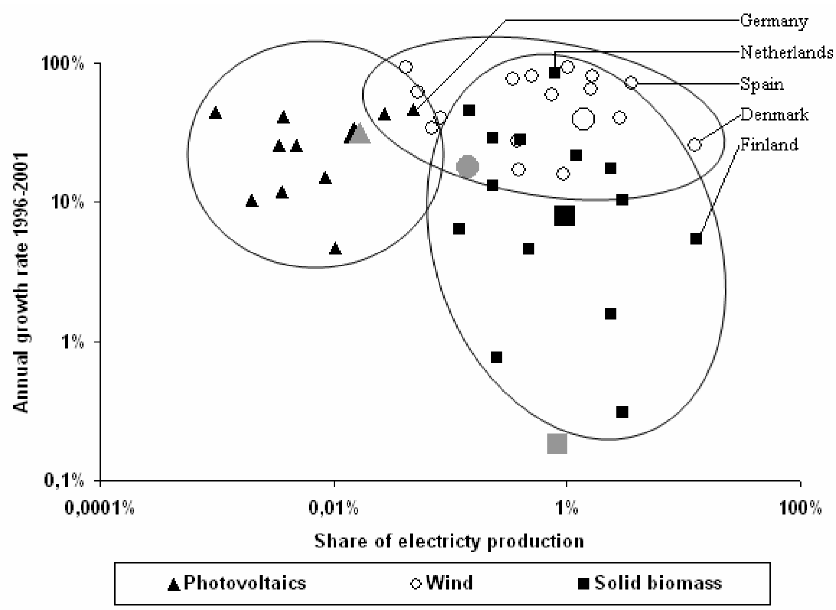


**Figure 4.** Annual growth rates and relative shares of national electricity production are shown for photovoltaic, wind and solid biomass in the EU member states. Note that large bold and grey symbols indicate average values for the EU (bold) and the remaining OECD countries (grey) for respective technology.

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 have been dominating the biomass usage - constitute more than half of the electricity produced from solid biomass in the EU; however, since 2002 there have been significance increases outside these top-three states (as seen in figure 5.). 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).

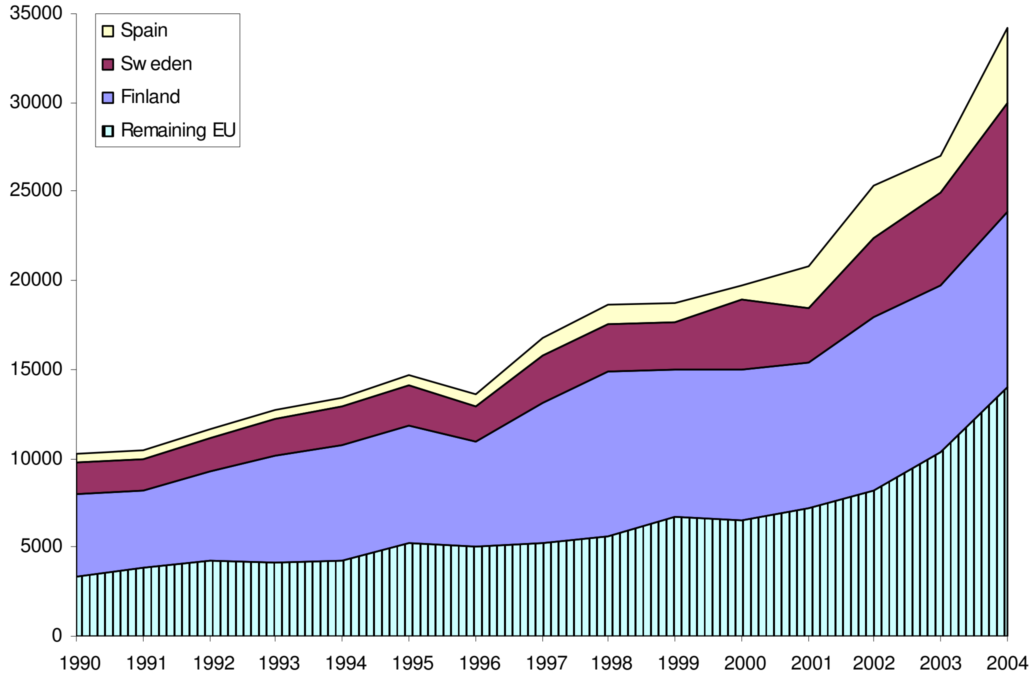


**Figure 5.** Electricity production from solid biomass in the EU-15 during 1990-2004, showing the three main contributors and the remaining EU (GWh/year). Source: data from IEA 2006

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 of wind power in the electricity system 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) and is currently dominating European wind power deployment.

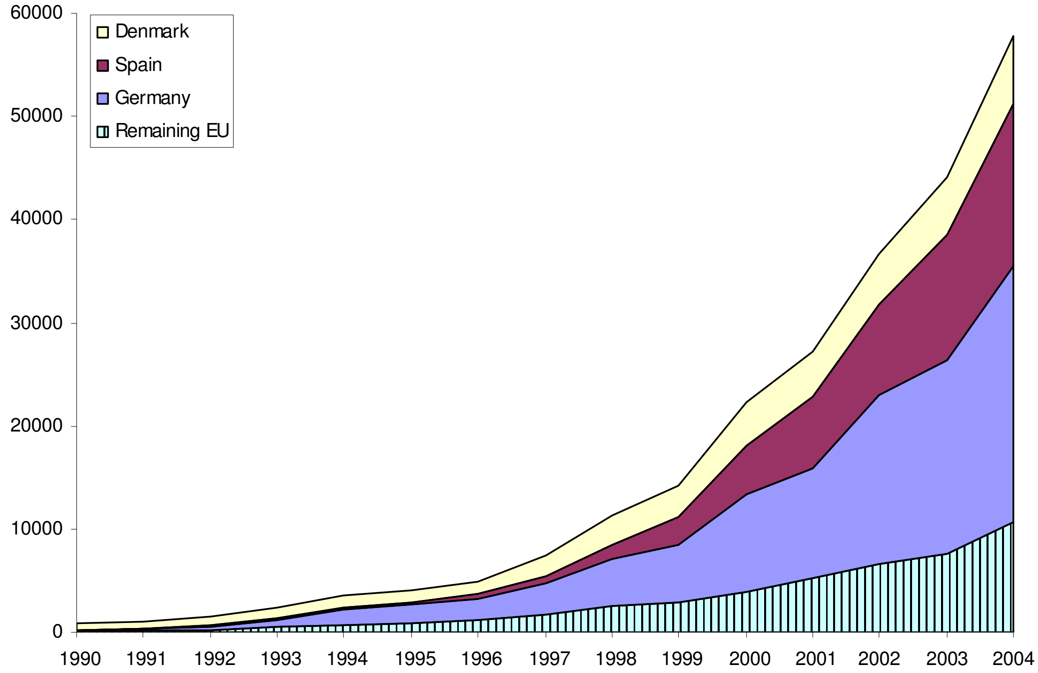


**Figure 6.** Electricity production from Wind Power in the EU-15 during 1990-2004, showing the three main contributors and the remaining EU (GWh/year). Source: Data from IEA 2006

Photovoltaic 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 photovoltaic by a factor of three, and produced in 2002 about 70% of the electricity form photovoltaic 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).

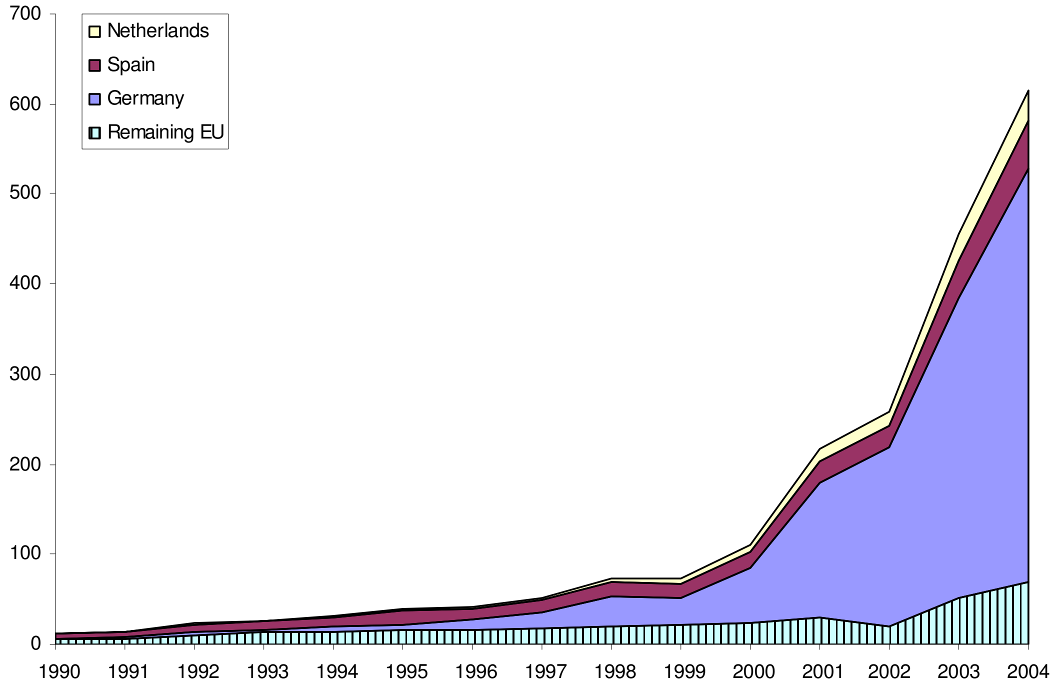


**Figure 7.** Electricity production from Photovoltaic in the EU-15 during 1990-2004, showing the three main contributors and the remaining of EU (GWh/year). Source: data from IEA 2006

# 3 Current state of RET supporting systems

## 3.1 Kyoto Protocol

No doubt a major influence on the global energy sector, the Kyoto Protocol was adopted in 1997 by the 3rd Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) as a first international effort to cope with global warming and climate change. The Kyoto Protocol commit industrialised countries (Annex I) to reduce their collective emissions of six greenhouse gases[9] (GHG) with 5.2% compared to the levels of 1990 by 2008-2010. To lower the overall costs of reaching the targets, the Protocol permits the use of three market-based "flexible mechanisms", based on the in-sight that reduction costs vary greatly from region to region, while the benefits to the atmosphere and climate are the same wherever the action is taken.

- *Emission trading* allows Annex I countries with less GHG-emissions than their respective national target to sell the remaining part as a permit for emission.
- *Joint Implementation* (JI) allows Annex I countries to be credited for emission reductions achieved by investing in projects located in other Annex I countries.
- *Clean Development Mechanism* (CDM) allows Annex I countries to be credited for emission reductions achieved by investing in projects located in developing countries (non-Annex I) under specific conditions (defined in the Protocol).

The European Union has agreed upon lowering its total GHG-emissions with 8%. According to the agreed burden sharing, the overall EU reduction target is translated into national GHG-targets for each member state. The national reduction levels have been proposed in the "Directive on the promotion of electricity produced from renewable energy sources in the internal market" (ref (2001/77/EC), see 5.2.2), based on the percentage of each country's consumption of electricity.

Even though the United States has chosen not participate, the Protocol is still an important statement from the international community and its commitment to reduce global warming, and a major driver for RETs with significant impact on regional and national policy efforts.

[9] $CO_2$, which is the most important one, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

## 3.2 EU policy guidelines and initiatives

The broader policy work carried out by the European Commission targeting electricity generation from RETs is primary driven by three factors: to reach the Kyoto and sustainability targets, to ensure a security of energy supply, and to boost European competitiveness and economic growth. The following section will introduce those general policies and directives of most significance to RETs and electricity generation.

### 3.2.1 White and Green Papers

Although not legally binding, the White and Green papers are important tools for the European Commission to communicate policy guidelines to the Council, Parliament, institutions, member state governments and the business world in general. Depending on the following debate and the degree of compliance they may further down the line affect the regulative and legislative settings.

*"Energy for the Future: Renewable Sources of Energy"*[10]

In 1997, the European Council and the European Parliament adopted the White Paper "Energy for the Future: Renewable Sources of Energy". The general objective was stated as: *"Renewable energy sources may help to reduce dependence on imports and increase security of supply. Positive effects are also anticipated in terms of CO2 emissions and job creation. Renewable energy sources accounted 1996 for 6% of the union's overall gross internal energy consumption. The union's aim is to double this figure by 2010."* Specifically for electricity production, a share of 22% RETs was set and complemented by indicative targets of 1 000 000 PV systems, 10 000 MW of installed large wind farms and 10 000 MW of biomass fuelled power installations to be reached by 2010.

*"Towards a European Strategy for the Security of energy Supply"*[11]

Five years later, in 2002, the Green Paper "Towards a European Strategy for the Security of Energy Supply" (ref) was published, where the Kyoto Protocol commitment and the target of the White Paper on renewable energy sources, to double the share of renewable energy sources by 2010, were further pointed out. At core topic in this paper was, however, the European Union's dependency on imported energy to cover its demand. The fact that 50% of

[10] COM(97) 599 final
[11] COM(2000) 769 final

current energy supply is imported and is expected to increase even further (the same figure is about 80% when including the new member states) was highlighted. To ensure a secure supply of energy and a sustainable development for the European citizens, the long-term strategy for the EU was pointed out as to increase the level of internal energy supply and, preferably, from renewable sources of energy.

*"A European Strategy for Sustainable, Competitive and Secure Energy"*[12]
To be continued…

### 3.2.2 Directives

The main instrument of the European Commission to force regulations is through directives; environmental regulation is no exception. In the following, the main directives for RETs and electricity generation are listed and shortly presented.

*"Directive on the promotion of electricity produced from renewable energy sources in the internal electricity market"* (2001/77/EC)
The main purpose of this directive, launched in 2001, is to promote an increased use of electricity produced from renewable energy sources and to create a basis of a future Community framework in support thereof. The directive includes a proposal on share of RETs in the individual members states by 2010 (see figure 8.) with the aim to comply both with the Kyoto-bindings as well as with the 22% RET share in EU electricity market stated in the White Paper "Energy for the Future: Renewable Sources of Energy". Although not legally binding, it seems that the national targets are generally accepted among the member states. The member states are obliged to report on the progress of implementing the targets, but may until 2005 chose the kind of measures and incentives necessary for implementation. Although the directive does not indicate which instruments that should be used to reach the targets, among the most relevant ones is the establishment of an EU-wide market for tradable green certificates (TGCs).

Grid access is regulated in the directive and prescribes member states to ensure a non-discriminating treatment of electricity generated by renewable energy sources. Member states are advised to put up a legal framework or make visible standardisation to the bearing of costs

[12] COM(2006) 105 final

of grid connection and reinforcement, which of the latter is of importance to any remote power installations.

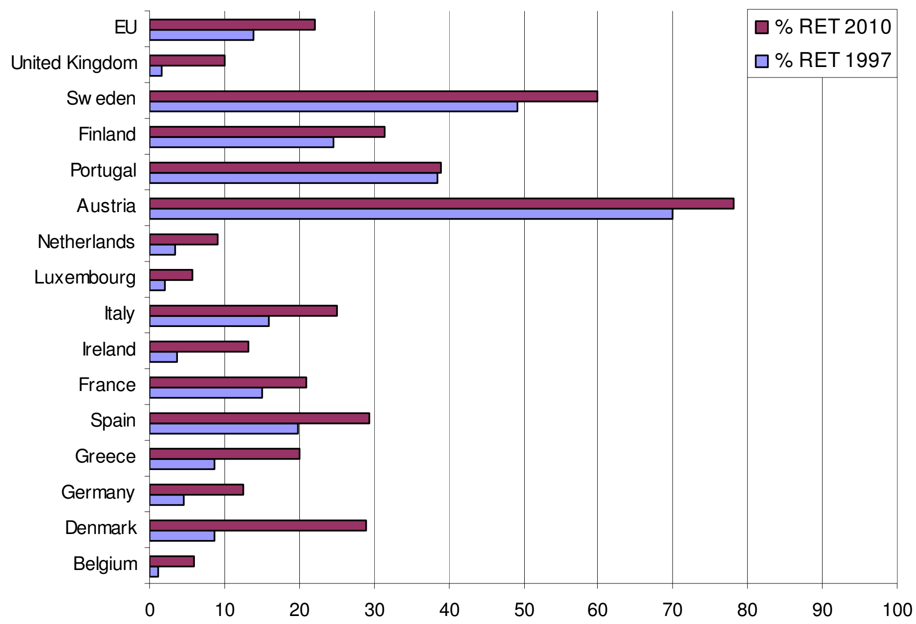


**Figure 8.** Reference and indicative national targets to comply with the 22% RET by 2010 and the Kyoto-bindings.

Another important mechanism in this directive is a requirement of implementing a "guarantee of origin" on member state level. To ensure consumer transparency and facilitate trade with renewable electricity there must be a clear distinction between electricity from renewables and non-renewable energy sources visible for market actors. Hitherto (September 2005), 9 of the 25 member states have fully transposed this mechanism into national legislation and put in place necessary governing bodies that will issue the guarantee of origin.

*"Directive concerning common rules for the internal market in electricity and repealing Directive 96/92/EC"* (2003/54/EC)

The directive on an internal market for electricity from 2003 launched a rule set to prepare for a common internal market for electricity within the European Union, where generation, transmission, distribution and supply of electricity are targeted. The directive is of importance to RETs mainly in the respect that it states national regulatory conditions for connecting new power generation as: *"taking full account of the costs and benefits of the various renewable energy sources technologies, distributed generation and combined heat and power."*

Additionally, a single internal market in Europe is a necessary prerequisite for implementation of EU-wide market based supporting schemes in the support of RETs, as e.g. TGCs. In general, efficiency gains, price reductions, higher quality of services and increased competitiveness are believed to be enhanced through an internal common market.

### 3.2.3 The European Union Emission Trading Scheme

Abatement costs of GHG-emissions vary among industrial installations. Hence, complying with the Kyoto-bindings should, to keep costs at a minimum, be taken where it is least costly to reduce GHG-emissions. This is the underlying principle of an emission trading scheme, which is one of the flexible mechanisms agreed upon under the Kyoto Protocol. The European Union Emission Trading Scheme (ETS) was implemented in 25 European countries in January 2005 as a key instrument to achieve compliance with the Kyoto target (8% GHG-reduction by 2008-2010). The scheme involves over 9000 energy intensive installations across the EU, which all have received specific quotas for GHG-emissions that may be traded both nationally and internationally. A net importer of quotas (or permits) a country may increase its GHG-emission beyond the national target, and vice versa for a net exporter. There is a penalty attached to those installations exceeding their specific share of emission allowance.

The scheme is still in early implementation and any significant impact on the EU business, industry and consumers has not yet emerged; the same with the potential impact, where both official and academic opinions differs. Costs of the permits (tonne $CO_2$) are, of course, the key issue. There is research indicating that the price needs to be as high as € 30 to reach the planned targets[13].[14]

### 3.2.4 European Photovoltaic Technology Platform[15]

The European Commission has encouraged stakeholders in the EU industry to form technology platforms where Europe's future growth, competitiveness and sustainability objectives are dependent on research and technological advances.[16] By mobilising actors from industry, national and regional authorities, and foster public-private partnership in technology research areas with a high industrial relevance, platforms are believed to significantly

[13] Current spot price as of 051209 is at €21/t$CO_2$ (http://www.climatecorp.com/pool.htm)
[14] Pelkmans, 2001 (L.N Haar & L Haar, 2005)
[15] http://www.eupvplatform.org/
[16] COM (2004) 353

contribute to the renewed Lisbon Strategy. The platforms will, however, mainly be self-funded; the gains will emerge from the momentum of collaboration and formation of alliances strong enough to tackle major R&D-challenges.

A platform dedicated to PV technology was recently launched aiming at: *"mobilising all the actors sharing a long-term European vision for photovoltaic; realising the European Strategic Research Agenda for PV for the next decade(s) and give recommendations for implementation; ensuring that Europe maintains industrial leadership."* The initiative is an effort to gather actors and stakeholders within the PV industry to strengthen networking and define common future R&D tasks with the goals of:

- Contribute to a rapid development of a world-class cost competitive European PV for a sustainable electricity production.
- Involve stakeholders in the formulation of research programmes.
- Ensure strong links and coordination between industry, research and market.
- To implement the strategic plan.

## 3.3 National policies

Since the implementation of the Kyoto Protocol, all EU member states have indicative targets to the share of RETs in the national energy systems by 2010. There are examples of member states with national RET policies reaching beyond the Kyoto commitments. Those EU countries with a relative high growth of RETs all have a strong national political support. National supporting schemes for renewable energy technologies and the electricity sector are currently well-established across the EU-15 (see table 1.). Every member state utilises, or has utilised, some combination of price support through feed-in tariffs, green certificates or competitive tender, together with investment subsidies, R&D-support and fiscal measures.

**Table 1.** Present (x) and current (h) supporting mechanisms in the EU-15.

| Country | Capital subsidies | Feed-in tariffs | Certificates/ Obligations | Competitive tender | Fiscal mechanisms |
|---|---|---|---|---|---|
| Austria | x | x | h | | x |
| Belgium | x | x | x | | x |
| Denmark | h | x | | | x |
| Finland | x | | | | x |
| France | x | x | | h | x |
| Germany | x | x | | | x |
| Greece | x | x | | | x |
| Ireland | x | | | x | x |
| Italy | x | h | x | | x |
| Luxemburg | x | x | | | |
| Netherlands | x | x | x | | x |
| Portugal | x | x | | | x |
| Spain | x | x | | | x |
| Sweden | x | | x | | x |
| UK | x | | x | h | x |

Source: EEA Briefing No 2/2004

### 3.3.1 Marked based instruments

*Carbon and energy taxation*

External costs of energy supply and use (costs of environmental damage, global warming, health etc.) may be internalised in prices through taxation. This has been discussed on an EU-wide level, but proved very hard to find any acceptable solution for the parties involved. On the national level, however, the majority of EU member states have some taxation on energy implemented as an instrument to comply with the national $CO_2$-reduction targets. The designs vary; they may be levied on energy use (both heat and power), power or heat generation, or $CO_2$-emissions. Energy taxation act in favour of RETs primarily because of the increased competitiveness of carbon neutral technologies against fossil based ones, the increased incentives for energy efficiency measures and the increased incentives to develop new carbon-neutral energy technologies. Raising prices of energy is often regarded as controversial and opposed by the claims of a decreased competitiveness and loss of jobs.

Energy taxation has been used in Sweden since 1950s and, even though the arguments at that time mainly concerned finance of the social welfare, and not the environmental aspects, has later on been complemented with a specific taxation on carbon emissions. The Swedish system is, however, quite complex with a numerous of exceptions in which several industrial activities have been partially or fully exempted. Regarded as a necessity to withhold standing international competitiveness, energy-intensive industries as paper, pulp and steel are all liberated from paying the carbon tax. The introduction of energy and carbon taxation has, in particular, helped both biomass district heating and biomass heat and power to expand considerably. The fossil-based options where made more expensive and thereby increased the competitiveness of RETs, as they are excluded from the tax.

Denmark was relatively early with implementing an environmental tax. From 1992 and onward users of energy were charged a $CO_2$ tax, with some of the revenues given back to generators of renewable electricity.

*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 PV. All new RET installations were guaranteed these tariffs during a 20 year period. PV has, since the implementation of this law, grown significantly and the industry as a whole been strengthened through increased specialisation in module manufacturing and adaptation of buildings.

Similar systems with fixed tariffs RET electricity generation can be found in Spain and Austria. 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 PV, 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.

*Tradable Green Certificate (TGC)*

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 and compared with the ongoing German feed-in-law system. There are plans on implementing a common union-wide market based instrument in a future liberalised European electricity market.

The underlying principle of TGC 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 predetermined share of total electricity consumption as green electricity. Thereby a demand of RET is guaranteed according to 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 TGC system. The main concern is regarding the possibilities of governing technology 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. The annual share growth is often not planned beyond 2010 as with the Swedish case, which raises a high degree of uncertainty for potential investors. Furthermore, RETs close to commercialisation will most likely be favoured over others, as a direct result from the induced competition. There is a risk that only minor incentives will exist to invest in emerging new technologies, which may be crucial in achieving long term goals, and that they, consequently, could be locked out.

*Competitive tendering*

Competitive tendering is based on a bidding procedure, where suppliers are invited to compete for governmental contracts to generate renewable electricity. The contract obliges the winner to install a fixed amount of RETs for operation. This approach has been used in UK, and currently is in France and Ireland, but often failed to cover the capital costs for the successful bidder in the investment of the new generation capacity. The current trend indicates a replacement of the competitive tendering system in favour of other support mechanisms as above mentioned feed-in tariffs and green certificates in France and Ireland.

### 3.3.2 Financial support

In the early stage of diffusion, financial support to new technologies is vital to facilitate development, market penetration and growth. It is a necessary complement to the market based instruments which are primarily beneficial for technologies close to being economically viable. Some level of financial support, usually through grants or favourable loans, are available to manufacturers and generators of RETs in almost all EU member states as a tool to reduce costs of RD&D, investments or operations.

*Investment subsidies*

Direct investment subsidies have been the prime choice of support mechanism available to RETs in the Swedish energy policy during the 1990s. In 1991, an investment grant targeting wind power investments was implemented, covering 25% of total investment costs. Two years later, the level of support was increased to 35% but limited in availability and distributed on a first-come first-serve basis. Thereafter followed a period with no subsidies until new funding had been raised in 1997 of a total of 300 MSEK (about EUR 32 millions), but on a reduced level of 15%. This new subsidy was by 2002 granted to 374 turbines, equalling an installed capacity of 290 MW. Investment subsidies were also available during this period for electricity produced from biomass; introduced in 1991 at a level of 4000 SEK/kW[17] of installed generation capacity. Plants had to use at least 85% of biomass fuels for a period of five years in order to qualify for the grant. The allocated funds were exhausted in 1994, when altogether 16 CHP plants in total had received support. The subsidy was not reintroduced until 1998, but at a reduced level of 3000 SEK/kW installed capacity.

In both Germany and Spain have investment grants been powerful tools to boost the high penetration of PV installations showed in the 1990s. In 1991 the German government introduced its 1000 PV roofs programme, where 50% of investment costs were covered. The programme was ended in 1996/97 and had successfully supported more than 2200 installations with a total capacity of 5.3 MW. This was in 1999 followed by the rather

[17] Equalling about EUR 420 at current exchange rates.

ambitious 100 000 PV roofs programme, but with a 30% investment support, and which further decreased to 15% in 2002. This new programme did, however, also include favourable loans with an initial interest level of 0%.

No doubt have the German PV investment support scheme succeed on a level far greater compared by any other European country during the same time period. Even though the level of support was lowered in 1999 and 2002, the amount of PV installations grew steadily. Due to the sheer amount of new installations, both investment and operation costs dropped considerably and, hence, the allocated subsidies could be reduced. To explain the German growth of both wind and PV installations, there are additional success factor than the investment grants, as the general political support at national and regional level and the feed-in law. Still, the progressive support to investment has played a crucial role.

### 3.3.3 Administrative

Public acceptance at the local level has proven an important factor to consider when prospecting for RETs projects; wind farms in particular. This and other measures have been identified by some regions and countries to ease the planning process and, thereby, speed up the diffusion:

- Some regions in Germany have dedicated appropriate sites for wind farms.
- Ireland has developed a wind energy atlas to support regional planning of wind.
- Swedish Energy Agency has suggested areas suitable for wind energy deployment.
- Strong promotion of local and regional authorities in Austria for biomass CHP and solar electricity production.
- Spain has induced a collaboration among local, regional and national authorities involved in the planning process of RET installations.

# 4 Barriers and drivers

On a broad societal level there are two main drivers to adoption of RETs: climate change and security of energy supply[18]. It is well-acknowledged by European politicians, academics and business world that to combat global warming and to ensure less dependency on import of energy from political unstable parts of the world, large-scale adoption of RETs is a crucial tool. Still, the EU is struggling to reach its objective of 12% renewable energy of the total energy supply and 21% of green electricity, both to be accomplished by 2010[19]; several member states is having a hard time to comply with their national Kyoto-bindings[20]. Thus, RETs is currently not disseminating at the preferred rate by society, which is explained by the presence of barriers to diffusion and adoption.

## 4.1 Barriers and drivers – overview

Barriers discourage consumer purchases and, consequently, market growth. From a policy design viewpoint, understanding the significance and nature of barriers is essential in the construction of efficient supporting schemes to induce successful market penetration.

In the context of this project, barriers and drivers are mainly analysed from a stakeholder perspective, i.e. the identification of driving and inhibiting forces for firms to engage in the development and adoption of RETs. This section will present significant barriers and drivers to adoption and diffusion of RETs found in the work carried out in WP1 (research and literature overview) and WP2 (stakeholder interviews and questionnaire study) and is discussed relative the policy instruments already implemented. Generally, the discussion is carried out for the technology cluster of RETs as a whole except those barriers and drivers that are deemed as technology specific.

The questionnaire analysis is carried out at an aggregated European level, generalising national difference in regulatory and institutional settings, culture, availability of natural resources and other factors affecting the driving and inhibiting forces of RET adoption. The

[18] Security of energy supply refers to two prime issues: firstly, to the unstable political situation in the Middle east and its consequences on oil prices and availability, and, secondly, to the fact that less and less new resources of conventional oil are found at the same time as demand increases. Hence, a domestic energy production based on domestic resources is desirable.
[19] European Commission, com(97)599 final
[20] 10 out of 15 EU member states are at risk to not reach their national Kyoto-targets by 2010 (IPPR, 2005).

questionnaire design and analysis is based on a behavioural approach, modelling the specific willingness of firms to engage in the development and adoption of RETs.[21]

**Table 2.** A summary of the identified barriers and drivers for RETs.

| Technology | Short term barriers and drivers | Long term barriers and drivers |
|---|---|---|
| **Wind power** | • Acquiring of building permits (lengthy process, complicated regulations, easy to appeal) (I, L)<br>• Technical performance (noise, shadows; large off-shore mills: bearing, gearbox etc.; high service costs) (I)<br>• Environmental performance (off-shore: affects on local marine eco systems?) | • Grid access (off-shore) (L, I)<br>• Grid affect (high ratio WP – unknown affects on a regional/national grid system)<br>• Uncertain investment responsibility of grid enlargement/upgrade (off-shore and remote) |
| **CHP (bio fuelled)** | • *Low costs relatively other RETs (when changing fuel in existing CHP plants) (L, I)*<br>• Technical issues (related to quality in fuel) (I) | • Conflict of interests in land/biomass usage (food, paper, energy etc.) |
| **Photovoltaic** | • High costs (I)<br>• Lack of tech. development (need improved price vs. performance, inverters life time ~10 years) (L, I)<br>• Cultural barriers (appearance on houses/buildings) (I)<br>• Lack of knowledge (integration in buildings, urban planning etc.) (L)<br>• "First" costs optimisation (primarily for residential usage) | • Material constraints (high efficiency ~ scarcer materials) (L)<br>• Environmental performance (LCA: PV modules often contains heavy metals)<br>• Grid access (remote installations)<br>• *Economies of scale (vast room for cost reduction ~ dissemination)* |
| **RETs in general** | • High costs (relatively incumbent energy tech.) (L, I)<br>• Tech. uncertainty (performance, standardisation, services etc.) (L, Q)<br>• Economic risk (dependent on supporting schemes) (L)<br>• Lack of long term design in supporting schemes (I)<br>• Lack of knowledge-transfer/networking (Q)<br>• *$CO_2$ neutral (L, I, Q)* | • Lack of long term design in supporting schemes (I)<br>• Regulative uncertainty (pace of phasing out nuclear power) (L)<br>• *$CO_2$ neutral (L, I, Q)* |

* Source; L=literature, I=Interviews and Q=questionnaires. Drivers in *italic*.

### 4.1.1 Economic

Costs of producing electricity from RETs have been greatly reduced during latest decades but are generally still above the ones of fossil fuels; in particular PV technology that is, roughly,

[21] Montalvo 2001, 2002 and WP2 case study report for further reading of the model theory and questionnaire study.

10 times as expensive as average generation costs.[22] The inability to include environmental damage costs of electricity generation (combustion of fossil fuels, nuclear power plants or even renewable technologies), the vast amount of direct or indirect subsidies, tax concessions etc. (figures!!) all distort competition on the energy market. This is resulting in increased consumption of fossil energy and increased environmental degradation, where RETs otherwise would be competitive. Even though most member states currently utilises some level of energy or carbon dioxide taxation, one could argue that the lack of *internalisation of external costs* in energy prices constitutes the major obstacle to wide-spread market penetration of renewables. Excluding some niche utilisations (off-grid installations e.g.), RETs are in most cases not able to compete with the incumbent technologies without some supportive measures as feed-in tariffs, green quotas, tax exemptions etc. Offsetting the higher costs is a necessity to ensure reliability for investors; from a firm point of view, it is a matter of reducing *economic risk* of investments, as stated by several interviewees.

Traditionally, generators of renewable electricity are small actors for which there have no or few possibilities to reduce risk of projects through balancing internal revenues. Investments must be covered by either venture capital or access to the capital market. Several interviewees and respondents to the questionnaire indicated a crucial need of having supporting schemes giving both an adequate level of return (at least to cover the additional generation costs above market prices) and to be defined long enough to secure early investments (around 15 years).

Whether the economic risk to invest in RETs is perceived as a significant barrier or not is to a large extent dependent on the supportive instruments put in place. The feed-in tariffs systems have rather successfully reduced risk of investments; particularly the German one with technology specific fixed subvention levels (reduced price risk), guaranteed up to 20 years (reduced financing risk). Whereas member states which chosen TGCs as primary support mechanism have to some level succeeded in supporting biomass and wind power rather than PV, but do not provide the same level of economic security in payment returns and longevity. The overall economic risk of investing in RETs is, as perceived by the questionnaire respondents, however, diminishing over time. Accordingly, economy as a driver (profits out of investments) contributing to the willingness of companies to engage is expected to increase in the future.

[22] Average spot market price for electricity in the Eu-15 was in 2004 about 30-35 €/MWh, which can be compared to

**Box 1** *Barriers constituting the economic risk as perceived by interviewees and questionnaire respondents*

- Uncertainty in environmental regulation (Q, I)
- Long time requirements to develop competitive RETs (Q)
- Few business opportunities derived from developing or adopting RETs (Q)

* I = interviews, Q = Questionnaire

### 4.1.2 Market

Demand of RETs is primarily driven by various supporting instruments in place; i.e. the demand is artificial created through either direct 'nursing' measures as a certain renewable share of total electricity consumption (TGC) or with guaranteed payments and outlet for generators (feed-in tariffs). Albeit there are political aspiration targets at EU and national levels, they are regarded as having minor impact to generate demand and new investments. Market inducement offered by generic measures, as the TGC, is inadequate to attract investments in early stage technologies. This is specifically the case of PV technologies in TGC regimes, which are risking to get 'stuck' in a stage between demonstration and pre-commercialisation as a consequence of not being able to compete with more commercially viable renewable options. Thus, access to a crucial niche market is lost and related opportunities to economies of scale, learning by doing/using and building important costumer/partner relationships.

In many member states customers may choose any supplier of electricity according to their preferences. Coupled with guarantee of origin, the spreading of environmental labelling and green pricing mechanisms, retail competition is increasing among suppliers and, consequently, the need to diversify and become more customer oriented is successively becoming an important driving force. This is recognised by many interviewees and respondents and is believed to be an increasingly important factor to derive future market demand. The current willingness of customers – both private and business/industrial users – to pay a premium for green electricity is regarded as rather low, however.[23]

[23] There are, however, some examples of e.g. public transport companies as the Swedish dominating railway operator SJ AB and the tram operator Västtrafik AB advertising their green electricity use as a marketing profile.

On a local level, the job and economic growth opportunities derived from an establishment of local electricity production is becoming increasingly recognised. RETs compared with fossil based technologies are generally more labour intensive and, coupled with increasing recognition of RETs to fulfil national/local sustainability targets, provides an attractive option for politicians and entrepreneurs to promote local business. This is particularly a driver to establish biomass power and, if locally available, biomass resources via crop or forestry industry.

**Box 2** *Significant factors inducing market pressure as perceived by interviewees and questionnaire respondents*

- Competitors are thinking of developing/adopting RETs (Q)
- High future customer pressure to develop/adopt RETs (Q, I)
- Complying with costumer demand (Q)

* I = interviews, Q = Questionnaire

### *4.1.3 Technology and infrastructure*

As described in section 2.1, both on-shore wind power and biomass are in general considered as reliable and mature technologies with well-developed supporting infrastructure in terms of services, maintenance personnel and grid access. Off-shore wind power and PV, however, are at an early stage of development that have not yet undergone same processes of learning and reached same range of complementarities. Several interviewees pointed out performance, power output fluctuations (intermittency), actual power generation costs (factoring in costs of maintenance and service etc.) and lifetime as technological uncertainties and potential barriers to up-take. There is a need for further RD&D (research, development and demonstration) to develop both specific technology characteristic and systemic issues as grid compatibility.

The intermittency and unpredictability of renewable power generation is not only of regulative concern (further discussed in section 4.5) but, as mentioned in section 2.1.2, an infrastructural as well. The varying power output of renewable generation and its consequences to power distribution is a source for controversy and may pose challenges in grid management. While it was earlier believed that even small fractions of intermittent capacity would cause instability on the power grid, new empirical data from practical examples[24] shows that it is foremost a question of grid-management techniques. The issues of intermittency and unpredictability are still though frequently raised concerns on the societal level and is, hence, perceived by several interviewees as barrier to wind and solar power in local and regional planning process.

**Box 3** *Significant technological and infrastructural barriers as perceived by interviewees and questionnaire respondents*

- Importance of supporting infrastructure (service, maintenance, grid access etc.) (Q)
- Lack of technological maturity of off-shore wind and solar power (I)

### 4.1.4 Networking and organisation

Acquiring 'new' knowledge is seen as a central process in innovation[25] where both exogenous and indigenous qualities need to be satisfied. Knowledge is obtained either from firms' internal capabilities (e.g. R&D) or via knowledge-transferring networks (partnerships, universities etc.), and is a necessity in decision-making processes. On average, interviewees and questionnaire respondents regarded their respective capabilities to acquire and facilitate knowledge creation as 'high'. There are some, however, pointing out a lack of necessary skills in the accessible workforce. Especially with regards to increasing internationalisation and competition, trained specialised personnel in R&D and applied engineering are becoming increasingly important resources to firms.

**Box 4** *Significant factors constituting knowledge-acquiring processes as perceived by the questionnaire respondents*

- Ability to identify suppliers and procurement chains for RETs
- Ability to assess the technological feasibility of RETs
- Ability to assemble problem solving teams in the development/adoption of RETs

* I = interviews, Q = Questionnaire

[24] E.g. in western Denmark, over 20% of the total load is covered by wind energy (IEA, 2005).
[25] Ref tex jacobsson...

### 4.1.5 Community

Citizens of EU member states are generally well informed of the environmental and societal benefits derived from RET usage; much due to various public informational and awareness campaigns executed at EU and national levels. Local opposition to RET planning is often based on conflicts in land usage and aesthetics, as opposed to lack of public knowledge and awareness. The former is most of a concern for biomass resource establishments (biomass crop and forestry), where aesthetics is often argued against wind farms, both off and on-shore, and PV installations on buildings. Several interviewees have faced strong opposition from local communities fearing negative affects on marine ecosystems (off-shore wind farms' impact on fishery) or simply statements that wind farms and PV installations on buildings are unattractive. There are some examples of local power companies lobbying against the building of wind power probably due to the potential competition it may pose.[26]

Hence, as reflected in the questionnaire results as well, the community in general is currently not regarded as a driving force to RET deployment, but is believed to be increasingly so in the future.

**Box 5** *Significant factors constituting the community pressure as perceived by the questionnaire respondents*

- High pressure from important shareholders to develop/adopt RETs
- High pressure from regional/local community to develop/adopt RETs within the next five years
- Important to develop/adopt RETs to withhold a good public image
- Opposing groups have the power to delay RET deployment

* I = interviews, Q = Questionnaire

### 4.1.6 Institutional and regulative

Currently, most of the EU member states have national indicative targets for share of renewable energy sources in the energy sector. Even though influential on the policy framework, such political aspirations are not perceived as significant drivers on a firm level, primarily as a consequence of that they are regarded as not sufficiently "bankable" by the

[26] Wang, 2004

investment community.[27] International agreements (Kyoto protocol), EU policies/directives and national environmental authorities do, however, constitute a regulatory pressure to develop or adopt RETs as perceived by the questionnaire respondents. To what extent they are successful or not vary, but a clear majority of interviewees emphasised the inconsistency and lack of time frame in the specific supporting measures currently in place as a concern. Longevity is particularly important to support investments in those technologies at early development stages that are currently not economically viable. This is especially true for off-shore wind and PV technologies in those regimes utilising TGC or various kinds or capital grant mechanisms only defined for a short period of time.

While wind power in general has gained in economic competitiveness, several interviewees mention regulative barriers as, perhaps, the main obstacle to wide-spread diffusion. Issuing building permits is a complicated and time consuming process, where in Sweden, for example, several authorities at various levels are involved at different stages. A projector has to face almost the same process twice against both planning and building and environmental legislation. The coordination between the involved authorities is regarded as not very well-organised and a large room to streamline the processes. Opposing groups may quite easily appeal and delaying the process up to several years, and, thereby, risking the economics of a project. Especially small actors with no internal legal resources may face great challenges in the planning phase of a project.

Even though the EU directive on promoting electricity from renewable resources (further described in 3.2.2) particularly prescribes member states to ensure a fair and a non-discriminating access to the grid at reasonable and transparent prices, the cost-sharing of new installations is still an obstacle in many member states. Particularly off-shore wind power, but remote generation in general, is often situated on such places that grid expansions and upgrades is a necessity. In addition, the intermittency of renewable power generation may require a certain degree of adaptation to grid infrastructure to avoid unwanted power fluctuations. Most member states grid regulations are, however, adapted to distributed power generation close to existing grid networks where new installations have required few grid investments. Lack of transparency and principles regarding cost bearing and sharing pose a high degree of uncertainty to cost estimates of projects.

[27] Grubb, 2003

**Box 6** *Significant factors constituting the regulatory pressure as perceived by the questionnaire respondents*

- EU policies/directives and national environmental authorities have the power to force development/adoption of RETs
- International agreements have significant impact on RET up-take within the next five years

* I = interviews, Q = Questionnaire

## 4.2 Statistical insights from questionnaire study

### *4.2.1 Methodology*

In Work Package 2 of this project, the behavioural approach of Montalvo (2001) is used to determine driving and inhibiting forces of innovative behaviour of firms. A central hypothesis is that the engagement of firms in the development or adoption of a new (cleaner) technology (*I*) can be explained by their leaders' willingness (*W*) to do so, which is determined by a series of domain indexes: perceived environmental risk (*EV*), economic risk (*ER*), community pressure (*CP*), market pressure (*MP*), regulatory pressure (*RP*), technological capability (*TC*), organisational learning (*OL*), strategic alliance formation (*AL*) and networks of collaboration (*NW*), according to the expression:

$$I \sim W = W(EV, ER, CP, MP, RP, TC, OL, AL, NW)$$

Each of these 9 domain indexes reflect the responses to a series of questions with multiple-choice answers on the basis of a 7-point scale, ranging from one extreme of an attribute (e.g. 'very unlikely') to the other ('very likely'). In total the questionnaire contained around 120 questions of which were common to the questions in the other case studies carried out in the POPA project. A schematic illustration of the different levels of explanation of the firm's innovative behaviour is given in Figure 9.

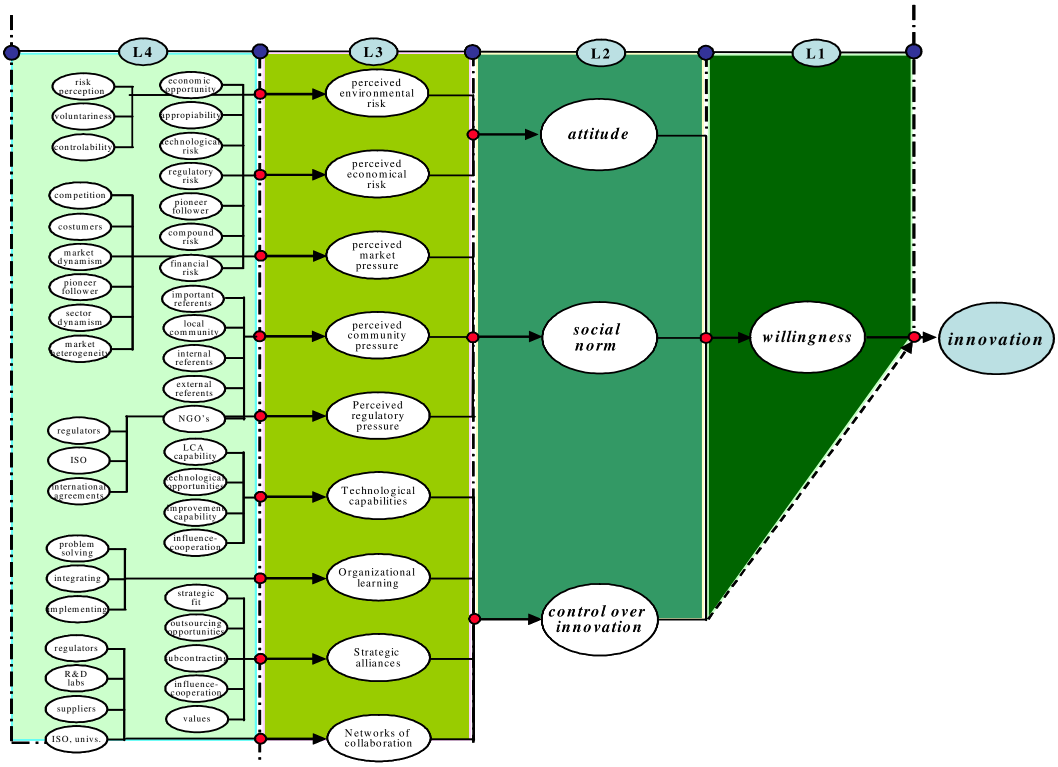


**Figure 9:** Schematic illustration of the levels of explanation of the firm's innovative behaviour.

The questionnaire was distributed in a paper version to 471 actors in the energy sectors in Sweden (141), United Kingdom (75), Germany (75), Spain (75), Netherlands (75) and Hungary (30); including both producers of technology, adopters, consultants and experts.[28] In total, 38 responses were gathered, equalling an answer frequency of about 8%, which of a vast majority was from Swedish actors.

### 4.2.2 Survey results

The survey included developers, adopters, distributors, regulators, policy analysts and researches involved in the RET industry. The regression analyses of barriers and drivers to innovation were first conducted including only focusing developers, adopters and distributors. The second set of regressions was conducted with 35 cases including all kind of stakeholders to notice the bias difference in the sample.

[28] The questionnaire distributed to Swedish actors was translated into Swedish; the rest was in English.

**Table 3.** A summary of the drivers to the adoption of RETs according to the questionnaire respondents for partly adopters and partly to all actor types included in the study.

| Time frame | Adopters | All |
|---|---|---|
| *Drivers at present* | • Technological Capability<br>• Market Pressure<br>• Regulatory Pressure | • Technological Capability |
| *Drivers in five years* | • Technological Capability<br>• Market Pressure | • Technological Capability |
| *Drivers in ten years* | • Economic Risk<br>• Organisational learning | • Technological Capability |
| *Drivers in the long term* | • Economic Risk | |

# 5 Options for policies

There are extensive amounts of literature explaining the various forces of technology innovation, adoption and diffusion. The traditional neo-classical economic approach has recently been complemented with innovation systems theories with a slightly broader scope, taking a systemic view on the innovation process including actors, networks and institutional settings as fundamental determinants. Where economists identify *market failures*, innovation system theorists discuss *system failures*. Their common ground, though, is to form explanatory models describing under what circumstances successful innovation and diffusion occurs - a basis for supportive policy design.

In the context of promoting the use of *clean* or *environmental-friendly* technologies through policy intervention, there is generally speaking a distinction between either (1) remove barriers for clean technology options (market barriers, disadvantageous regulations and legislation, lack of knowledge etc.); (2) stimulate drivers to adoption of clean technologies (subsidies, economic support instruments, awareness campaigns etc.); or (3) to create barriers for "dirty" ones (taxes, emission limitations, remove subsidies, raise awareness etc.).[29] Economy wide, market based instruments as taxes, permits, trade systems, certificates, tariffs etc., are generally viewed as the most cost-effective way of reducing anthropogenic environmental degradation (Sterner, 2002). They induce competition among actors and incentives to develop more advanced supply, conversion and end-use technologies (Sandén, 2004). Plausible instruments reach, however, beyond economic tools ands strict regulation. Society is in the need of intermittent policies, where policy makers need to consider institutional set-up, behavioural patterns, social norms, education, knowledge and information in addition to economic factors of innovation[30]. Additionally, the time frame, the geographical scope, cost distribution and the choice between targeting one technology, a group of technologies (cluster), a certain sector (transportation, production, electricity generation etc) or the economy as a whole, are all crucial aspects of policy design.

[29] In several cases, a certain aspect of diffusion may, depending on level of support, act as either a barrier or a driver; i.e. low cost – high cost, low demand – high demand, technological uncertainty – proven technology, politically controversial – political commitment, lack of advocating coalitions – strong lobbying groups etc.

[30] Policy instruments in the context of this study are defined as: "any concrete activity initiated by a government/authority in order to enlarge market implementation of renewables" (M. Harmelink *et al*, 2004).

## 5.1 Policy options to promote renewable electricity

As obvious from chapter 3, there are currently a wide range of policies implemented at both EU and national levels, aiming to address various imperfections in the innovation process and market for RETs. As expressed by Paul Komor (2004), the energy market currently consists of a "complex web of policies, programs and subsidies" so that main focus for decision makers should be "policy change" rather than "policy intervention". It may be true to the extent that changing an existing supporting system is far from always politically feasible; especially implementing market-based instruments, which interfere with energy prices and core-industry competitiveness, are often regarded as controversial. In addition, a central feature of any supporting system is consistency, which, obviously, would be undermined by too much change in the policy framework. Even though it might be possible to identify the optimal policy choices, at least from a theoretical view point, the political room for manoeuvre necessary for any political action could be lacking.

The range of policy *types* used in the energy and electricity sector are summarised in table 4., categorised from softer policy options as political ambitions, visions and guidelines to strict regulation and legislation.

**Table 4.** A non-exhaustive list of viable policy options to the support of renewable electricity, and the geographical level which they have traditionally been implemented on. Several explicit applications of these policy types are described in chapter 3.

| Policy area | Policy type | EU | National | Local |
|---|---|---|---|---|
| *Political aspirations/guidelines* | Aspirational Targets/Objectives | x | x | x |
| | Road Maps | x | x | x |
| | White/Green Papers | x | x | |
| *Information and knowledge* | Awards/Recognition | | x | |
| | Labelling | | x | |
| | Public Information/Education | x | x | x |
| | Demonstration | x | x | x |
| | Platforms/Networking | x | x | x |
| *Market* | Tradable Certificates | | x | |
| | Tradable Permits | x | x | |
| | Fixed Tariffs/Premiums | | x | |
| | Competitive Tendering | | x | |
| | Fiscal Measures | | x | |
| *Regulation and administration* | Obligations (to buy/to supply) | | x | x |
| | Public Procurement | | x | x |
| | Subsidies/Subsidy removal | x | x | |
| | Standardisation | | x | |
| | Regulatory Reforms | | x | x |

*Political aspirations and guidelines* (e.g. indicative targets for carbon emission reductions, future share of RETs in the electricity sector) is an important political tool to point out visions for the future. The main idea is to demonstrate a political commitment to a desirable path of developments for society or a certain sector or industry. In case of low compliance, indicative targets may further down the policy chain be complemented with explicit regulations and legislation.

The generation and transfer of *information and knowledge* are essential in the development of new technologies. Initiating R&D-projects, the formation of networks for knowledge sharing 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.

There is a great variety in policies that have been implemented to boost the market for RETs. First, there are direct economic support from authorities such as procurement, investment subsidies, tax redemption and soft/favourable loans. Secondly, authorities can influence the consumers' willingness to pay for green energy with the implementation of e.g. environmental labelling and green electricity stock exchanges, and thereby increase demand. And finally, there are market mechanisms that transfer the extra cost of new technologies to all consumers through a marginal increase of general energy prices. The former two are important in early phases of development to raise awareness and foster market demand. To support technologies closer of being commercially viable, market based instruments are deemed as more effective. In the electricity sector, primarily two different policy designs are being tested on the national level to increase the market share of RETs; either creation of protected market space, as the case with the certificate systems, or guaranteed prices for green electricity with a fixed tariff system (further described in section 3.3.1).

# 6 A proposed “short” list of policy instruments

This section develops a list of proposed policy instruments to boost growth and diffusion of RETs by addressing the barriers identified in chapter 4. As mentioned earlier, it is not always politically feasible to implement the policy options considered (theoretically) optimal; as in the case of an EU-wide carbon taxation, there are strong opposing groups lobbying against such an implementation and, in addition, a general lack of common understanding among the EU member states on the basis for such a tax. On the national level, most member states does currently have some level of market-based support, but the inertia of replacing a system is often stronger than modify an existing one. Hence, the justification of the proposed instruments in this section is based on: firstly, identifying options which have proved successful in other member states as a general recommendation to those that currently are lacking sufficient RET support. These instruments have gained legitimacy throughout the public, business world, politicians and are not viewed as risky ventures to same extent as unproven concepts. Secondly, several cases of existing supporting systems are not performing as expected but would be less costly and destructive to modify rather than replace as a whole, and still achieve sufficient market growth of RETs. Thirdly, there are some areas identified which are in need of new policy concepts to address certain barriers or reinforce drivers of adoption and diffusion. The proposed list of policy instruments are summarised in table xx with corresponding barriers and drivers.

**Table 5.** A summary of proposed policy instruments with corresponding barriers and drivers.

| Barrier/driver | Policy |
|---|---|
| Investment risk<br>High costs<br>Niche markets | *Market-based support*<br>• Feed-in Law<br>• Tradable Green Certificates<br>*Subsidies*<br>• "Buying down costs" of PV-modules |
| "Green" demand | *Procurement*<br>• Green Public Procurement |
| Technology uncertainty<br>Infrastructure uncertainty (Grid) | *R&D*<br>• Technology Platform (Off-shore wind power)<br>• R&D focused on grid management of intermittent power generation |
| Lengthy/complicated permit processes<br>Grid extension costs (lack of transparency) | *Administrative measures*<br>• Land allocation<br>• Regulative reform (simplified permit issuing process)<br>• Grid access/expansion |
| Long term visions | *Political aspiration*<br>• EU objectives/road map on RET-share 2020 and beyond |
| Growth opportunities/job creation | *Regional/local multi-purpose programme*<br>• Branch development projects |

*Feed-in Law*

Currently used with a great success in Germany and Spain, among other member states, is the feed-in law mechanism. Germany has during the latest decade emerged as a world-leader in both wind and solar power installations. In the German system utilities are required to purchase electricity from renewable generators at a market price topped with a fixed premium, balanced on a level to cover additional production costs of renewable electricity above the average electricity price. The premium is technology and site dependent; meaning that uncompetitive technologies receives a higher remedy and that e.g. wind power plants with a lower production due to bad wind conditions also receives a higher compensation. Although decreasing over time, generators are guaranteed to receive the remuneration over a period of 20 years. Network operators are required to connect all renewable installations to the grid and accept their full power production output. Costs of the system are born by end-consumers and are designed to be spread through-out the whole country.[31] The added costs to end users of electricity have increased in the range of 0.18-0.26 ct/kWh (BMWi, 2002). As

[31] In the preceding feed-in system, active during 1991-1998, each network operator had to bear the total costs of renewables individually in their area.

total share of RETs increases in the national system, there is less need for generous premiums and by decreasing the levels, system costs are kept at a minimum.

Guaranteed long term subsidies to renewable generators at sufficiently high levels have proved to effectively reduce risk of investments in RETs and increase their economic competitiveness. Risk reduction is an important criterion to induce adoption and diffusion; in which the feed-in system has succeeded to a larger extent compared to renewable obligations or certificates (Mitchell *et al*., 2006).

*Tradable Green Certificates*

TGCs, or *Renewable Obligations* (RO), have recently been implemented in e.g. the Netherlands, Sweden and the UK. Even though they on an elaborate level are varying some in design, they all share the same basis: inducing a market for RETs by forcing end users of electricity to purchase a certain share of their total consumption as renewable electricity. Renewable generator acquires certificates in proportion to the power production, which is tradable on a specific certificate market. The profit from selling certificates constitutes the actual subsidy to renewable generators.

In comparison with the feed-in law, TGC is technology neutral and the trading mechanism keeps added end user costs at a minimum by inducing competition among suppliers of renewable power. It could be argued that goal-fulfilment is easier to achieve with a quantity-based instrument as the TGC, compared to the feed-in laws' pricing mechanism, but experience demonstrates that it is not necessarily the case (Kåberger *et al*, 2006).[32] Criticism put forward against a tradable certificate system, as it has been implemented in Sweden, mainly concerns:

- Governmentally controlled demand curve which is only planned to 2010 gives few incentives to invest above the predefined share of RETs and high investment risk. Normally, investments in RETs are done on pay-back periods of 15-25 years and, hence, the system is not able to give adequate input for the full life time of such decisions. (Kåberger *et al*, 2006)

[32] In the Swedish system, firms can pay a fine instead of buying certificates.

- Quota obligation does not apply to all users; the heavy industry is excluded which accounts for about 40 TWh electricity consumption (approximately 25% of total electricity demand).
- While being technology neutral and promote competition among various RET alternatives, TGC does primarily support RETs close to commercialisation. New technologies as off-shore wind and solar power, which are considered important in the long run of changing the energy system, are to a large extent excluded from this support.

Thus, there are some serious flaws with the current design of the TGC system, but which may be corrected with some modifications. First, a demand curve defined far beyond 2010 to ensure necessary inputs in decision-making processes regarding new investments in RETs. Secondly, including the whole range of electricity consumers to the TGC system would severely increase its effectiveness to reach climate objectives. Assuming same percentage on RET share, the total RET market would increase and give room for more technology options. To support development and diffusion of new technologies, the TGC would either have to be complemented with additional subsidies, or redistribute profits from green certificates with a less proportion to relatively established RETs.

*Subsidy*

The diffusion on larger markets that would lower costs of PV technologies is mainly inhibited by the high costs; a Catch-22 situation (Sandén, 2004). Subsidies are in an initial phase a strong tool to “buy down costs” of PV systems; increasing experience and learning of PV manufacturers and further lower costs by economies of scale. PV technologies are suitable for such an approach since it is possible with relative ease to integrate PV modules in the public sector as buildings, infrastructure etc. Rooftop PV installations have a great potential in providing municipalities with self-generation and mitigate electricity expenditures and, vice versa, public investments may play a crucial role in directed aid to the PV industry as well as a forceful tool to influence the market-place.

Aiming at reducing costs of PV modules to competitive levels, overall costs of such a subsidy programme depends on the relationship between cost reduction and adoption. During the last 20 years, each doubling of cumulative PV production volume has reduced manufacturing costs with 18-23%. According to Sandén (2004), annual costs of a subsidy programme that would make PV systems competitive on the electricity market by 2021 would add no more than 0.1 US cent/kWh to the electricity bill in OECD countries at its peak.

*Green Public Procurement*

Public procurement is, on a political level, a well-established public policy in the EU with several documents and directives (e.g. 2004/17/EC, 2004/18/EC and "*Buying green! – A handbook on environmental public procurement*") prescribing guidelines and frameworks for authorities in arranging public supply contracts and green purchasing strategies. Benefits of public procurements are, primarily, two-fold: increase demand and raise awareness/legitimacy for. The former is trivial in that the public sectors is purchasing (procuring) the product., while a raised awareness and legitimacy for a product often emerges as a positive consequence of exposure. As with subsidies, PV is suitable for procurement campaigns due to the relative simplicity of integrating modules into e.g. public property and buildings.

*Technology Platform and additional R&D efforts*

Currently there are 28 platforms, which of one on PV technology described in chapter 3. It is arguable that there should be such a platform on off-shore wind power as well, which is a technology with vast growth and export possibilities and an important component in a future sustainable European energy system. As mentioned earlier, off-shore wind power has some technology barriers to overcome that may inhibit large-scale diffusion, mainly concerning quality of plant sub-components and services, and grid connection/expansion issues related to intermittent and remote power generation. Especially the latter requires co-operation of a wide range of various actors, including manufacturers, adopters, grip operators and authorities, to find adequate solutions.

While the formation of technology platforms is mainly on the initiative of the industry stakeholders themselves, a first step to form networks and coalitions could be initiated with governmental involvement by arranging sectorial workshops etc.

*Simplified permit processes and land allocation plan for wind power*

There are primarily two concerns with issuing building permits for RETs – wind power in particular; there are a large numbers of authorities involved at different levels (national, regional and local), and excessively long lead times to obtain necessary permits, sometimes as long as up to seven years.

This could be addressed partly through the establishment of a one-stop authorisation agencies, as suggested by the European Commission (COM(2005) 627 final), that will process all necessary administrative matters and provide assistance to applicants. Partly by pre-planning areas suitable for RET installations on either national or local level. National authorities or municipalities should allocate areas that are available to projectors of RETs, with severely reduced permit requirements and reduced lead times.

*Grid access and extension*

Even though the Commission have released a dedicated directive to grid issues as cost transparency and access, these are still of great concern in the planning of projects. In particular, the burden sharing of grid extension costs poses a high degree of uncertainty in cost calculations.

Denmark, Finland, Germany and the Netherlands all have strict rules for the bearing and sharing of costs of grid connection and extension and serve as good practice examples. Commonly, project developers are responsible for costs of connection, while grid operators have to cover costs related to grid extension and reinforcement at distribution or transmission level. All associated costs should be both transparent and non-discriminative in manners that project developers may in an early phase of planning elaborate on necessary capital investments. (COM(2005) 627 final)

*EU objectives on RETs beyond Kyoto*

If the EU is to meet its longer terms goals for sustainability, secure of energy supply and climate change, a continued dedication and support to RETs is a prerequisite. The European renewable electricity industry would benefit greatly from having a strong commitment from the EU commission, with clearly defined targets for RET penetration far beyond those of Kyoto. Such targets should have an attached roadmap indicating supportive measure at the short, medium and long term for successful achievement. This would give further incentives at member state level to reinforce national supportive measures motivated by the common EU goal.

# 7 Conclusions, recommendations and next steps

The political controversy of promoting renewable energy sources is, at least in within the European Union, past. Instead RETs are increasingly looked upon as a crucial part of the solution to global warming and increased security of energy supply. Though, as shown throughout this project, there are a multitude of various barriers inhibiting the adoption and wide-spread diffusion of RETs - barriers that needs to be addressed by policy measures. Chapter 5 and 6 in this report elaborated on possible policies deemed as suitable to address those barriers identified in chapter 4. The design and implementation of policies is a rather delicate process; especially in a field such as the energy/electricity sector that directly affects economy, industry and society in general. Consequently, from pressure and lobbying of various interest groups, there is a 'gap' between what is a theoretically optimal policy strategy and policies that are politically possible to implement. This is particularly true for the implementation of a mandatory EU-wide taxation on energy use or carbon dioxide emissions, which by many is looked upon as an 'optimal' tool for carbon mitigation but has proven too politically difficult to implement. Hence, there are barriers not only to technologies but to policy implementation as well.

Putting the political reality aside, policy construction aimed at technology adoption and diffusion has to focus a great deal on innovation system processes. As described earlier, a tradable quotas system is expected to a greater extent support technologies close to commercialisation (i.e. wind and bio power) but neglect technologies in an experimentation and early development phase (i.e. photovoltaic). Long term progressive climate targets will need a large-scale diffusion of new advanced technologies and, thus, it is obvious that e.g. photovoltaic is in the need of dedicated support in addition to market-based schemes. Though, as denoted above, innovation is a *process* where barriers and drivers are changing over time. Therefore the supporting systems will have to change as well, following inventions to innovations to commercially viable products; from open-ended policy designs inducing experimentation to nursing niche markets and supporting demonstrations to actual market-based measures allowing competition between new and incumbent technologies.

## References