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Decentralised Energy Systems

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DIRECTORATE GENERAL FOR INTERNAL POLICIES
POLICY DEPARTMENT A: ECONOMIC AND SCIENTIFIC POLICY

INDUSTRY, RESEARCH AND ENERGY

Decentralized Energy Systems

Abstract

We are moving from a highly-centralized to a more decentralized energy system relying on more distributed generation, energy storage and a more active involvement of consumers through demand response.

The present study makes an assessment of the status quo of decentralized energy systems, both in terms of technological developments and the legislative and policy framework. The analysis then discusses the current technical, economic and policy challenges and barriers facing decentralized energy production.

Finally recommendations are provided in terms of the EU legislative and policy framework; infrastructure issues; R&D, investments and technological developments; monitoring and coordination of Member States incentive schemes; and SME support measures.

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CONTENTS

LIST OF ABBREVIATIONS

CAES	Compressed Air Energy Storage
CHP	Combined Heat and Power
CSP	Concentrating (or concentrated) Solar Power
DEP	Decentralized Energy Production
DER	Distributed Energy Resource
DG	Distributed Generation
DH	District Heating
DR	Demand Response
DSO	Distribution System Operator
EC	European Commission
EPBD	Energy Performance of Buildings Directive
EPIA	European Photovoltaic Industry Association
ESCO	Energy Service Company
ESD	End-use Efficiency and Energy Services Directive
ESMA	European Smart Metering Alliance
EU	European Union
EV	Electric Vehicle
FIT	Feed-in Tariff
IEA	International Energy Agency
NER	New Entrant Reserve
NREAP	National Renewable Energy Action Plan
PV	Photovoltaics

RE	Renewable Energy
RES	Renewable Energy Source
RES-E	Electricity production from renewable energy sources
RO	Renewable Obligation
SCADA	Supervisory Control And Data Acquisition
SME	Small and Medium-sized Enterprise
TFEU	Treaty on the Functioning of the European Union
TGC	Tradable Green Certificate
TSO	Transmission System Operator
WAMS	Wide-Area Measurement System

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EXECUTIVE SUMMARY

Background

Europe is beginning a transition from a centralized and largely fossil-fuel and nuclear-based power system delivering electricity to passive consumers toward a more decentralized power system relying to a larger extent on small-scale (sometimes intermittent) generation from renewable energy sources (RES) and Combined Heat and Power (CHP) units, allowing greater active participation of consumers by becoming producers themselves and/or by smarter demand response management of their own energy use.

This profound change is brought about by a combination of converging drivers:

- The necessity to combat Climate change by reducing greenhouse gas emissions by 20% by 2020 from the 1990 level;
- The rise of renewables: Europe has set itself a goal of achieving a share of 20% of RES in its energy mix by 2020;
- The widely recognized necessity to use energy in a more efficient manner: Europe will have to improve energy efficiency by 20% by 2020;
- A growing concern over the security of European energy supply due to the increasing share of intermittent power production from RES;
- Rising electricity demand throughout European countries, and
- the liberalization of Europe's energy markets.

The evolution of the power system will impact the entire energy value chain, from generators to transmission and distribution all the way to individual consumers. The coherent long-term EU-wide facilitation and coordination of this necessary change is no small task for the EU as it will involve a very broad range of subjects, legislation, policies and players.

Aim

The European Parliament Committee on Industry, Research and Energy (ITRE) has requested a study on "Decentralized Energy Production – Current Barriers".

This study is intended to provide an overview of the status quo of decentralized energy systems (production and distribution) in Europe and to describe the EU legislative and regulatory framework. The main challenges and barriers to their deployment will be identified and analysed and will serve as a basis for recommendations to the European Parliament.

The study does not attempt to fully cover all Member States, but provides a broad overview of the current situation across the EU and some reflections on observed geographical differences.

The study is based on key documents of the European Commission as well as on independent sources. It thus reflects a broad range of views in the area and attempts to provide a balanced picture of the variety and breadth of views and independent critical assessments currently being considered among professionals in the field.

Status quo of decentralized energy production and distribution

The power system is increasingly influenced by distributed energy resources (DER). DER involves three components:

1. Distributed Generation (DG)
2. Demand Response (DR), Transmission and Distribution
3. Energy storage

First, **Distributed Generation (DG)** is made **of relatively small-scale generation capacities connected to the distribution network** (medium and low voltage: 110kV and lower). **The primary energy source is often renewable** (wind, solar, biomass, biogas, hydro, geothermal or ocean-based) **and frequently available on a local basis**. This definition however is not limiting, as **in some cases fossil fuels can also be used as the principal energy source**. Since CHP plants improve energy efficiency, they are also part of DG even though they may use fossil fuels in some cases. CHP units are often used by local players such as municipalities, companies or households.

The EU is the leading region for **wind power** (though China and the US were ahead in terms of new installed capacity in 2009). In 2008, 53.9% of the World's wind capacity was located in Europe, representing a production of 118TWh and up 13% from 2007. In 2008, 0.5% of EU electricity production came from wind turbines.

Hydro power represents the largest share of renewable energy sources in the EU today. In 2007, hydroelectric installations generated over 300TWh of electricity. 87% of this came from large-scale hydro (over 10GW of installed capacity). Not surprisingly, given its high cost, the contribution of small-scale hydro is relatively minor. Pumped hydro provides highly efficient energy storage capacity to balance supply and demand and is largely utilized for this purpose.

CHP encompasses a large range of technologies and sizes. DG-sized CHPs are usually based on simple construction to keep costs down and are utilized by SMEs, municipalities, commercial sites, households and industries. In 2006, estimates suggest that CHP plants generated 11% (366TWh) of European electricity demand. Approximately 50% of this came from plants with a capacity less than 10 MWe.

Other DG technologies remain very marginal in terms of installed capacity. In 2008, the EU had over 80% of the World's installed **photovoltaic** capacity. The market is extremely dynamic and more than doubled in size between 2007 and 2008, from 1,833 MWe to 4,747 MWe. Solar thermal electricity has great potential in Southern Europe. **Solar thermal electricity** is more competitive in cost terms than photovoltaics and can potentially allow heat storage (for example in molten salt) especially at night, thus facilitating the balancing of supply and demand. The **ocean** harnesses five different types of ocean-energy flows: **tidal, wave, current, osmotic pressure** (due to the salinity difference between fresh water and the ocean), **and deep water thermal gradients**. **Most of these technologies are currently very immature** and at the prototype or demonstration stage, making them economically uncompetitive.

Demand Response (DR) is the second key component of a decentralized power system. Demand Response does not necessarily save energy, but rather **shifts energy loads around in time**. This is very important since it potentially avoids the need to shed excess energy supply at times of low demand or high supply. The management of small end-users must be achieved automatically at the user level which requires online communications. In this regard, smart meters represent a key enabling technology of **Demand Response (DR). The distribution networks will also have to evolve increasingly towards smart grids**. **Smart grids are active and dynamic electricity networks** where the smart grid functions as a facilitator for active end-users as opposed to the traditional passive top-down (uni-directional, producer-to-consumer) power system. The emergence of smart grids will involve significant changes in the way networks are operated.

In addition, more market system integrations as well as interconnections will be needed allowing more cross-border energy flows. We are likely to see **the emergence of new market players or aggregators currently referred to as "Energy Service Companies" (ESCO).** New companies of this kind will serve as an interface between consumers/producers and the rest of the power system by optimizing end-user production and consumption and aggregating flexibilities for the overall benefit of the whole power system. New business models are likely to emerge.

In the context of rising intermittent production, the third key component of a decentralized power system is **energy storage**. **It will allow storing part of the energy produced by intermittent sources during low-consumption hours and feeding this energy back into the power system when most needed during peak hours**. Pumped hydro and heat accumulators (as power users) are already in use today and Compressed air energy storage (CAES), hydrogen and electric vehicles are some of the most promising new technologies for future energy storage.

Finally, separate from the power system, the **natural gas network** is also relevant when considering decentralized energy systems. While inherently a highly centralized system, **the natural gas network offers the possibility of injecting locally produced biogas.** In this sense it may also become part of the decentralized energy system of tomorrow. New gas networks built solely for biogas are another solution, as these do not require stringent biogas purification processes before introduction into the network.

The Current legislative and policy framework

The Climate and Energy Package

The Climate and Energy Package adopted in December 2008 set a triple target for Member States. First, at least 20% of EU's final energy consumption should come from renewable energy. Second, energy efficiency will have to be improved by 20% by 2020. Third, EU GHG emissions must be reduced by 20%. As part of the Climate and Energy Package, the RES directive provides for priority or guaranteed access to the grid-system for electricity from renewable sources. Thus, from a legal point of view at least, the necessary precondition for the development of renewable sources is given. **Whether the directive will be favorable to DG remains mainly a question of "how" the directive is implemented at the national level**, in particular with regard to grid access and priority RES uptake, with grid access probably the most important issue.

The Third Energy Package

The Third Energy Package has provided a new regulatory framework which should be favorable to the further deployment of DG. Effective unbundling is an essential prerequisite to ensure non-discriminatory access to the grid network for DG producers. Grid connection very often represents a legal, administrative and economic hurdle for DG. Given the relative size of DG units, the associated connection costs for small producers tend to represent a larger share of total investment costs. Renewable energy producers should receive priority access to the grid and a competitive and non-discriminatory environment for grid access should be ensured. **This requires an adequate enforcement of the Third Energy Package. The implementation of the individual components of the Third Energy package should be closely monitored, with best practice sharing across countries.**

The Energy Performance of Buildings Directive (EPBD)

The Energy Performance of Buildings Directive (EPBD) addresses the energy consumption of buildings, which represents 25-40% of total European energy consumption and is responsible for 40% of total CO2e emissions of the European Union. **According to the proposed EPBD, from 2021 on, new buildings must incorporate "very high energy performance"** (the definition remains to be clarified in the final version of the directive). **Inconsistencies exist however between the EPBD and the CHP directive**. The heat demand of buildings is expected to decrease significantly in the coming years as a result of the new EPBD, thus affecting the specifications of energy needs—especially in terms of heat. CHP development needs to take this into consideration because it implies potential modification requirements in the design of CHP units. This aspect however is absent from the CHP directive. The EPBD requirement to construct buildings with a "very high energy performance" may have negative repercussions for heat generated by other systems—in particular CHP and district heating systems—which will then be likely to produce surplus heat. Reconsideration of these inconsistencies across the CHP and EPBD—in particular before the finalization of the EPBD—may be appropriate.

The EU-ETS

The EU-ETS offers few incentives for distributed generation. It focuses primarily on large emitters and promotes emission reductions from highly carbon-intensive industrial installations and power plants. Though the EU Effort Sharing Decision requires Members States to reduce emissions in non-ETS sectors and provides flexibility to trade emissions across borders in those sectors, this device does not yet offer sufficient flexibility in the trading of carbon credits. **We would advise the European Parliament to evaluate the possibility of allowing emission trading between ETS and non-ETS sectors**. In general, an increased degree of flexibility across the ETS and non-ETS sectors would likely provide far stronger incentives for DEP (and RES) deployment.

Smart metering support

The EU has set itself the goal of placing intelligent metering systems in 80% of households by 2020 (subject to the outcome of an economic evaluation due at the end of 2012). **This deployment is indispensable for decentralized energy production (DEP) but may be a long and costly process**. Currently the installed base for smart electricity only represents 6% of the European electricity sector. There are significant differences across Member States and only eleven of them have actually begun introducing the deployment of smart meters. Pioneer countries like Italy, Sweden and Finland have taken the lead and have already come very close to achieving a penetration rate of 100%. Others like France, the UK or Spain have taken significant steps toward mass deployment. On the other hand countries like the Netherlands and Germany have encountered difficulties and in a large number of countries smart-metering is only in the very early developmental stages (some evaluating studies are underway, but implementation has typically not begun).

National strategies for accelerating the rapid integration and adoption of smart metering systems should continue to be developed and implemented. However, whether national level efforts will be enough to achieve these goals across all EU Member states remains to be seen. **In our assessment, the European Commission could be delegated the task of closely monitoring developments in the implementation of smart meter technologies.**

Infrastructure

The level of interconnectedness of grid networks is an issue of strategic importance for the deployment of DEP. Generally speaking, the more integrated the European transmission network and energy grid becomes across European space, the easier the management of intermittent supply. **To-date, the objective of a 10% rate of interconnection agreed by the European Council in Barcelona in 2002 has not been achieved and there has been little progress since. In this regard, it is imperative to accelerate the construction of cross-border grid interconnection lines**. As part of the second package under the European Economic Recovery program, the EU agreed to spend 2.3 billion Euros on grid network interconnections for electricity (910 million Euros) and gas (1.39 million Euros). This funding is likely to have a positive impact on speeding up these necessary developments. However, **past progress in the construction of cross-border grid networks suggests that close monitoring by the European Commission is highly advisable.**

EU-SET Plan

The basic intention of the EU SET Plan is to spend significant additional resources on researching low carbon technologies. Generally speaking the SET Plan aims to foster innovation across a broad range of RES, CCS, Smart Grid, Nuclear and Smart City technologies. While the SET Plan intends to spend a total of 2 billion Euros on Smart Grid technologies and a significant share of the total 58.5-71.5 billion Euros on RES technologies, a surprisingly large share of these monies has been dedicated to CCS technologies (10.5-16.5 billion Euros). Given the potential return and proven status of many of these technologies, this distribution of resources should potentially be re-considered.

We recommend that far more attention and funding be dedicated to Smart Grid, RES, and DEP technologies. Moreover, we also see considerable advantages to greater R&D funding for storage technologies, base load forms of renewable energy generation and energy-saving and heat-related technologies.

National incentive schemes for DEP

At the national level, Member States have retained sovereignty in the choice and design of their national supporting instruments for promoting renewable energy technologies. This has resulted in significant differences across Member States. While these differences allow Member states to base their strategy on national comparative advantages (e.g. the national potential of individual RES technologies), **better monitoring and coordination at the EU level is highly advisable**, in particular in order to avoid conflicts between national and EU-level policy instruments and to help promote best practice strategies.

For the national level, current practice suggests **a combination of a *differentiated* feed-in tariffs (FIT) and a carbon tax may be the best supporting policy for the rapid, mass-deployment of both large and small scale RES and DER technologies. Further, we recommend that the European Parliament evaluates the possibility of implementing an EU-wide scheme comprising both a FIT approach and a carbon tax**. In its current form, the EU level Guarantee of Origin strategy is likely to have perverse and negative effects on EU and Member state RES and DER development.

Main Lessons Drawn from the Legislative Framework

Overall, the EU legislative framework provides many positive elements in terms of supporting DEP but does not adequately and specifically address the questions posed by decentralized power.

Compared in particular to larger-scale systems, small -scale energy production is not adequately incentivized or supported by existing mechanisms. A better integration of DEP into the existing regulatory framework is therefore highly recommended as well as the resolution of inconsistencies across individual directives. Finally, we recommend the EU strongly consider the introduction of an EU-wide FIT strategy combined with a modest carbon tax.

Challenges and barriers

Physical and Technical Developments and Challenges

The **main barriers to decentralized energy systems** are:

- Increased reserve requirements due to intermittent and unplanned production
- Need for forecasting
- Excess production and energy storage
- Need for ancillary services
- System operation and range at transmission and distribution level
- Security of supply
- Upgrading network infrastructure
- Flexibility and aggregators

Economic and financial

As long as an international climate agreement following Kyoto is not adopted allowing the internalization of environmental externalities associated with fossil fuel use, cost factors are likely to remain a significant constraint in the development of future energy generation systems. In the state of the art, highly decentralized electricity generation is frequently less cost-efficient compared to large, centralized systems.

However, cost measurement is a difficult task that can easily be obscured by overlooking sub-regional variation and recent technological innovation. **Data suggest that DG technologies may not be as expensive as frequently believed.** Currently, the two most competitive RES technologies are first geothermal and then wind power. Over the last few years, while the price of fossil fuels have continued to rise, RES technologies have steadily declined in price and will presumably continue to decline with continued R&D investments and commercialization incentives.

SMEs

Small and Medium sized Enterprises (SMEs) are key players for DEP. Today there are 23 million companies across Europe and 99% of them are SMEs. Combined, SMEs represent 30% of Europe's energy consumption. **While DG and DR are clearly SME friendly, they face significant barriers in SMEs.** First of all they are **burdened by high capital investment requirements**. Moreover, there is a general **lack of understanding and awareness** of energy issues and the potential advantages of DEP. DG and DR projects are also **perceived as bringing no short-term financial rewards** while the time-horizon characterizing SMEs is primarily short-term. Moreover such projects often have to compete with other internal projects that are usually granted priority because they are perceived as necessary in order to retain short-term competitiveness.

Additionally **SMEs very often face significant knowledge gaps**. There is a clear need for adequate and relevant information, ranging from the legal and policy framework to the economics of DER and the technical feasibility of different solutions.

The intensification of communication, dissemination and training is absolutely necessary and seems more efficient when carried out at local level by familiar and trustworthy local actors such as chambers of commerce or local sectoral business associations where many SMEs already engage in frequent information exchange (especially the top management). Local energy agencies could play a major role by providing support and expertise to local actors. In order to facilitate this, we would recommend strengthening the existing network of local energy agencies (under the Intelligent Energy Program), to enhance its functioning and to provide it with adequate resources for these objectives.

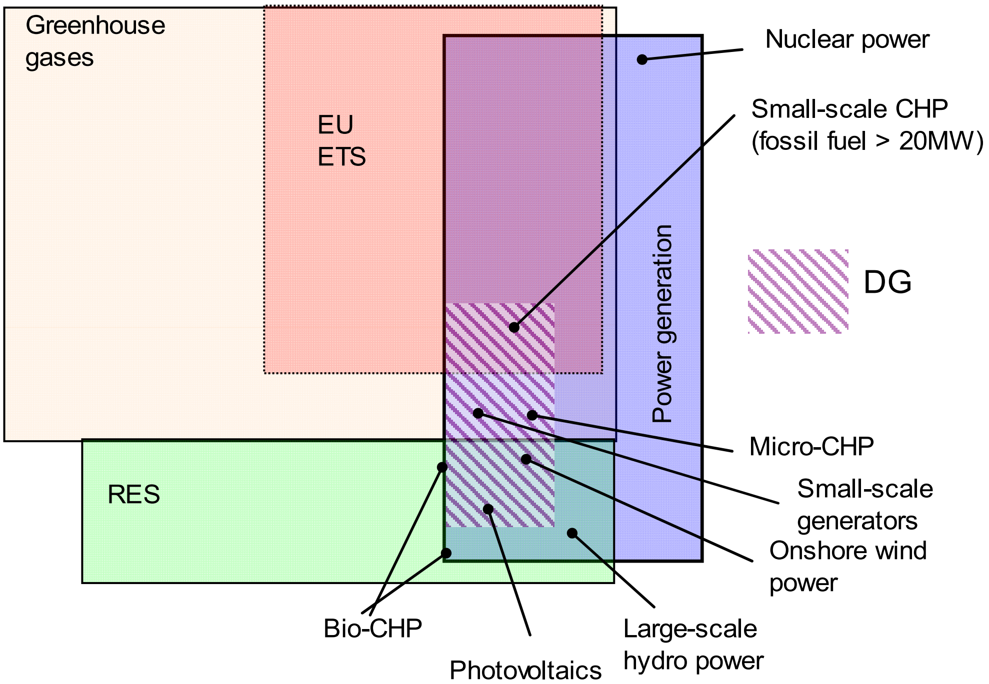
In our assessment, **developing and disseminating DEP sectoral toolkits, offering among other things the possibility to benchmark, would be advantageous**. Additionally, we would recommend trying to identify barriers to the development of ESCOs and aggregators—key players in making the case for DEP more financially attractive to SMEs. These two aspects could for example be set as priorities of existing EU research programs such as the Intelligent Energy Program.

1. Introduction

The energy system is undergoing significant and far-reaching changes in the EU. The drivers behind the changes are the need for reducing greenhouse gas emissions, the desire to increase the use of renewable energy sources (RES), the goal of improving energy efficiency, the need for new power production capacity and to some degree also the question of security of supply. The targets are overlapping and often even contradictory. Security of supply might lead to favouring domestic fossil fuels; use of biomass and biofuels is often less energy efficient than the use of fossil fuels; the most cost-effective way to reduce greenhouse gases might not be renewable energies but energy efficiency and nuclear power, etc.

The drivers and targets, however, concern the whole energy system. As illustrated in the figure below, a change in the power system by increasing distributed generation is but one part of the whole. The power system is by nature very conservative. It is composed of long-term investments in fixed capital installations. There are still hydro power plants in operation from the early 1900s and nuclear power plants being built today (e.g. in France and Finland) will still be running after 60 years. It is thus advisable to set the development of the boundary conditions well in advance. This likewise concerns the treatment of DG.

Figure 1: The relations between energy-related greenhouse gas emissions, the EU ETS, RES, power generation and DG



Note: The figure also illustrates the fragmentation and lacking coherence of the current EU legislation. Energy efficiency measures or security of supply issues are not shown, but they affect the sizes of and relationships between areas in multiple ways. Some examples of the location of different power production types are indicated.
Source: VTT

Although the expanding adoption of RES technologies is closely associated with DG, DG is not the only potential strategy for adapting to environmental and climate constraints. Other adaptation potentials exist which may be even more cost-effective. RES can be used for heat and for transport fuels, not only for electricity production.

Greenhouse gas reductions can be achieved, for example, with nuclear power and improved efficiency. Energy efficiency improvements reduce the need for and the use of energy (including fossil fuels) in different sectors.

Decentralized energy systems — in this study energy production connected to a gas or electricity network — potentially brings production closer to the point of consumption. The natural gas grid is a very centralized energy distribution system and only the usage of gas is decentralized. There is, however, one aspect where the gas grid has a new role and that is as a recipient and conveyor of locally produced biogas, here including biogas grids.

The power system has conventionally been a relatively centralized system with electricity production in large power plants and power flowing down the voltage chain, this will change. Small-scale production capacity at the local and user level is increasing due to either local energy resources or local energy demands. Wind and solar power are based on local energy sources, as is power production from biomass - including biogas - and waste, whereas combined heat and power (CHP) production, which allows for a more energy efficient use of fuels, depends on a local demand for heat.

As the production side is changing, this affects the transmission and distribution networks. CHP and the intermittent nature of the principal new renewable-based electricity generation sources, wind and solar, bring new balancing requirements to system operators. Traditionally, when flexible hydro power is not available in sufficient amounts, balancing is managed with power plants suited for this purpose, e.g. coal condensing plants and gas turbines. It would be very expensive to erect the necessary amount of balancing power in each network. Thus, other, more cost-effective solutions are sought. On the transmission side, this includes new interconnections, especially cross-border interconnections and market coupling, easing the balancing of intermittent production. In addition, distribution and transmission networks are transitioning toward smart grids which allow for an increased use of distributed energy resources (DER). In addition to DG, DER also includes the use of energy storage - not restricted to electricity storage - and demand response (DR). Active end-user participation through DR will be very helpful in balancing of the power system in a cost-effective way.

DG faces several barriers. Some barriers are legal or authority dependent, such as permits and environmental restrictions, while others, justly or unjustly, are set by network utilities (e.g. grid connection regulations). The connection of a DG-unit to the network also always raises safety issues, for example what response should be required in the case of network failure. One of the main barriers is cost, since many small-scale DG's are not competitive without financial support. Technological barriers, for example, are not so much about a lack of technology. They are about the cost of the available technology or about who should pay for the required technological implementation. Decentralized energy production and distribution has to find its own place in European energy systems.

2. Status Quo of Decentralized Energy Production & Distribution

2.1. Definition of distributed generation of electricity

Decentralized electricity production is the opposite of centralized electricity production. The power systems in Europe have mainly been built to accommodate central power plants, meaning large fossil fuel condensing plants, nuclear plants and hydro power stations. This is changing, more and more distributed energy resources are being introduced into the power system. The distributed energy resources concern the power system and are seen to include not just distributed generation, but also energy storage and demand response. End-users are becoming not only producers but also active participants in network balancing operations.

EU Directive 2009/72/EC defines DG as generation plants connected to the distribution system where the distribution system is the high-voltage, medium-voltage and low-voltage network as opposed to the extra high-voltage and high-voltage transmission system. Decentralized generation is not defined per se in the recent directives as it is used more in the descriptive sense. Micro-generation is a term referring to very small generation units connected to the low-voltage network, which means capacities below 50 kW (e.g. connections under 3*63 A). There are more precise and restricting definitions for DG, but these vary. However, a broad consensus is that DG units are connected to the distribution grid and are not large-scale units. They usually have one or several strong local dependencies: they are connected to the distribution network, not the very high voltage transmission grid; the energy source is produced locally (wind, solar, biomass, biogas, geothermal, ocean energy, hydro); electricity production in combined heat and power plants is dependent on local heat demand; production is used by the producer; or the owner is a relatively small actor on the electricity market (e.g. a municipality, an end-user, a private investor or consortia, a land owner).

The DG-GRID[1] [2007] project, for example, sees offshore wind, geothermal energy, hydro power larger than 10 MWe, and CHP-plants larger than 50 MWe as not part of DG. A more detailed definition of DG is from EU-DEEP[2] [2009], see (Table 1). Here the classification is more meticulous and gives a good overall view of the variety of technologies including fuel, capacity range, commercial status, economics, application sectors and cost ranges. This hopefully conveys that DG stands for very diverse alternatives both to use, size and, in consequence, barriers. Except for photovoltaics, low temperature fuel cells, Stirling engines and reciprocating internal combustion engines, most of the technologies are not suited for household use. More technologies are suited for end-users (industries, services, farms) with larger consumption.

The EU-DEEP definition table should only be seen as a guideline. For example, small wind power plants with capacities below 500 kW, the lower range given here, are found on the market. They are, however, considerably more expensive than the cost range provided here for onshore wind power.

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[1] The DG-GRID project analysed technical and economical barriers for integration of distributed generation into electricity distribution networks. It was supported by the European Commission.

[2] EU-DEEP (EUropean Distributed EnErgy Partnership) was a European Project supported within the Sixth Framework programme for Research and technological development, involving 42 partners from 16 countries over 5 years. The project lasted 1/2004 - 06/2009. www.eu-deep.com.

Table 1: Overview of distributed generation technologies

	TECHNOLOGY	FOSSIL OR RENEWABLE							RENEWABLE					
		Small steam turbines	Gas turbines	Micro turbines	Reciprocating internal combustion engines	Stirling engines	Fuel cells - high temperature	Fuel cells - low temperature	PV	Small hydro	Wind onshore	Wind offshore	Geothermal	Solar thermal
BASICS	Type of fuel	gas, coal, peat, biomass	gas	gas	diesel, oil, biofuel, gas	gas, solar	gas, hydrogen	gas, hydrogen	solar	water	wind	wind	earth heat	solar
	Capacity range * ** [MWe]	0.5 - 10+	0.5 - 10+	0.03 - 0.5	0.05 - 10+	<0.01 - 1+	1 - 10+	<0.1 - 3+	<0.001 - 5	0.05 - 1	0.5 - 6+	5 - 10+	0.5 - 3+	<0.001 - 2
	Status	Commercial	Commercial	Developing/ commercial	Commercial	Developing/ demo/ commercial	Developing/ commercial	Developing/ commercial	Developing/ commercial	Commercial	Commercial	Developing/ commercial	Developing/ demo/ commercial	Developing/ demo/ commercial
	Pure economics	€	€	€€	€	€€/€€€	€€€	€€€	€€€	€€€	€€€	€€€	€€	€€€
	Environmental features	☼/☼☼	☼/☼☼	☼☼	☼/☼☼☼	☼☼	☼☼/☼☼☼	☼☼/☼☼☼	☼☼☼	☼☼☼	☼☼☼	☼☼☼	☼☼☼	☼☼☼
	Social motivation	●	●●	●●	●	●●/●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●●
	Actual deployment	High	High	Small, increasing	High	Small	Small	Small, increasing	Small,rapidly increasing	Medium	Medium	Small,rapidly increasing	Small	Small
APPLICATION	Industrial	***	***	*	***	*	***	**	*	**	**	-	-	-
	Commercial	*	**	**	***	***	*	***	**	*	*	-	-	-
	Residential	-	-	***	**	**/***	-	***	***	-	-	-	-	-
	CHP possible	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes
COSTS ***	Capital cost [€/kW]	550-1250	500-1100	1000-2000	350-1000	1500-8000	3500-10000	2000-8000	4000-8000	1400-5000	800-2000	1200-3000	800-4000	1500-2000
	Installation [€/kW]	100-200	65-150	50-200	60-120	40-200	500-850	500-850	40-150	100-200	100-200	600-800	200-400	100-200
	Electricity generating cost [€ct/kWh]	3-7	3-5	8-15	4-7	9-15	15-35	10-25	20-40	6-14	6-10	8-15	NA	NA
	Expected life-time	20	20	20	20	15	10	10	20	60	20	20	20	20

** Typical power ranges vary depending on various factors, i.e. on the different manufacturers, on the legislation in the countries, expected cost reduction of different technologies, grid connected or island mode of operation, or country of installation etc. Hgher capacity out of EU-DEEP scope*

*** Different sources have a different upper limit for DG. For example, DG Grid sets the upper limit at 50 MW for heat power plants and at 10 MW for small hydro power plants, while offshore wind is not DG at all.*

**** Cost figures give only a rough estimation as they strongly depend on many factors, i.e. interest rates,el prices, expected life time, kind of operation with varying full load hours, different Country's legislation etc.*

€;€€;€€€: cheap, moderate, expensive technology
☼;☼☼;☼☼☼:poorly, moderately, absolutely environmentally friendly
●;●●;●●●;●●●●: low; medium; high; very high level of social acceptance
*;**;***: usable; suggested; perfectly match to the requirements of the sector -: not suggested

Source: [EU-DEEP 2009]

2.2. Wind power

At the end of 2008, the European Union was responsible for 53.9% of the world's wind power capacity (put at 120,954 MW) and seven of the top ten countries in terms of installed capacity are EU Member States. Germany however lost its world leadership to the United States in 2008 [EurObserv´ER 2009], and both China and the USA installed more new capacity in 2009 than Europe [GWEC 2010].

European wind turbines produced 118 TWh of electricity in 2008 compared to 104.4 TWh in 2007, i.e. a 13% increase (13.6 TWh). This additional gain is less than its 2006-2007 increase (22.2 TWh). The wind power sector is Europe's number two source of renewable electricity after hydroelectricity. Cumulative installed wind power in 2007 and 2008 in the EU is shown in Table 2. [EurObserv´ER 2009]

Germany had quite stable capacity increases in 2007 and 2008, 1700 MW each year, and a slight rise during the recession year 2009 to 1900 MW. Altogether Germany had a wind power capacity of 25,777 MW at the end of 2009. Spain had the second largest wind capacity in the EU with 19,149 MW at the end of 2009. Spain had the largest increase of all the EU member states in 2009, approaching 2500 MW. Denmark had the third largest wind power capacity in the EU in 2007, but by 2009 was only the 7th. France, Italy and the UK had strong annual increases in the vicinity of 1000 MW, but Portugal also surpassed Denmark in 2009. [EurObserv´ER 2009; EWEA 2010]

Table 2: Cumulative installed wind power, decommissioning included, in the EU in 2007 and 2008 (in MW)

	2007	2008		2007	2008
Germany	22 247	23 903	Belgium	287	384
Spain	15 151	16 740	Bulgaria	30	158
Italy	2 726	3 737	Czech Rep.	114	150
France	2 482	3 542	Finland	110	143
United Kingdom	2 477	3 406	Hungary	61	124
Denmark	3 124	3 166	Estonia	58	77
Portugal	2 150	2 862	Lithuania	47	65
Netherlands	1 747	2 225	Luxembourg	35	43
Ireland	855	1 028	Latvia	26	27
Sweden	831	1 021	Romania	3	11
Austria	982	995	Slovakia	5	5
Greece	871	985			
Poland	262	451	**Total EU**	**56 681**	**65 247**

Note: Overseas departments are included in the figure for France
Source: [EurObserv´ER 2009]

Wind power production in the EU in 2008 was equivalent to 4% of EU electricity consumption. Germany is the largest wind power producer in the EU with an output of 40 TWh in 2008. This, however, only represents about 7% of German consumption. Spain and Portugal have exhibited steep increases in the last two years and wind may very well have reached 10% of demand by now. Denmark has the largest wind energy share: circa 20% at the moment. Wind energy provides higher production shares for shorter time periods, for example in Spain 50-60%, and in Denmark and Germany market prices have even occasionally been negative due to strong wind production, especially during low demand periods.

Wind power is an intermittent power source depending on irregular wind currents. Capacity is frequently not utilised near its maximum. Comparing wind, for example, with nuclear power, one should always compare total production, not installed capacity, as nuclear capacity is three to four times as productive. On average, the capacity utilization rate is around 25% (equivalent to circa 2000 hours utilization period of maximum load), although individual wind farms may fare much better or worse depending on the local wind profile and average wind speed. New wind power installations have the advantage of being bigger and higher up in the air where wind speeds are better. On the other hand, in many regions the best and windiest areas have already been taken, forcing new installations to areas with less wind. Offshore wind offers the possibility for high utilization rates, but the salty, wet environment is technically very demanding for the physical wind power installations and investments are decidedly more expensive than on land.

Wind power installations have the tendency to be placed in clusters, usually in more desolate areas, and may therefore result in local network balancing problems which demand several different types of preparedness. One problem is the occasional overproduction compared to local electricity demand. Some distribution and transmission networks need upgrading and/or new power lines to be able to accommodate a larger intrusion of wind power. This has brought the use of energy storage to the agenda as an alternative or addition to upgrading. Electricity cannot currently be stored to any great extent.

This could change, as **electric vehicles** will have large batteries and be connected to the network. EVs can operate as DR, for example, postponing loading of their batteries for a time, but may also in the future act as active storage by feeding power back into the network during high demand periods or disturbances. EVs will offer a very promising power system balancing platform in the future, especially since the storage investment cost is part of the transport cost and does not require additional investment costs for the power sector. Other types of power storage like batteries (other than EVs) and capacitors are not very useful on a network scale.

2.3. Hydropower

Hydropower, in itself, is one of the principal renewable sources with an annual production of over 300 TWh. Swiss and Norwegian hydro production provides an additional 150 TWh to the European power system. Small-scale hydro production, on the other hand, only represents a minor part of this, 39.9 TWh or 13% of all EU hydro production in 2007 [EurObserv´ER 2009]. Here small-scale is less than 10 MW.

Due to environmental concerns and because the potential has already been significantly exploited, only small amounts of new hydro are expected. Small-scale hydro is not as commercially viable as large-scale hydro, although it is on par with wind power. This also means that small-scale potential is not yet as developed as large-scale potential. Small hydropower capacity, 12,791 MW in 2007, is however approaching its maximum potential in the EU-countries [EU-DEEP 2009]. Disturbing rivers is not as acceptable today and licensing may be cumbersome or not even permitted.

Hydropower is very useful and, in particular with large-scale hydro plants, is frequently combined with reservoirs with capacities running from hours to months. Hydro reservoirs are used as electricity storage and for balancing the power system. The river flow has only one direction through the reservoirs, but the output can be regulated.For example, to react to an excess supply of power, less hydropower is produced and the water is left in the reservoir.

Pumped hydro storage, also in use, pumps water up to a hydro reservoir with surplus electricity. The water is then used for hydro power production when electricity is needed.

Table 3: Hydro power production in TWh in the EU 1996-2007 by EU Member State

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
EU-27	323.3	332.4	343.5	340.9	353.2	372.7	315.4	306.2	323.6	307.0	309.0	310.0
Belgium	0.2	0.3	0.4	0.3	0.5	0.4	0.4	0.2	0.3	0.3	0.4	0.4
Bulgaria	2.7	2.8	3.1	2.8	2.7	1.7	2.2	3.0	3.2	4.3	4.2	2.9
Czech Republic	2.0	1.7	1.4	1.7	1.8	2.1	2.5	1.4	2.0	2.4	2.6	2.1
Denmark	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Germany	22.0	17.4	17.2	19.6	21.7	22.7	23.1	19.3	21.1	19.6	19.9	20.9
Estonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ireland	0.7	0.7	0.9	0.8	0.8	0.6	0.9	0.6	0.6	0.6	0.7	0.7
Greece	4.3	3.9	3.7	4.6	3.7	2.1	2.8	4.8	4.7	5.0	6.0	2.6
Spain	39.5	34.8	34.0	22.9	29.5	41.0	23.0	41.1	31.6	19.6	25.9	27.8
France	65.7	64.4	62.7	72.9	67.7	75.2	61.1	59.7	60.4	52.3	56.7	58.7
Italy	42.0	41.6	41.2	45.4	44.3	46.8	39.5	36.9	42.7	36.1	37.0	32.8
Cyprus	-	-	-	-	-	-	-	-	-	-	-	-
Latvia	1.9	3.0	4.3	2.8	2.8	2.8	2.5	2.3	3.1	3.3	2.7	2.7
Lithuania	0.3	0.3	0.4	0.4	0.3	0.3	0.4	0.3	0.4	0.5	0.4	0.4
Luxembourg	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Hungary	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Netherlands	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Austria	34.2	36.1	37.2	40.5	41.8	40.2	39.9	32.9	36.4	35.9	34.9	36.0
Poland	1.9	2.0	2.3	2.2	2.1	2.3	2.3	1.7	2.1	2.2	2.0	2.4
Portugal	14,8	13,1	13,0	7,3	11,3	14,0	7,8	15,7	9,9	4,7	11,0	10,1
Romania	15,8	17,5	18,9	18,3	14,8	14,9	16,0	13,3	16,5	20,2	18,4	16,0
Slovenia	3,7	3,1	3,4	3,7	3,8	3,8	3,3	3,0	4,1	3,5	3,6	3,3
Slovakia	4,3	4,1	4,3	4,5	4,7	4,9	5,3	3,5	4,1	4,6	4,4	4,5
Finland	11,9	12,2	15,1	12,8	14,7	13,2	10,8	9,6	15,1	13,8	11,5	14,2
Sweden	51,7	69,0	74,3	71,7	78,6	79,1	66,4	53,5	60,1	72,8	61,7	66,2
United Kingdom	3,4	4,1	5,2	5,4	5,1	4,1	4,8	3,2	4,8	4,9	4,6	5,1

Note: Malta is missing
Source: [Eurostat 2010]

2.4. CHP and other thermal power stations

Combined Heat and Power (CHP) systems include a variety of technologies and sizes. There are no good statistics on CHP production according to size. DG sized CHPs are usually based on simple construction to keep down costs and are used by SMEs, municipalities, commercial sites, households or/and industries.

In 2006, installed CHP capacity in the EU-27 was about 95,000 MW_e, generating approximately 11% (366 TWh) of electricity demand. [EU-DEEP 2009] estimates that about 50% of the total CHP generation is from plants with a capacity less than 10 MW_e. On the other hand, almost all Finnish CHP production of well over 25 TWh comes from power plants larger than 10 MW_e. Smaller CHP plants using local energy sources (solid biomass, peat) have only become competitive in recent years due to technological innovations and financial support. CHP as percentage of gross electricity production (2007) is the largest in the EU in Denmark, 44%, followed by Latvia, 41% and Finland, 34% [Eurostat 2010].

Electricity production from biogas in the EU in 2008 was 20 TWh. 42% was in Germany and 27% in the United Kingdom, both using primarily electricity-only plants. Nordic (Denmark, Sweden and Finland combined) electricity production from biogas is small, 0.3 TWh, but it is practically all CHP based. Most Member States produce biogas primarily from sewage sludge and landfills, though Germany and Austria have an overwhelming bias toward other sources (mostly decentralized agricultural plants etc.). Nordic production of electricity from solid, renewable municipal waste is twice that of the UK, but still only half of Germany's 4.5 TWh [EurObserv´ER 2009].

Gross electricity production from solid biomass in the European Union reached almost 60 TWh in 2008. Finland, Sweden and Germany are the big players, each producing about 10 TWh [EurObserv´ER 2009].

District heating solid fuel CHP's have only recently come down in size. The support for RES must be seen as the main driver. Small CHP's are able to exclusively use biomass as a fuel, while larger units have difficulty procuring adequate amounts of biomass at reasonable prices within reasonable distances (distance correlates strongly with price). Standardized biomass fuels like pellets, which are easier to transport, are already much more expensive than raw biomass. Most of the wood used in Finnish biomass small scale CHP is waste wood from saws or forest processed chips out of stubs, branches or forest thinning. Due to feed-in tariffs, saws in Germany are now also producing electricity from waste wood.

District heat consumption has a diurnal, weekly and seasonal variation. But the variation correlates with the electricity load variation. As capacity cost is high in CHP plants in comparison to heat boilers, CHP capacities are dimensioned for high capacity utilisation. High capacity utilisation is not achieved by dimensioning according to peak heat load, but to a lower heat load. It is seldom very cold, so peak heat capacity consists of inexpensive heat-only boilers. Therefore CHP production will not vary during cold weather when electricity demand peaks. Summer heat demand is usually not above CHP start up minimum load in smaller district heat networks. In larger networks only one CHP plant is operational and at partial loads. This may change with the spreading of district cooling (absorption pumps using district heat to produce cooling at site). This is not only true for warmer climates. Surprisingly, cooling is also needed in the Northern countries and all year round, e.g. in department stores and offices.

While CHP is used for district heating primarily in the North and East European countries, in other countries CHP applications have been primarily restricted to industry and commercial buildings. Small-scale CHP systems have only recently begun experiencing some development growth due to the large potential market in the residential and commercial sector for CHP units of 100 kW_e and above. Micro-CHP, particularly below 20 kW_e, is still in the demonstration phase (Stirling engines, organic Rankine cycle). Applications of that size in the EU have used internal combustion engines. Fuel cells display high electrical efficiency but have a very limited deployment due to cost considerations [EU-DEEP 2009].

Heating systems, whether district heating networks or single households, may have **heat accumulators**. Heat accumulators can be very large. Heat accumulators can be used to prime CHP production, the traditional use, so that better load factors result for the CHP plant and smaller demand for excess and costly peak heat plants. Denmark has also implemented electrically heated storage to siphon excess wind power from the grid. The heat is then used for heating. **Electric boilers** using electricity to produce heat are also used by industries and DH utilities, although to a lesser extent than before. With the increase in intermittent power production they might become cost-effective once again. In the Nordic countries, which have a lot of electrically-heated houses, hot water household tanks are usually heated at lower tariffs (during the night). **Hot water tanks** may also be utilised in connection with end user demand response, being loaded with heat by electricity at low market prices (e.g. during times of excessive wind power production). Hot water tanks may also be an important part of household CHP. In households, heat demand is more volatile and the principal heating capacity must be reserved for hot tap water where hot water tanks are not in use. Overall, the heat energy for hot tap water might be 30% or more of total heat demand even in the cold Nordic climate. This share is expected to increase with more stringent building codes on heat loss.

Compressed air energy storage (CAES) involves compressing air using inexpensive energy so that the compressed air may be used to generate electricity when the energy is worth more. To convert the stored energy into electric energy, the compressed air is released into a combustion turbine generator system. Typically, as the air is released, it is heated and then sent through the system's turbine. The storage system round-trip efficiency is around 75%. [Eyer and Corey 2010]

CAES is a large-scale technology at the moment, with two large installations active, but also small scale solutions (also in combination with CHP and heat storages) are studied.

2.5. Other DG types

2.5.1. Photovoltaics (PV)

Germany produced 3.1 TWh of electricity and Spain 0.5 TWh from photovoltaics in 2007 [Eurostat 2010]. Other Member States produced less than 0.04 TWh.

In 2008, over 80% of the world's installed photovoltaic capacity was in the EU. European capacity more than doubled from 1,833 MW_e in 2007 to 4,747 MW_e in 2008, and was to 99.8% connected to the grid. The largest capacity increase of 2,700 MW in 2008 took place in Spain. Cumulative German photovoltaic capacity in 2008 was 5,400 MW_e and Spain's was 3,400 MW_e. Italy has the third largest capacity (500 MW) and France the fourth (100 MW). [EurObserv´ER 2009]

Photovoltaics are seen as more of a Middle to South European than a Nordic form of DG. Although the sun also shines up North, it is primarily during the summer and not during the winter, when electricity is most needed. The sun has a similar basic daily rhythm as general consumption and in areas requiring air conditioning, like Southern Europe, production and consumption take place at the same time. Consumption and production peaks are slightly offset one from the other as cooling demand is highest in the late afternoon.

Photovoltaics are well suited for end-user installations, where only surplus production needs to be sent to the grid. Some feed-in tariffs might demand all production to be put into the grid, as the German tariffs did, but the trend is toward on-site use of production. As photovoltaic is a very low capacity form of DG, it can be seen as reducing distribution losses while the negative effects on the distribution network are diminutive. As such it has high potential for efficient energy use, but remains costly.

Building codes may restrict installations in some architecturally valuable areas. The solar orientation of installations is frequently not optimised, but rather placed according to available mounting surface on facades and roofs. This lowers the efficiency of the panels. Large photovoltaic installations can be placed on the ground or on flat roofs and may have moving panels. Thin-film PV, with markedly lower cost but lower efficiency, is not as affected by these restrictions.

2.5.2. Solar thermal electricity

Worldwide concentrated solar thermal capacity stood at 679 MW_e in 2008. Spain was the one and only major player in Europe with a capacity of 81 MWe. The largest unit in Spain is 50 MW, with a twin unit to be completed in 2009. [EurObserv´ER 2009]

Solar thermal electricity, or Concentrating Solar Power (CSP) as it is also known, has potential as regular power plants, though not really as DG. It is more cost-effective than PV. The best potential is in Southern Europe. In contrast to photovoltaics the heat can be stored, allowing for smoother intra-day operations.

2.5.3. Geothermal electricity

Geothermal electricity production is dependent on suitable ground heat. The European net electricity capacity is 719 MW_e in 2008, with Italy being by far the most dominant Member State, producing 95%, i.e. 5.6 TWh, in 2007. Geothermal units are operated as base load units as the energy is without cost but the capacity is expensive. The overall production costs are competitive, but depend on suitable geographical location.

2.5.4. Ocean energy

The ocean -or thalasso-energies- harness five different types of sea- and ocean-energy flows: tides, waves, currents, osmotic pressure (due to the salinity difference between fresh water and the ocean) and deep water thermal gradients. Currently, the tidal power sector is the most mature. A single French site -the Rance tidal 240 MW power station commissioned in 1966- produces 90% of the world's current thalasso-energy. [EurObserv´ER 2009]

Ocean energy capacity faces a tough marine environment. Most technologies are at prototype stage and as such are small-scale. These remain very expensive technologies and face severe environmental constraints. This may favour small unit size even in the future. Tidal power, however, is more typically a form of centralized production as it, of necessity, is very large, matching larger offshore wind farms. Tidal power represents less of a technological problem than an environmental problem. Tidal power is very regular and manageable, and so is osmotic pressure or deep water gradients (more for tropical climates), whereas wave power is intermittent.

2.6. Gas

2.6.1. Biogas

The natural gas network is a very centrally oriented operation. The main decentralized aspect is the possibility of supplementing biogas to the gas network. This is a way of turning a decentralized (renewable) energy source into a centrally used alternative. Helsinki Energy, for example, has a target to become CO2 free by 2050. As a municipality with a massive electricity and district heating production of near 10 TWh, nowadays produced by over 90% with fossil fuel CHP's, it will be logistically expensive and difficult to get that amount of renewable energy delivered.

Helsinki Energy has a 630 MW_e combined cycle gas turbine power plant, so instead of using natural gas it could use biogas produced at different locations along the natural gas pipeline.

Biogas networks are also a possibility, either in areas where there is no natural gas grid or when the upgrading of biogas to natural gas quality is seen as too expensive. This might be the case if biogas is only used for heating, for example. Biogas consists of to 45% to 75% methane, whereas natural gas networks demand methane contents of over 96% depending on the Member State and natural gas network [Persson 2006]. Biogas has to meet other demands also, both in relation to energy content and to other gases, before it can be inserted into the gas grid. Vehicles using compressed natural gas may use upgraded biogas.

Natural gas has a role in decentralized electricity production as it is most suitable for end-user CHP. Not only does it have low CO2 emissions compared to oil or coal, it also has low particulate and SOx emissions. Natural gas has a CHP potential at existing end-use customers who have a reasonable heat load, but the CHP system at the customer end must be reliable, safe and fully automated. Natural gas is also used for industrial and DH CHP.

Power production from biogas has increased steeply, mainly in Germany and Austria, due to generous FIT's [Persson 2006]. Power production from biogas was 20 TWh in 2008, but most of it took place at the biogas production site. The optimal use of biogas uploaded to the gas network would be in vehicles, benefitting all the principal EU targets. As the RES target is measured as final energy use, low-efficiency power production seems to be a waste of a scarce renewable resource.

2.6.2. Hydrogen systems

The interest in **hydrogen** stems from its being a very clean fuel, as there are no emissions except water. Hydrogen can with advantage be used in high efficiency stationary or mobile fuel cells, but their use as an alternative transport fuel is the more important one. Hydrogen is not a natural raw material on earth. It must be manufactured. This is done, for example, using natural gas or biogas. Electrolysis is another choice, but it is more energy inefficient. The idea is to use excess intermittent power production, e.g. from wind power, to produce and store hydrogen for the transport sector. The hydrogen system might also be a future active solution for the balancing of intermittent power production, using stored hydrogen to produce power when needed.

Hydrogen can be compressed for storage, but this still requires significant amounts of space compared to gasoline tanks; thus it represents a more meaningful solution for the stationary sector. Mobile hydrogen storage is a problem and the use of hydrogen as a transport fuel is what is really targeted with hydrogen systems. Hydrogen tanks exhibit several difficulties. The hydrogen molecule H_2 is very small and reactive, imposing high demands on the tanks. Hydrogen stored in chemical compounds, e.g. metal hydrides, is a safe media being researched for mobile tanks. But all in all this makes the tanks expensive and quite heavy relative to their energy content.

3. Current Legislative and Policy Framework

3.1. Member States rights and Implications for Decentralized Energy's Deployment

Energy has become a shared competence with the entry into force of the Lisbon Treaty. Article 194 of the TFEU lists both the EU's and Member State competences. EU level competences as stipulated in article 194 paragraph 1 are the following: ensuring the security of supply, the completion of the internal market, the promotion of the interconnection of energy networks, energy efficiency, energy saving and the development of new and renewable forms of energy, those are. Nevertheless, all European measures taken under this article should not affect Member State rights to determine the conditions for exploiting their energy resources, the choice between different energy sources and the general structure of their energy supply, as underlined in paragraph 2 of the same article. In sum, important aspects in the field of energy remain intergovernmental.

However, EU policy drivers such as the Third Energy package and the Energy and Climate Package with its 20-20-20 binding targets temper Member State competences[3]. Sovereign on the definition of their national energy mix, Member States must comply by 2020 with legally-binding commitments on the reduction of carbon gas emissions and the promotion of renewable energy sources (RES). The Energy and Climate Change package also creates indirect pressures to improve energy efficiency, even though the goal of increasing the EU's energy efficiency by 20% by 2020 is not binding. This said, the 2006 End-use Efficiency and Energy Services Directive (ESD) directive does establish a requirement for a 9% increase in energy efficiency by 2016 as a binding target for the non-trading sector[4].

All these elements influence the definition of the national energy mix towards the increase renewable sources of energy supply (biofuels, biomass, wind, solar, geothermal, ocean and hydro-power) depending on national sensibilities and geographical constraints. Thus by 2020, at least 20% of the EU's final energy consumption should come from renewable energy sources. In order to meet this goal, the Commission assigned the Member States national binding targets in a range going from 10% in Malta to 49% in Sweden, in function of their capacity to increase their share of renewables[5]. Directive 2009/28/EC on the promotion of renewable energy provides an important legal framework for meeting this goal, through the requirement of creating national renewable energy action plans (NREAPs). Member States nevertheless have the flexibility to decide for themselves how they will meet national targets and how they will support the further adoption of renewable energy technologies. The NREAPs create predictability and transparency and offer a secure climate for private investors in each Member State. On the 11th of March 2010, the European Commission announced that the EU as a whole will exceed its 20% renewables goal by 2020, even though different situations can be observed in different EU Member states.

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[3] All EU Member States have agreed on the 20-20-20 binding targets stipulated by the December 2008 Energy and Climate Package.

[4] See the End-use Efficiency and Energy Services (ESD) Directive (2006/32/EC).

[5] http://ec.europa.eu/environment/climat/climate_action.htm

The Third Energy Package[6] provides a regulatory framework, which should be favourable to the further deployment of DG. Indeed, the powers of national regulators have been reinforced, a Regulatory Agency at the EU level has been created and the effective unbundling of networks should be achieved in order to ensure the completion of the internal energy market. Rules laid down in the Second Energy Package's Electricity Directive 2003/54/EC with regard to 'effective unbundling'[7] have not been fully implemented and enforced by several Member States, especially at the distribution level (DSOs)[8]. The latter, if '*part of a vertically integrated undertaking shall be independent at least in terms of its legal form, organisation and decision making from other activities not relating to distributing*[9]'. Nevertheless, this directive allows Member states to remain exempt from legal unbundling requirements for DSOs with fewer than 100,000 customers, both for electricity and for gas[10]. This clause gives little incentive to DSOs to be proactive in their initiatives to integrate new DG independent producers. Moreover, some small DSOs that remain exempt from this legislation possess their own DG installations connected to their network. Indeed, in Third Energy Package Directives 2009/72/EC and 2009/73/EC, the 100,000 customer exemption without time limit still exists. Thus some Member States can implement the exemption in a narrow way, by fixing the threshold at less than 100,000 customers (Denmark), whereas others can interpret it broadly (Germany, France). Despite these different national implementations of Directive 2009/72/EC, there is a common energy goal at the EU level based on three pillars: sustainability, security of supply and competitiveness, which should eventually lead to further DG deployment.

6 The Third Energy Package is made up of five EU legal acts: Directive 2009/72/EC concerning common rules for the internal market in electricity, Directive 2009/73/EC concerning common rules for the internal market in gas, Regulation (EC) N° 713/2009 establishing an Agency for the Cooperation of energy Regulators; Regulation (EC) N°714/2009 on conditions for access to the network for cross-border exchanges in electricity and Regulation (EC) N°715/2009 on conditions for access to the natural gas transmission networks.

7 The European Commission defines the effective unbundling as such: "the effective separation of networks from activities of generation and supply" (Directive 2009/72/EC).

8 Communication from the Commission to the Council and the European Parliament, report on progress in creating the internal gas and electricity market, COM (2010)84 final, Brussels, 11 March 2010.

9 Article 26, Directive 2009/72/EC concerning common rules for the internal market in electricity.

10 Ibid. The objective of this clause is to offer protection to small DSOs, with few employees.

Table 4: Unbundling of DSOs in Electricity

Electricity	Number of DSOs	Number of DSOs Owner-ship Unbundled	Number of DSOs Legally Unbundled	Application of 100.000 Customer Exemption	Numbers of DSOs with less than 100.000 Customers
Austria	130	0	11	YES	119
Belgium	26	NA	26	NO	NA
Bulgaria	4	4	4	NO	1
Cyprus	1	0	0	YES	0
Czech Republic	3	0	3	YES	278
Denmark	89	0	89	NO	82
Estonia	40	NA	1	YES	39
Finland	89	1	50	NO	82
France	148	0	4	YES	143
Germany	862	0	150	YES	787
Great Britain	19	0	19	NO	5
Greece	1	0	0	NO	0
Hungary	6	0	6	NO	0
Ireland	1	0	0	NO	0
Italy	151	130	12	YES	139
Latvia	10	9	1	YES	9
Lithuania	2	0	2	YES	5
Luxembourg	8	0	1	YES	7
Malta					
Northern Ireland	1	0	1	NO	0
Norway	162	9	41	YES	155
Poland	20	0	14	YES	6
Portugal	13	10	11	YES	10
Romania	35	5	8	YES	27
Slovak Republic	3	0	3	YES	159
Slovenia	1	0	1	NO	0
Spain	346	0	346	YES	340
Sweden	175	0	175	YES	166
The Netherlands	8	5	8	NO	2

Source: Regulators Data

Table 5: Unbundling of network Operators,: Gas Distribution

Gas	Number of DSOs	Number of DSOs Owner-ship Unbundled	Number of DSOs Legally Unbundled	Application of 100.000 Customer Exemption	Numbers of DSOs with less than 100.000 Customers
Austria	20	0	8	YES	14
Belgium	18	NA	18	NO	NA
Bulgaria	32	NA	0	YES	32
Cyprus	NAP	NAP	NAP	YES	NAP
Czech Republic	91	0	8	YES	83
Denmark	4	0	4	NO	2
Estonia	27	NA	1	YES	27
Finland	32	0	0	YES	32
France	24	0	3	YES	21
Germany	686	NA	145	YES	659
Great Britain	8	8	8	NO	0
Greece	3	0	0	NO	2
Hungary	10	0	5	YES	5
Ireland	1	0	1	NO	0
Italy	295	130	292	YES	214
Latvia	1	0	0	NO	0
Lithuania	6	0	0	YES	5
Luxembourg	4	0	0	YES	4
Malta					
Northern Ireland	2	0	1	YES	1
Norway					
Poland	6	0	6	YES	1
Portugal	11	0	4	YES	7
Romania	38	2	38	YES	36
Slovak Republic	46	1	1	YES	45
Slovenia	17	0	0	YES	17
Spain	20	0	20	NO	13
Sweden	5	0	5	YES	5
The Netherlands	12	10	12	NO	2

Source: Regulators Data

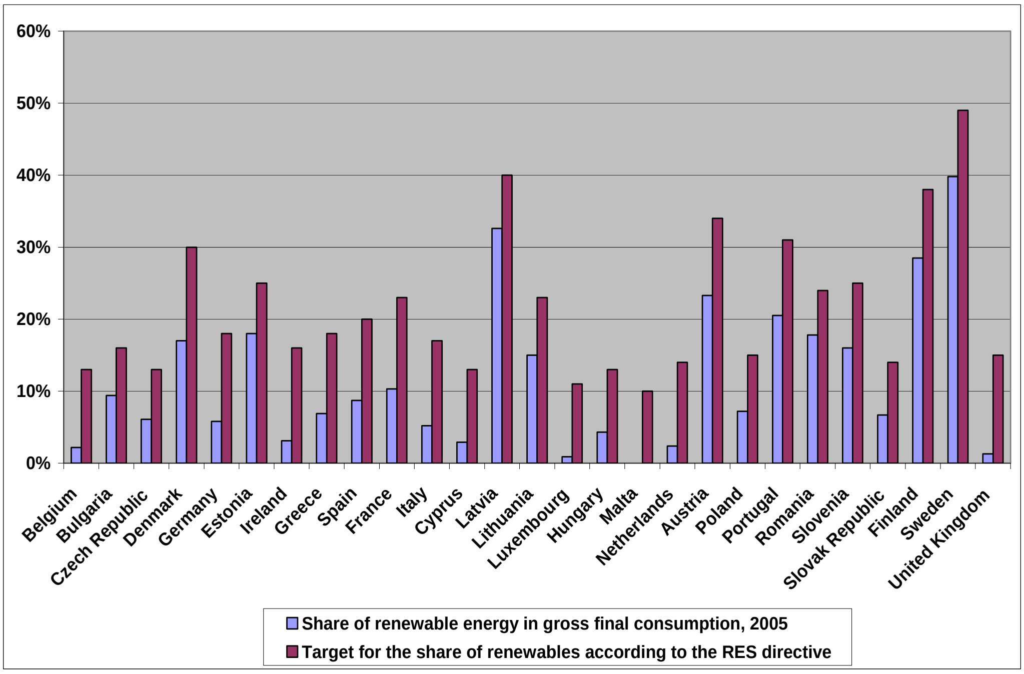
Source: Vattenfall, Germany

3.2. RES and CHP directives, EE legislation, 3rd energy package, in terms of sources of energy, distribution, supply and demand components

3.2.1. The Directives

The renewable energy directive was proposed on 23 January 2008 and was adopted by the Council and the European Parliament at the end of 2008. According to the RES directive [2009/28/EC] each Member State of the European Union is required to significantly increase the contribution of renewable energy sources in the national energy mix, leading to a 20% share of renewables in the EU by 2020. Further, each Member State is required to reach a 10% share of biofuels in the overall use of transport fuels by 2020.

Figure 2: National overall targets for the share of energy from renewable sources



Source: [2009/28/EC Directive]

Renewable energy sources (wind, solar, biomass, geothermal, biogas, ocean power etc.) produce comparatively less energy per unit of input than fossil fuels. As a result, in practice, micro or small-scale energy producing/ transforming devices necessarily contribute to the increasing decentralization of energy systems. According to Article 16 of the RES directive, Member States should provide for either priority access or guaranteed access to the grid-system of electricity from renewable sources. Based on this, from a regulatory point of view at least, the necessary condition for the development of renewable sources is given, though how individual states decide to implement this requirement remains to be seen.

The promotion of renewable energy technologies contributes to the development of decentralized energy production. However, easy access to the energy grids (electricity and gas infrastructure) remains a problem, not only in technical but administrative terms, as well. Operators of electricity or gas grids in most cases are/were at the same time energy producers, as well. They were therefore not interested in offering easy access for renewable energy producers and made network access difficult and costly, making renewable energy investments unfeasible or unprofitable. The European Union decision makers recognized this problem and after a long procedure established the so-called third energy package.

The package, including [directives 2009/73/EC, 2009/72/EC and regulations 714/2009/EC, 715/2009/EC], requires energy network operators to be independent (see above). Network operators must make network usage fees public and have to set the same conditions for different network users. Through the unbundling of network operators from energy producers, energy network operators will face few incentives to exclude other energy producers from the network and to make network access for other producers, e.g. decentralized energy producers, prohibitively expensive. Network usage fees should be the same for each energy producer which creates non-discriminatory access to the network and thus a competitive business environment.

As soon as the third energy package is integrated into the Member States' legislation and enforced, the legal and economic barriers of grid access will be significantly diminished. For decentralized energy systems/producers easy and non-discriminatory grid access is of crucial importance. However, if connecting to the electricity network requires additional investment of the same order of magnitude (depending only to a very small extent on energy generating capacity), micro-scale energy producers could, for profitability reasons, be excluded from decentralized energy production. Similarly, gas network connections may require high quality gas with specific pollutants removed and distributed at a specific, stable gas pressure. Complying with these requirements may be prohibitively expensive for small-scale biogas producers.

There are several reasons why the **directive on the promotion of combined heat and power production** [2004/8/EC] should be mentioned. First, CHP produces heat as a by-product. Second, energy use is more efficient if not only the generated electricity but also the generated heat energy is used. Third, CHP production requires connection to the electricity grid, thus the third energy package is relevant here. Fourth, CHP devices should be designed based on heat energy needs. However, since a sharp rise in the energy efficiency of buildings is currently being promoted by the European Union, this will significantly affect future heat energy demand and therefore the potential to benefit from CHP devices.

The CHP directive, approved in February 2004, addressed several problems in promoting CHP generation. However, electricity network connection remained an obstacle for a quick spread of CHP production and for small-scale, decentralized CHP production. The implementation of the third energy package could relieve this problem. However, although network connection should be free of discriminatory fees, energy network connections could remain prohibitively expensive for very small scale CHP producers (network connection issues are discussed below).

Finally, regarding CHP the **directive on the energy efficiency of buildings** (EPBD) should also be discussed. The directive [2002/91/EC] was adopted in 2002 to assist the EU in meeting its Kyoto Protocol commitments. However, as a process to amend this directive is ongoing, we note only the expected impact and requirements of the proposed new directive. According to text agreed by the European Commission and the Parliament in November 2009, all buildings built after 31 December 2020 must have "very-high energy performance" and their energy needs must be covered to a very significant extent from renewable sources. Further, according to the proposed directive, existing buildings will have to be improved in terms of their energy performance if this is technically, functionally and economically feasible. The agreed text still has to be formally approved by the Council and endorsed by the Parliament at the beginning of 2010.

3.2.2. Assessment of the relevant and future legislative framework

For decentralized energy systems and small scale power producers, energy network connection is seen as crucially important. If the creation of independent energy network operators promoted in the third energy package is realized, discriminatory tariffs for certain energy producers should be abolished. This would create a level playing field for different energy producers and enhance competition between market players. However, as discussed above, electricity or natural gas grid connection may require investments whose costs could be higher than acceptable for very small (household-) scale energy producers. Thus, in our assessment it would be advisable that the European Network of Transmission System Operators for Electricity/Gas elaborate network connection rules and third-party access rules [see Article 8 of regulations 714/2009/EC and 715/2009/EC]. These rules could make clear who pays for what in the case of new network connections. Although these rules are crucial for decentralized energy producers, as they have not yet been formally established, it is impossible to further evaluate network connection conditions. It would therefore be advisable that further decision making focus on these rules as, until quite recently, network connection costs have been one of the main obstacles for decentralized producers.[11]

Inconsistencies across CHP and the proposed energy performance of buildings directives (EPBD)

The energy consumption of buildings represents 25-40% of the energy consumption of European countries and is responsible for one third of the total CO_2 emissions of the European Union. The building sector is the only big energy consumer where energy consumption can be reduced to a very significant extent at reasonable cost. Recognizing this, European decision-makers proposed a recast of the EPBD which will primarily exert significant pressure on the heat energy needs of the building sector. Although the new EPBD was diluted during the decision-making process (e.g. modifying "zero energy" houses to houses with "very high energy performance" and energy covered to a *significant extent* from renewables, as well as the postponement of deadline from end 2019 to end 2020), it has important implications for heat production and therefore the design of CHP capacities.

From 2021, newly-built houses must have "very high energy performance", though the definition remains to be clarified in the final version of the directive. This means that no or only a very small amount of additional energy will be needed in buildings and households. 60-80% of the energy needs of households (depending on climate conditions) are made up by heat energy, used mostly for space heating. This share can easily be reduced or eliminated, unlike electricity consumption. Further, the new EPBD prescribes that existing building energy performance has to be improved after major renovations if this is technically, functionally and economically feasible. This means that future renovations will result in reduced energy consumption and thus reduced heat energy needs. Consequently, considerable attention should be paid to the promotion of CHP capacities—and more precisely to the dimensions of CHP installations—since significant reductions in the heat energy consumption of the household sector can be expected in the future.

Surplus heat generation capacity could result in lower efficiency of CHP generators and potentially increased carbon emissions. Further, district heating systems (pipelines) require huge investments. Pipeline lifetimes are planned for several decades, a time period long enough to make essential changes in heat energy demand possible. Consequently, newly built or currently proposed district heating systems can in the long run get into trouble if heat energy needs are reduced significantly in 20-30 years time.

[11] Current efforts of the European Regulators Group for Electricity and Gas seem to point in the right direction [see ERGEG 2009a].

Certainly, district heating systems are rarely planned to satisfy the needs of all the households in a country. However, a sharp increase in the energy efficiency of buildings reduces heat needs and therefore requires the district heating system operator to connect further households to the system, resulting in huge investments in pipeline laying. It has to be taken into consideration that heat energy needs of houses can be reduced by 50-80%[12]. Finding new buyers for this amount of heat requires the connection of many new households to the district heating pipeline.

Further, CHP units should allow for the exclusive production of electricity, as well. As heat energy demand is far lower in spring, summer and autumn than in winter, systems should be integrated into energy systems which can adapt to the flexible modification of the produced heat/electricity ratio, meaning that the CHP generator can be adapted to the changing heat energy needs. There are of course several countries (especially in Scandinavia) where average temperatures are lower and heat energy demand extends over 9-10 months per year. As a result, in these countries CHP production faces fewer constraints than in the case of Southern Europe. On average however, selling excess heat energy as hot water for households or steam for industrial use appears to be a reasonable solution. However, the hot water needs of households are far smaller than space heating requirements, especially in countries with colder climates. Selling heat energy for industrial uses is rather difficult, as well. Generally, industrial heat needs differ widely (in temperature and pressure) from household needs and require different pipelines. While pipelines for district heating are planned for a maximum of 120-150 degrees Celsius and the necessary pressure to avoid boiling, the industry mostly requires 3-400 degree (or warmer) hot steam to be delivered in the form of water at very high pressures. Even if this issue is solved, satisfying industrial needs in wintertime might cause difficulties as CHP units are preoccupied with producing heat for the district heating system. However, the problem of excess heat in summer might be resolved if new technologies such as tri-generation (production of electricity, heat and cold heat for cooling) become every-day-technologies.

Next, the electricity systems of some EU Member States lack energy storage capacities, namely electricity storage capacities. System operators, even in case of a low level penetration of decentralized energy production, face problems in balancing electricity supply and demand. In some Central and Eastern European countries, reducing electricity supply beyond certain limits is difficult. The reasons for this are for the most part technical. Many old power plants are not capable of adjusting to load changes or only at very slow rates. Generally, old coal-fired or nuclear power plants work at full capacity and for technical reasons their load is very rarely changed. Some gas turbines offer load following services but even these turbines face limitations: their performance can be reduced to 50% of maximum capacity, sometimes to 30%. Due to the high share of older power plants, in some countries it is difficult (and therefore costly) to balance electricity supply and demand. CHP units are normally operated depending on heat energy needs. During winter nights, when electricity demand is low but heat energy demand is high, CHP generators have to be in operation in order to fulfil heat energy needs, hence generating both heat and electricity. Due to the increased heat energy demand, electricity supply increases at times when demand is lowest, putting electricity system operators in difficulty.

[12] This is not only true for the Central and East European countries but for Germany, as well. For this see Deutsche Bank Research: „Bauen als Klimaschutz, Warum die Bauwirtschaft vom Klimawandel profitiert", 2008, in Aktuelle Themen 433, Frankfurt am Main, especially pp. 20-23.

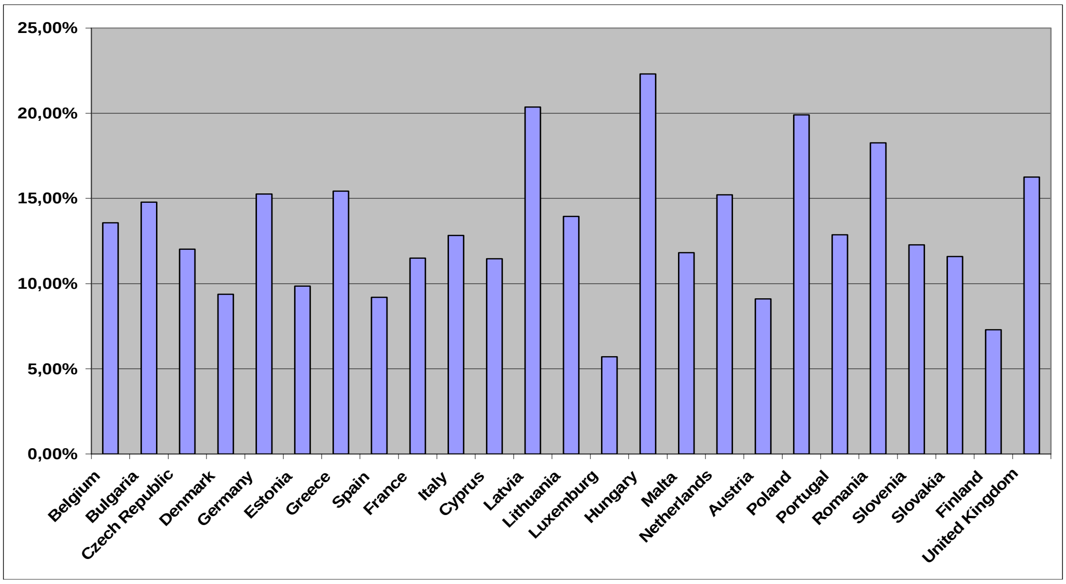
Due to the lack of adequate electricity storage technologies (see above, like hydro power plants, pumped storage, heat accumulators (not very efficient in countries in warm climates) or the relatively new compressed air energy storage), balancing is difficult. The calculation of the magnitude of such electricity production shifts reveals the importance of the problem.

A HUNGARIAN EXAMPLE

In Hungary there are approximately 4 million households. A normal household has a furnace with a heat capacity of roughly 20kW. A CHP unit having a heat capacity of 20kW has an electrical capacity of 3-7kW. If only 10% (400 thousand) such furnaces are replaced by CHP units, with operation of all the furnaces at the same time, 400000*(3-7kW) = 1,200-2,800MW new electrical capacity would have to be integrated into the electricity system. Electricity demand in Hungary during winter nights is roughly 3200-3400MW. In practical terms, this would mean that almost all big power plants (centralized power producers) would have to be switched off during that time. As, for technical reasons, the load of older type coal-fired power plants cannot or can only to a limited extent be modified and the reduction of load of older nuclear power plants results in a reduction of their lifetime, this is technically infeasible. More modern coal-based power plants already offer load-following services. New nuclear power plants are able to follow load, as well. However, there is an economic reason for operating nuclear power plants at maximum capacity: nuclear power stations are very expensive to build and they are profitable only if their capacity factor is high. This means that nuclear power plants, for economic reasons, have to be in operation at full capacity 7000-8000 hours a year in order to be profitable. Thus, they are not and will not be used as load following power plants.

Generally speaking, electricity supplying systems are designed such that electricity demand fluctuates between 30 and 75% of the net installed electricity-generating capacity. In other words, an electricity system with a net installed capacity of 1,000 MW supplies a system with a minimum electricity demand of 300 MW and a peak demand of 750 MW. If pumped storage power plants are in operation, the minimum necessary load can increase to 40-50%, depending on the capacity of the pumped storage power plant[13].

Figure 3: CHP electricity generating capacity compared to the total net installed electricity generating capacity, in case of a 10% penetration of CHP units with a 5 kW electricity generating capacity in households



Source: Eurostat data: net installed electricity capacity and the number of private households in 2007, own calculations

[13] Other factors such as electricity import and exports may play a role as well.

Electricity systems are designed such that at least 30% of the capacities are always in operation, since this amount of electricity is always in demand on the market. Figure 3 above shows that if all the assumed new CHP units (in 10% of the households) are operating (because heat is needed), on average 10-15 percentage points (!) higher electricity generating capacity is in operation. This means that electricity demand always has to be above 40-45% of the total net installed capacity. The problem is often that electricity demand falls far below the 40-45% level. Without higher electricity demand valleys an oversupply of electricity results and poses serious problems for balancing the electricity grid.

The above calculations draw attention to the fact that even a low penetration (10%) of CHP units replacing household furnaces can significantly increase electricity-generating capacity since these are assumed to be always in operation.

The problem could be solved in one of two ways: either heat or electricity should be stored. First, small (household) scale CHP units should have **heat energy storage** facilities, like relatively inexpensive hot water storage tanks. In this case, the electricity system operator switches on the CHP units in times of peak electricity demand (in the mornings, late afternoons and evenings), releasing the burden on centralized electricity producers and producing heat for storage in CHP units to be used up during times of lower electricity demand. Even in this case, in summer, excess heat is generated and a modification of the produced heat/electricity ratio seems unavoidable. Second, electricity should be stored in an inexpensive way. Despite the fact that a lot of effort has been put into research on cheap electricity storage, there are only a few tried and tested technologies that are widely available for all locations (unlike heat accumulators or hydro power plants) and it is hard to find an inexpensive and environmentally acceptable solutions. On the EU-level, however, the electricity/heat storage requires different approaches. As discussed above, in the Northern countries, electricity or excess heat (produced by CHP units) can be stored in heat accumulators as significant amounts of heat are needed during the whole year. This means that excess electricity can be used in times of low electricity demand for heat production. The other solution is to store excess heat produced by CHP plants. In continental European (excluding the Northern countries), especially in Mediterranean countries, however, space heating needs only occur 2-6 months a year. Using heat accumulators for storing electricity in these countries might be an inefficient solution.

The use of geothermal **heat pumps** provides a solution for satisfying heat energy needs without causing difficulties in the electricity system. Heat pumps can be operated based on the individual (household) heat energy needs, which means, they can be fully independent from each other. The promotion of geothermal heat pumps is therefore a good idea. However, two problems can occur. First, too many people shifting to geothermal heat pumps might significantly reduce heat energy purchases from district heating systems. This is a problem especially if these are based on biomass or CHP. Second, simply installing heat pumps as a substitute for traditional furnaces is, in terms of primary energy saving and environmental protection, not always the best solution. Heat pumps need electricity produced through the transformation of primary energy sources, with nation-wide average thermal efficiencies ranging between 30-40%. Heat pumps produce roughly 3-4.5 kWh of heat energy by consuming 1 kWh of electricity (coefficient of performance (COP) value is 3-4.5). Thus, if the average thermal efficiency of the electricity production in a country is 33% and a heat pump with a COP-value of 3 is installed, no primary energy saving is achieved. The primary energy consumption in an electricity generating power plant amounts to 100 units (calorific value). This is then converted into 33 units of electricity which is afterwards converted back into 99 units of heat by the heat pump. Moreover, as electricity prices are often much higher than for instance natural gas prices, the cost advantages are often not as obvious as implied by the reduction of energy paid for.

It can be true that only 33% of energy in the form of electricity (33kWh) is purchased for heating compared to the traditional furnace where 100kWh of energy is purchased in form of primary energy (natural gas). But 33kWh of electricity might cost as much as 60-80 kWh of natural gas, meaning that financial incentives are far less attractive. In countries with subsidized natural gas prices, the financial advantages might completely disappear. Certainly, heat pumps offer significant primary energy savings and environmental benefits if electricity is produced without combustion (e.g. using RES technologies). Next, if a heat pump installation replaces an outdated heating system, it may also bring efficiency increases. Further, price differences between electricity and natural gas/biomass used for heating might differ widely across countries. Thus national considerations should always be taken into account.

Knowing, that CHP units represent an efficient form of energy production, we support CHP production. However, we would like to draw attention to the changing heat energy needs of households resulting from the new EPBD. While change may happen very slowly, CHP capacities should be designed in a way that they are adaptable to heat energy needs. Fortunately, harmonization of the CHP directive and the EPBD offers a solution. If buildings are first switched to very energy efficient ones with significantly reduced heat needs, smaller capacity CHP units may be installed, resulting in smaller amounts of electricity production and an easier and less costly balancing of the electricity on the grid. Further, during summertime, a much smaller amount of superfluous heat is produced. As a result, electricity system operators are spared unnecessary burdens. The other way of integrating large capacity CHP units is to build energy storage facilities and use them to respond to electricity demand valleys. The third option is to delink heat production from electricity production, though in this case all the benefits of combined heat and power production are lost.

Geothermal heat pumps offer a good solution without causing imbalances in the electricity network. However, the first order of importance should be the energy performance of buildings. This should be favoured prior to the installation of heat pumps. If building shells are insulated and energy efficient windows are installed first, significant primary energy savings can be achieved. As a result, less heat energy is needed, resulting in both lower heat pump electricity consumption and lower carbon emissions.

3.3. National schemes, monitoring and Member State experiences

3.3.1. Policy options for supporting renewable energy sources

The various forms of regulatory instruments used to support the deployment of RES technologies have been extensively discussed in the literature [see e.g. Ragwitz et al, 2006]. We first discuss the principal strategies employed across different countries in some detail and then provide examples from selected countries.

Investment incentives often take the form of direct grants made available to support specific kinds of renewable energy technologies. There can be many variations of such grants but the main idea is to directly transfer funds from a public authority to the owner of the installation and, according to Connor et al (2009), that is what makes them so popular. The other main advantage of this strategy is its simplicity leading to low transaction costs and the fact that it allows the targeting of very specific technology segments. On the other hand, the fact that it directly burdens public budgets means that it is very dependent on the political climate of the moment. This makes such strategies unstable, or at least not stable enough for long-term investment planning. Moreover, investment incentives ultimately provide fewer incentives for the efficient operation of new systems once they have been installed.

Tax incentives are price-driven generation-based mechanisms that provide tax breaks to renewable electricity producers by exempting them, for example, from paying normally applicable electricity taxes. In practice, tax incentives act just like a negative or avoided cost and thus can be compared to feed-in tariffs (see description below). For the most part, tax credits have been implemented for wind and solar at federal level in the US. This mechanism has ultimately proven far less successful than some of the other mechanisms discussed below. However, this is presumably not a function of the mechanism itself, since many of the incentive schemes employed in some EU Member states have provided far more generous subsidies. Moreover, boom-and-bust cycles in the US renewable energy market during the 2000s have resulted primarily from the changing political consensus. This in turn has resulted in repeated failures to renew tax credits on a timely basis. Other schemes are likewise possible such as reductions of the VAT in order to favour targeted technologies.

Tendering systems are quantity driven mechanisms consisting of a bidding process among project developers to obtain favourable financial conditions for individual projects. This can either take the form of a direct and upfront subsidy for each kW of renewable electricity capacity installed (i.e. *investment focused*) or a predefined price for each kWh of electricity produced during a predefined period of time (i.e. *generation-focused*). More often than not, in these bidding rounds different technologies do not compete against each other as tenders are usually only open to specific eligible technologies. Project size may also be defined in the specifications. As an example, the EOLE program launched in France in 1996 only targeted large-scale wind. The main advantage of tendering strategies is that they offer an environment of competition in which lower prices are encouraged for the benefit of the consumers. The downside is the great incentive for producers to offer unrealistic and unattainable price and performance targets in order to be retained during the bidding round. However, this can potentially be avoided with the imposition of adequate penalties for the case of non-delivery. On the other hand, further criticisms plague tendering strategies. One such criticism derives from their intermittent nature: they do not work on a continuous basis like some of the other instruments described in this section. The result is they fail to promote continuous growth of renewable energy sources [Connor et al, 2009]. A final downside to tender strategies is that they tend to favour larger scale producers who have the necessary resources and expertise to put together and place bids on available tenders.

Feed-in tariff (or FIT) models pay either a fixed price or a premium on top of the electricity spot price for the generation of renewable energy technologies based on the number of kilowatt hours of energy generation. The duration of the contractual period is of crucial importance as it directly impacts investor security. At the time of writing, it is the most widely-used incentive mechanism in EU Member States (see below). The tariff should be set at level higher than the marginal cost of generation [Ragwitz et al. 2006]. FIT strategies often provide "*differentiated*" feed-in tariffs based either on the type of technology used or on geographic location. In this sense, one specific advantage of FIT strategies is that countries can choose to favor different technologies (based for example on regional comparative advantages or some other logic) and develop a corresponding tariff structure. Thus for example Germany employs a FIT strategy that is differentiated both by technology and by the geographic location of energy generation. Higher FIT's are paid for Solar PV energy generation than for wind power, for example, and higher tariffs are also paid for wind power in low wind locations and for off-shore wind power (in order to encourage both geographic dispersal and off-shore wind power). Thus Spain, for example, could choose to favour solar PV and CSP technologies, while Germany could choose to favour wind power. Moreover, where particular technologies are not advisable (for whatever reasons), countries can always choose not to include individual technologies.

Thus countries that have limited biomass resources, for example, might choose not to set tariffs on biomass-based energy generation. Differentiation by size is also possible and frequently used. Slovenia for example applies the following segmentation for self-standing solar PV structures [EREF 2009], which tends to favour the smaller installations:

Table 6: Tariff levels for self-standing

Size	Tariff
<50kW	390.42 €/MWh
<1MW	359.71 €/MWh
up to 5 MW	289.98 €/MWh

Source: [EREF 2009]

There appear to be few immediately obvious downsides to the use of FIT strategies. Complaints occasionally arise concerning the tariff levels set by individual governments or for individual technologies. For example it has been argued that the solar PV tariff in Spain was previously too high, resulting in massive and extremely rapid adoption of solar PV technologies. Complaints have also been raised about the undifferentiated FIT in Hungary, since it provides no variation in tariff levels for different technologies and it generally sets the renewable tariff at a level that provides very limited incentives to invest in renewable technologies [see e.g. Ellison and Hugyecz 2008]. Further complications can arise in countries that use the FIT strategy, but these are frequently related to features not related to the FIT. For example, in some countries, the permitting process for wind power installations can be restrictive. None of these criticisms, however, are specifically related to the FIT as a mechanism.

Under **Renewable Obligation (RO) regimes**, producers, suppliers or consumers of electricity have a legal obligation to produce, supply or consume a certain share or amount of renewable electricity. Players that do not respect this obligation are fined. Making RO efficient very often requires combining it with market-based instruments such as **Tradable Green Certificates (TGC)**, whereby players have the choice between directly complying with the RO or buying certificates from another player who has surplus renewable production (similarly to the exchange of carbon credits under the EU-ETS). This strategy is fairly new compared to FIT strategies but it is used in a number of Member States. The tendering processes frequently used to gain the right to build RES installations tends to favour larger scale RES producers and creates disincentives for smaller scale RES producers due to the expertise and resources required to submit formal tenders. Moreover, since the certificates sold are usually based on 1 certificate = 1 MW of energy generation, RO systems are not differentiated by technology and/or location. It is frequently argued that such non-differentiated strategies tend to favour the cheapest RES technologies, typically wind power. It is worth noting that the EU RES Directive chose the RO model as a means of trading credits in RES energy generation across Member state borders. It is also worth noting that a number of countries that previously used the RO model have now also introduced complementary FIT strategies (such as the UK). RO strategies also frequently suffer from volatility the prices for green certificates which create barriers to long-term investment planning.

Apart from mechanisms directly supporting the deployment of renewables, it is also worth discussing **two indirect instruments that also have an effect on the development of sources of energy: carbon markets and carbon taxes**. In both cases, the primary objective is to reduce carbon emissions. In this sense, these instruments only indirectly favour the use of renewable technologies.

By putting a price on carbon and raising it over time, a carbon market or a carbon tax provides a price incentive to reduce emissions: either by reducing energy use altogether, making energy use more efficient, or by shifting to low carbon technologies. Thus, these instruments improve the price competitiveness of clean energy sources compared to conventional fossil fuels. An explicit advantage of this model is that economic players tend to favour the most cost-effective mitigation options, whether fuel switching, energy efficiency or renewable energy production. Several of the timber-rich countries for example, that have introduced carbon taxes are heavy users of bioenergy resources, in particular for heating and power (Finland and Sweden, e.g. are the top two users of bioenergy).

3.3.2. Comparing the efficiency of support schemes: examples of national practices

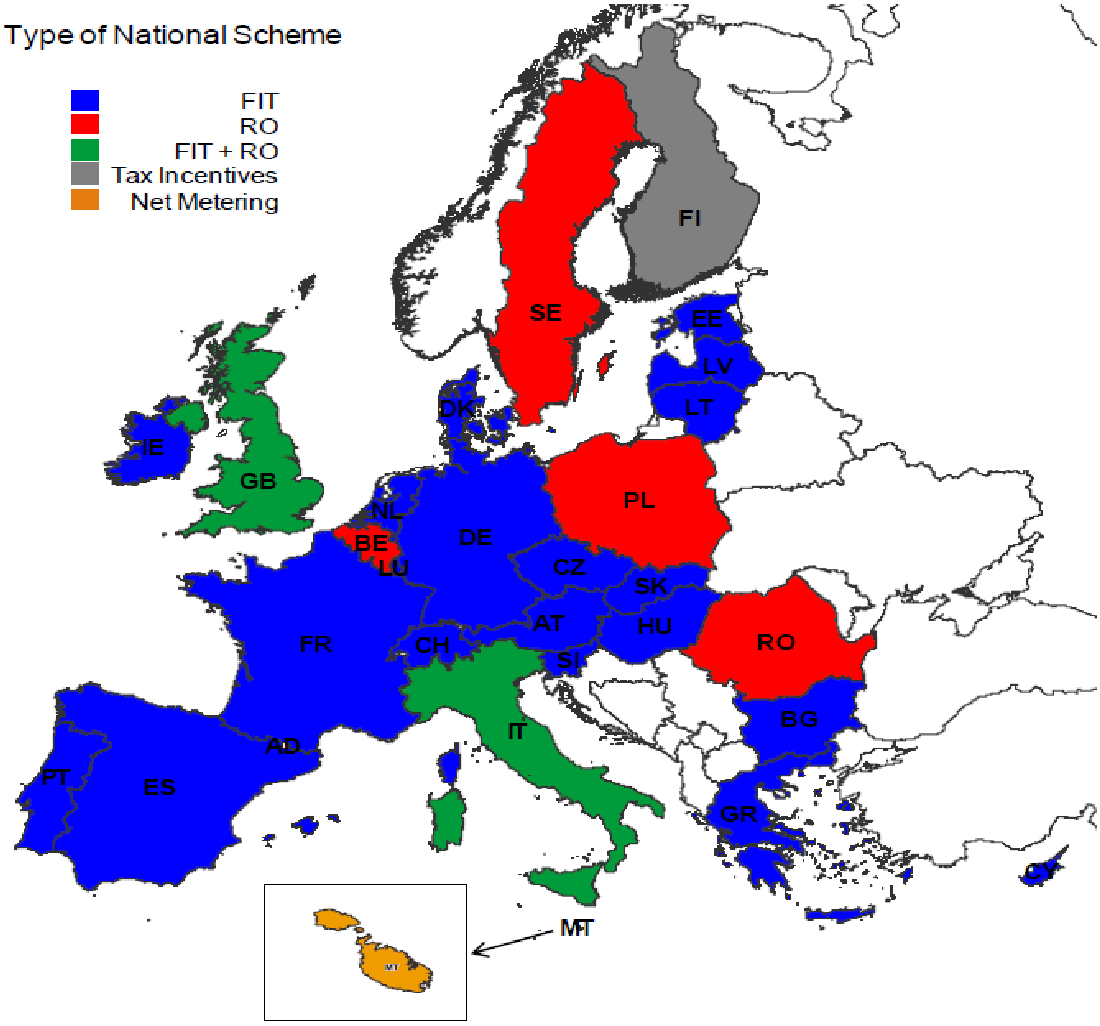
To-date there has been no EU-wide harmonization of regulatory instruments supporting decentralized energy production between Member States. The Directive on the promotion of the use of energy from renewable sources adopted by the EU in 2009 only encourages the design and coordination of joint support schemes among Member States. Consequently, each Member State has chosen its own combination of mechanisms taking into account its national renewable objectives as well as national circumstances. Thus states can choose to favour different renewable energy sources based on potential, the status of the national industry, or the need for job creation, etc.

The relevance of each scheme is highly dependent on the maturity of the technology considered. As the maturity of a technology increases, the most favourable combination of instruments to support its deployment gradually changes, moving from market-push measures supporting directly highly capital-intensive non-mature technologies to market-pull measures when alternative technologies get closer to being competitive with conventional ones. In this regard, R&D investments tend to fall into the category of pre-market or market-push measures while FIT or the Green Certificate model (TGC's) should be thought of as market-pull measures that help to commercialize increasingly viable technologies. Investment subsidies and large one-time tax write-offs, on the other hand, are particularly relevant as commercializing measures where initial capital outlay requirements are high (e.g. as with solar PV systems). Carbon taxes, on the other hand, are potentially more relevant where initial capital investment costs are not significant, but where consumers are not otherwise likely to shift away from conventional beliefs and behaviour. Various combinations of these different incentive schemes may also prove useful. For example, the combination of a FIT model with some investment subsidies could prove a potentially useful tool for convincing some small investors and households to adopt RES technologies more rapidly.

To-date, the debate on supporting policies has typically focused on discussion of FIT and RO (combined with TGC) and has tended to neglect carbon taxes. Consequently, with a very few exceptions, Members States have chosen one of the two as the primary policy instrument for promoting the rapid adoption of renewable technologies.

The principal support schemes in use in the Members States are illustrated on the map below:

Map 1: Primary support schemes for renewable within the EU



Source: Adapted from Fraunhofer Institute, Energy Economics Group, 2008. Modified based on data from EREF 2009 and EREC: http://www.erec.org/policy-actions/national-policies.html.

A number of recent changes have occurred with this graph takes partially into account. **The UK, long a supporter of the RO certificate-based model, recently adopted a FIT strategy** that went into effect on 1st April 2010 [Ofgem] in order to encourage the uptake of small-scale decentralized energy technologies. However, the RO scheme will remain in place for large-scale installations. France has also recently moved toward the parallel adoption of a FIT strategy. Additionally, Finland is planning to implement feed-in tariffs for wind power this year. Malta, on the other hand, utilizes a *FIT-like* net-metering strategy. Finally, countries can and do choose mixes of the various basic models outlined above. In addition to the UK example just mentioned, Sweden also sports both a quota strategy and significant carbon taxes. In addition to these models, countries quite frequently employ a range of additional strategies such as RES investment subsidies, tax rebates and other incentives.[14]

FIT strategies typically target the substitution of RES technologies for fossil fuel-based electricity generation at both large **and** small scale (all the way down to individual household systems).

[14] Several sources are currently available on national level strategies. Perhaps the most exhaustive and up-to-date of these is provided by EREC: http://www.erec.org/policy-actions/national-policies.html.

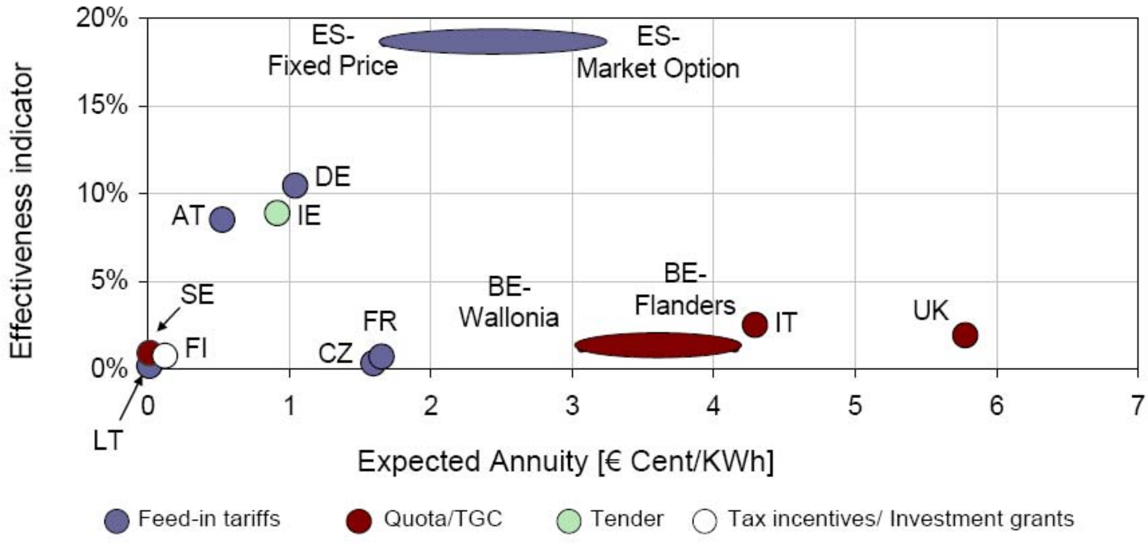
Since FIT strategies have this particular small scale advantage, they thus have the additional advantage of encouraging RES technologies that potentially reduce load (or demand) on the energy grid: at the smallest scale, building-based energy generation (e.g. solar PV), is (or at least can be) used directly. Thus FIT strategies provide the opportunity to bring energy production closer to the point of consumption. In this sense, FIT strategies are highly compatible with decentralized energy systems in the sense that they can promote the introduction of *both* larger *and* potentially very small scale electricity generation systems. Moreover, comparing the performance of RO-based and FIT strategies, FIT strategies clearly have performed better at promoting both the overall adoption of RES technologies as well as the more specific adoption of smaller scale household based energy generation systems. Further, it is presumably this fact which explains the recent shift to FIT incentive strategies in the UK and France. Though other mechanisms can potentially be used to encourage small scale and very local adoption of RES technologies, to-date, the FIT strategy has proven the most effective and efficient at achieving this goal.

In this general context, **the 2009 EU RES Directive [2009/28/EC] provides for trade in guarantee of origin certificates (Art. 15). This is essentially an EU-level Green Certificate strategy for trade in Renewable Energy Production credits**. This strategy corresponds to the RO method discussed above and adopts the 1 certificate = 1 MW of energy generation metric. The strategy does not allow for the differentiation of technology support based on type of technology, location or the size of individual generation units. Though it is often argued that such strategies tend to promote the cheapest forms of renewable energy (in particular wind power), there is little to no evidence that such strategies work well in practice.

Many Member states with national level FIT strategies were concerned that an EU level RO strategy could potentially disrupt the smooth functioning of national level incentive strategies and also favour wind power over other renewable energy sources, thereby weakening national level attempts to promote more diversified forms of RES [see Ellison and Hugyecz, 2008: Appendix A]. These Member state fears were not diminished by the adoption of a phased strategy. Moreover, the European Commission has agreed to review this strategy by 2014. In this sense, the EU-wide RO strategy may ultimately weaken efforts to promote more decentralized energy systems and encourage excessive use of a single RES technology, i.e. wind power.

As part of the Intelligent Energy Europe Program, the **2007 OPTRES project** provides a comparative analysis of the two strategies based on detailed data gathered in the Member States. As seen from the following figure, feed-in tariffs when well-designed are more efficient (in terms of costs) and more effective (in terms of renewable deployment) than RO combined with TGC.

Figure 4: Historically observed efficiency of support for on-shore wind



Source: [OPTRES 2007]

This example further illustrates that a strategy based in quota obligations (in combination with Green Certificates) tends to be more expensive and less stimulating for the deployment of renewable energy than a mechanism involving feed-in tariffs. Support mechanisms relying on quota obligations are relatively new compared to other instruments and still need to demonstrate that they can help achieve ambitious renewable objectives at the lowest cost possible. To date this has not been the case. Such instruments tend to generate wind-fall profits for producers. As shown on the above chart, **countries like UK, Italy or Belgium have paid a very high price for renewable energy sources (corresponding to high profits for producers) and have generally exhibited very ineffective results (very low rates of RES technology adoption)**. Furthermore, as a market mechanism, green certificates are subject to price volatility, creating a climate of uncertainty for investors. This, along with the uncertainty of bidding under tender strategies (projects can always be turned down) is important for investors who seek confidence, continuity and long-term perspective.

Feed-in tariffs prove to be much more efficient for deploying renewable sources of energy at lower cost. Of course there are important differences between countries but the exceptions can be explained either by an inadequate design of the instrument or by non-economic barriers preventing the development of projects. At the time when the analysis was made by OPTRES, France was a perfect example of how non-economic barriers can slow the ramping-up of renewables. However, this may no longer be true since the support instruments have been redesigned and reinforced in recent years and now offer a more favourable context for the sector as demonstrated by the recent boom in the wind and solar markets. The European Commission has likewise made similar arguments concerning the advantages of feed-in tariffs and their relative success at promoting renewable technologies, introducing a wider range of renewable technologies (not just wind power) and being more cost-effective[15].

[15] See e.g. "The Support of Electricity from Renewable Energy Sources", SEC(2008)57 and the precursor to this more recent study COM(2005)627. For other references making the same argument, see Lipp (2007) and Meyer (2007). For very brief introductions to the advantages of feed-in systems see Mendonca (2007) and NRP (2008).

We also see on the chart that **Spain and Germany are good examples of the successful implementation of FIT**. The German FIT applies to hydro, wind, biomass/biogas, PV, geothermal and is typically set for a fixed duration of 20 years. Tariffs are "stepped" *(differentiated according to the size of the installation)*, technology-specific and are set to decrease over years for new installation which tends to encourage R&D and cost reductions. As an example, the tariffs strongly encourage off-shore wind development: the basic tariff is set at 30€/MWh. On top of that a premium price of 130€/MWh is applied during the first twelve years after commissioning of the plant. The total tariff for the first 12 years is therefore 160€/MWh. In comparison, the basic tariff for onshore wind is 50.2€/MWh and the premium price is 92€/MWh or a total of 142.2€/MWh for the first 12 years of the project lifetime. This gives a high degree of confidence and long-term visibility for investors. These differences in the tariff level reflect the higher cost of offshore wind compared to onshore wind. The digression rate is set at 5% per year as of 2015 for offshore wind against an immediate 1% per year for onshore wind, thus reflecting a more mature technology [EREF, 2009].

The Spanish support scheme architecture is very similar to the German one. As in Germany, investors can benefit from a high certainty and long-term visibility. In this case, the target technologies are: hydro, wind, biomass/biogas, solar energy (PV and thermo-electric) and others (geothermal, Waves, Tidal, Dry hot rocks, Ocean–thermal, and Sea current). As in the German case, the tariffs are technology-specific, stepped and decrease over time for new installations. Support is fixed for a period of 15 to 25 years. However a fundamental difference should be underlined. Green power producers can choose between receiving a fixed price for their electricity or a premium price on top of the electricity market price (except for solar energy). In Spain, on-shore wind electricity producers can choose either to receive a fixed price of 78.18€/MWh for 20 years and 65.34€/MWh thereafter, or a premium price on top of the electricity market price of 31.27€/MWh [EREF, 2009]. Premiums provide incentives to produce during peak-hours where the spot price for electricity is the highest.

Many are tempted to argue that FIT strategies—since they rely on subsidies—are likely to lead to higher prices, lower rates of innovation and cost-inefficient energy generation. However, the opposite is in fact true. The reason for this is quite simple. While in some traditional models, subsidies are paid directly to producers (thereby reducing incentives for innovation and efficiency), **FIT tariffs are paid instead to investor/generators. The result is that such investor generators face strong market incentives to favour the most cost-efficient of the RES technologies available on the market. And producers in turn face strong market incentives to provide the most up-to-date and cost-efficient technologies in order to remain viable on the market**. Moreover, any potential undersupply of capacity is likely to be rapidly filled due to the typically advantageous market conditions created by FIT strategies. In the long run, FIT strategies (as long as they provide adequate tariff levels) provide very powerful mechanisms for encouraging the rapid adoption of new technologies, for facilitating their commercialization, for promoting investment and innovation, and ultimately for encouraging highly competitive markets.

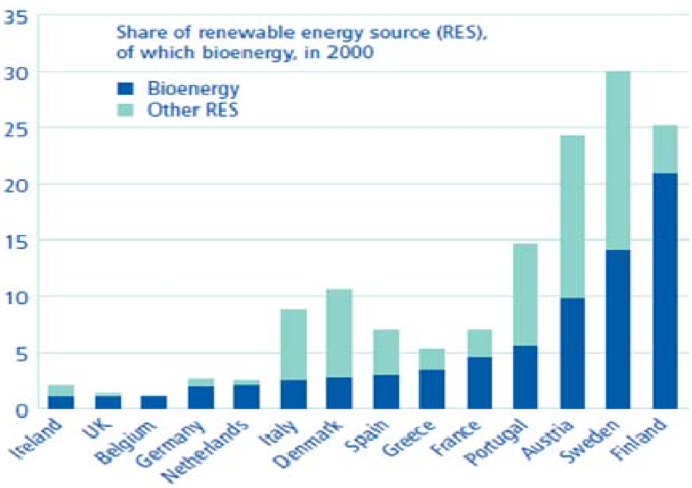
A **number of Member States have also implemented a carbon tax in combination to FIT or RO. Sweden for example, famous for its carbon tax, also employs a certificate-based model to encourage RES development, in particular for wind power.** Sweden also offers various investment subsidies. Carbon tax-based models encourage a broad range of consumers to adopt energy-saving and fossil fuel substituting technologies.

Since this applies more or less equally to households as well as to commercial and industrial users (assuming equal taxes)[16], both larger and very small-scale technology adoption is favoured.

Not all advances or positions in the introduction of renewable can necessarily ascribed to the role of these different national schemes. Many countries, for example, enjoy the advantage of formidable renewable energy resources that have historically been used on a regular basis for energy generation. The most common of these is hydropower. However the use of vast forest resources also tends to fall in this category to some degree. Although the recent and somewhat rapid expansion of CHP-type biomass plants is relatively new, biomass resources have long been used in various ways in these countries. However, the rapid adoption of the newer RES technologies has been most successfully achieved with national level FIT schemes and to some extend also with the introduction of carbon taxes.

Comparing FIT and carbon tax based strategies, FIT strategies are clearly better at promoting the newer electricity-based RES technologies (in particular wind and solar power). Carbon tax-based strategies may do relatively little to support wind and/or solar power but they have had a significant impact on the adoption of energy-saving and biomass-based technologies (which are considered carbon neutral and thus not subject to the carbon tax). Such biomass-based technologies also support the co-generation of heat and electricity and the construction of biomass-based district heating systems. Such CHP systems are among the fastest growing RES technologies in the more timber-rich countries. Several of the Nordic countries (e.g. Finland and Sweden) and Austria have quite high shares of bioenergy generation (see Figure 5, below). In Sweden, for example, 62% of district heating is based on biomass and 40% of heating is supplied by such district heating systems [EREC, Renewable Energy Policy Review, Sweden].

Figure 5: Biomass Energy Generation



Source: [EREC 2009: 3]

DG units and decentralized energy systems are ultimately most compatible with carbon tax-based and FIT models. Both of these strategies encourage both small and potentially larger scale DER and RES technologies. **The combination of carbon tax and FIT models potentially provide perhaps the optimal foundation for the rapid adoption of technologies linked to decentralized energy systems.**

[16] In Sweden, for example, industrial users pay a lower carbon tax than other fossil fuel users (EREC, 2009; Renewable Energy Policy Review, Sweden).

An EU-wide FIT model, as well as the potential addition of an EU-wide carbon tax, could potentially improve upon this situation and further support the EU-wide adoption of smaller scale RES technologies. Various models for an EU-wide FIT strategy have been proposed (for one example, see [Ellison and Hugyecz, 2008: 45-6]. Based on this type of model, it is technically possible to introduce a type of 'lowest common denominator approach' at the EU level that would not compete with other more generous national-level FIT strategies.[17] The important point here is that **investors/generators would still be able to benefit from introducing RES technologies even in the absence of a corresponding national-level incentive strategy**. Moreover, countries could still *trade* in RES efforts across borders since they would be required to purchase EU-wide FIT certificates whenever they fail to meet the EU targets set for the national level.

Finally, one additional strategy that could be pursued that has so far not been seriously discussed, would be to **include the construction of storage systems in national level FIT strategies (and potentially also an EU-wide strategy)**. In this regard, California has recently chosen to introduce a renewable production standard (or RPS), similar to the RO model described above, for energy storage systems. "AB 2514" mandates the construction of storage facilities capable of handling 2.25% of peak power by 2014 and 5% by 2020.[18] Though energy storage systems are typically one of the least developed features of energy generation and transmission systems, quite a wide variety of energy storage systems are currently under development and are beginning to come onto the market.[19] Thus while such technologies could still benefit from Research and Development funding, many solutions could potentially begin to find their way onto the market far more quickly with appropriately targeted public spending strategies. One such possibility might be to develop a modified FIT model that would encourage the construction of storage capacity by rewarding the number of kWh of storage made available and used by the power system.

3.3.3. Support schemes for Smart Metering

At European level, two directives refer to smart meter deployment. [Directive 2006/32/EC][20] (Article 13) mentions the use of smart meters to increase energy efficiency and better inform customers about their consumption. Further, Directive 2009/72/EC (Third Energy Package) encourages the implementation of smart grids, '*in a way that encourages decentralized generation and energy efficiency'*. The first step is the implementation of smart-metering. Based on [Directive 2009/72/EC] and depending on the results of the economic assessment period ending the 3rd of September 2012, all DSOs shall equip at least 80% of households with intelligent metering systems by 2020[21]. Member State governments and the national regulatory authorities (NRAs) shall be involved in all stages of the national roll-out.

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[17] Though we currently have no strong preference regarding the type of EU-wide FIT model (an extensive independent analysis would be required to make this determination). The important point is that such a model 1) make differentiation in the degree of support possible across technologies and size or location differences (e.g. installation size and on- and offshore wind power), 2) should not threaten to undermine national-level strategies, and 3) should encourage cross-border trade in renewable certificates.

[18] See e.g.: "California Proposes First Renewable Energy Storage Requirements", (CleanTechnica.com, Mar. 2nd, 2010: http://cleantechnica.com/2010/03/02/california-proposes-first-renewable-energy-storage-requirements/)

[19] For an overview of energy different storage systems see Eyer and Corey (2009). For a detailed discussion of Compresses Air Energy Storage systems (CAES), see Succar and Williams (2008) or watch a short video on General Electric's Adele energy storage system (http://www.ge.com/audio_video/ge/innovation/say_hello_to_adelle.html).

[20] Directive 2006/32/EC of the European Parliament and of the Council on energy end-use efficiency and energy services

[21] Noted in Annex 1 of the 2009/72/ EC Directive.

Regulators have generally been involved in the definition of the roll-out timetable, minimum technical standards and the level of return on investment [ERGEG, 2009b: 26]. According to a Berg Insight report[22], this goal is presumably attainable even though there is little certainty about the effective cost of smart-metering deployment. As smart-metering is a relatively recent phenomenon, only limited data on current practical experience are available.

The 2008 ESMA Annual Report on the Progress of Smart Metering raises the issue of legal and economic barriers when it underlines that '*smart metering implementation is a very long and costly process, requiring considerable capital expenditure from responsible market actors that need clear policy decisions from government and regulatory certainty regarding key concerns, so as not to deter investment*'. Who "owns" smart meter is potentially an important issue, as it can influence both costs and benefits. Indeed, DSOs, who are responsible for the capital and installation costs may not be the principal beneficiaries of the investment. There are also financial and organisational risks to be taken into account in an environment where no subsidies should be expected from national governments. Moreover, it is worth noticing that in some Member States, DSO revenue is directly proportional to electricity consumption: less consumption means lost revenues. Thus, DSOs face mixed incentives regarding the promotion, investment in and deployment of smart-metering. However, as ESMA notes it in its latest report, 2009 has seen important developments in smart metering technology and markets show more confidence [ESMA 2010: 56].

There are significant national level differences in the degree of implementation of smart meters. Pioneer countries such as Italy, Sweden and Finland are the most advanced, reaching a penetration rate of almost 100% [ESMA 2009]. Italy was the first Member state to adopt smart-metering in the early 2000s. By 2011 all Italian electricity customers are expected to be equipped with smart meters [ibid]. If the European average remains around 6%, this is because out of the 27 Member States, only eleven have actually begun deploying smart meters [ibid]. An acceleration of smart-metering deployment is foreseen, with an estimated annual market growth of 16% by 2014[23]. At this pace, 25-40% of households will be equipped by 2012[24]. Member State such as France, the UK and Spain have taken important steps forward. In France, based on the results of a trial, at least 50% of smart meters should be installed by the end of 2014 and 95% by the end of 2016[25]. In Spain, Endesa and Iberdrola have deployed 20 million smart meters and the nationwide roll-out, initiated in January 2008, is expected to reach completion in 2018. On October 28th, 2008, the British government decided to install 27 million smart meters for all households by 2021[26].

Some countries such as the Netherlands and Germany have encountered difficulties. The Dutch Consumer Association[27] has expressed reservations concerning privacy issues and, after a successful campaign in the Dutch Upper Parliament, proposed legislation on a compulsory roll-out was rejected [ESMA 2009: 34]. In Germany, there is still no national mandatory legislation for roll-outs, even though RWE developed the first plan to install smart meters. Many countries however remain at the stage of conducting initial studies on the possibility of introducing smart-metering and have not even begun with implementation.

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22 Berg Insight Institute, Smart Metering in Western Europe, 6th Edition, June 2009.
23 Christoph Hammerschmidt, Smart meters face uneven acceptance across Europe, 30 June 2009
24 Frédéric Bordage, Smart Grid: l'Europe généralise les compteurs intelligents, 30 October2009
25 This disposal concerns DSOs with more than 100,000 customers. ESMA (2009 : 23).
26 Ibid.
27 Ibid

Moreover, there is a significant difference between electricity and gas smart meter deployment, (see Table 7 below). Only 9 Member States have projects in both gas and electricity smart metering and deployment is less mature for gas.

Table 7: Review of Smart Metering Schemes in Selected Member States

Country	Electricity	Gas
Austria	30,000 installed, no national obligation but this under review	Roll out under discussion
Belgium	Trials under way –results will determine any national roll-out.	
Cyprus	There is no smart metering deployed in Cyprus.	
Czech Republic	Trials underway-results may determine any national roll out.	
Denmark	Several electricity DSOs are deploying smart meters but there is no national plan.	
Estonia	A major roll out is under discussion and a roll out may begin in 2011 that would conclude in 2013	
Finland	In March 2009 new legislation that requires nearly full penetration of hourly metering and settlement by 1st January 2014 came to effect.	
France	ERDF expected to commit to a full roll-out in 2010 based on results of trial.	Roll –out under discussion
Germany	Around 50 trials, a full national roll-out is under discussion.	Similar situation with electricity metering but there is no planned roll-out
Great Britain	The government decided on a national roll-out of duel fuel smart metering for all 27 million households before 2020.	As for electricity.
Greece	A roll-out has been decided and will be carried out between 2010 and 2013.	
Hungary	A study is currently under way	
Ireland	A pilot study is underway and it is anticipated that this will lead to a full roll out, but the decision has not been made yet.	As for electricity.
Italy	By 2011, all 36 million electricity consumers will be equipped with a smart meter	Has made decision to roll-out of gas meters with a target of 80% installed by 2016.
Luxembourg	A number of trials are being carried out by DSOs.	
Portugal	The Regulator has made a preliminary study.	
Poland	There is discussion of a roll out beginning in 2010 and completed by 2017.	As for electricity.
Romania	There is no official national plan on smart metering.	Same as for electricity
Slovak Republic	Discussions of a roll out underway.	
Slovenia		Roll out under discussion.
Spain	A roll-out is under way, to be completed in 2018.	No economic case for roll-out of smart gas meters for customers using < 5,000,000 kWh/y
Sweden	The first one to achieve a 100% penetration (in July 2009 when monthly collection of meter data become mandatory).	
The Netherlands	Dutch Senate rejected proposed legislation including a compulsory roll out of smart metering for reasons of privacy and security. Proposed legislation and smart meter standards are now being revised for new discussion in Parliament in order to allow a voluntary roll out. New decisions are expected in Autumn 2010. In the meantime, Dutch fourth largest energy supplier Oxxio has installed over 100,000 smart meters in the residential sector already.	As for electricity.

Source: [ESMA 2009]

3.4. Infrastructure Development, Research Support and the SET Plan

3.4.1. Infrastructure

The infrastructure necessary to support the creation of decentralized energy systems is still a thing of the future. In this framework, several features should be considered and discussed. In particular, the cross-border interconnections of transmission grids, energy sector liberalization and the regulatory framework governing grid connections, and investments to improve the overall quality of the grid are all features necessary in order to promote the expansion of decentralized energy systems. As noted above, the ability of the European Union to intervene in such questions is limited by Member state prerogatives on determining many of the features of energy systems at the national level in EU Member states.

International Cross-Border Grid Interconnections

The current state of international cross-border grid interconnections is a matter of considerable concern. The relative importance of such interconnections as a tool for balancing the over- and under-supply of energy is demonstrated by such examples as the Danish dependence on cross-border interconnections to Germany and the Nordic countries in order to balance intermittent surplus electricity generation from wind power [RISO, 2009, 2005]. Spain has also made an issue of the importance of cross-border interconnections as a strategy for balancing its rapidly increasing share of renewable energy generation from both wind and solar[28]. Moreover, as in the Danish and Spanish cases, cross-border interconnections likewise facilitate the ability of some countries to exploit natural comparative advantages in renewable energy generation. Generally speaking, with regard to the decentralized energy system approach, improving the geographical extent of transmission networks facilitates evening out imbalances across available supply and demand. Thus the more integrated the European transmission network and energy grid becomes across Europe, the more even and more efficient the energy network will be.

In this regard, the current version of the Regulation on cross-border interconnections may be inadequate for promoting decentralized energy systems. In 2007, a CapGemini report noted the EU was very far away from its goal of expanding cross-border interconnections;

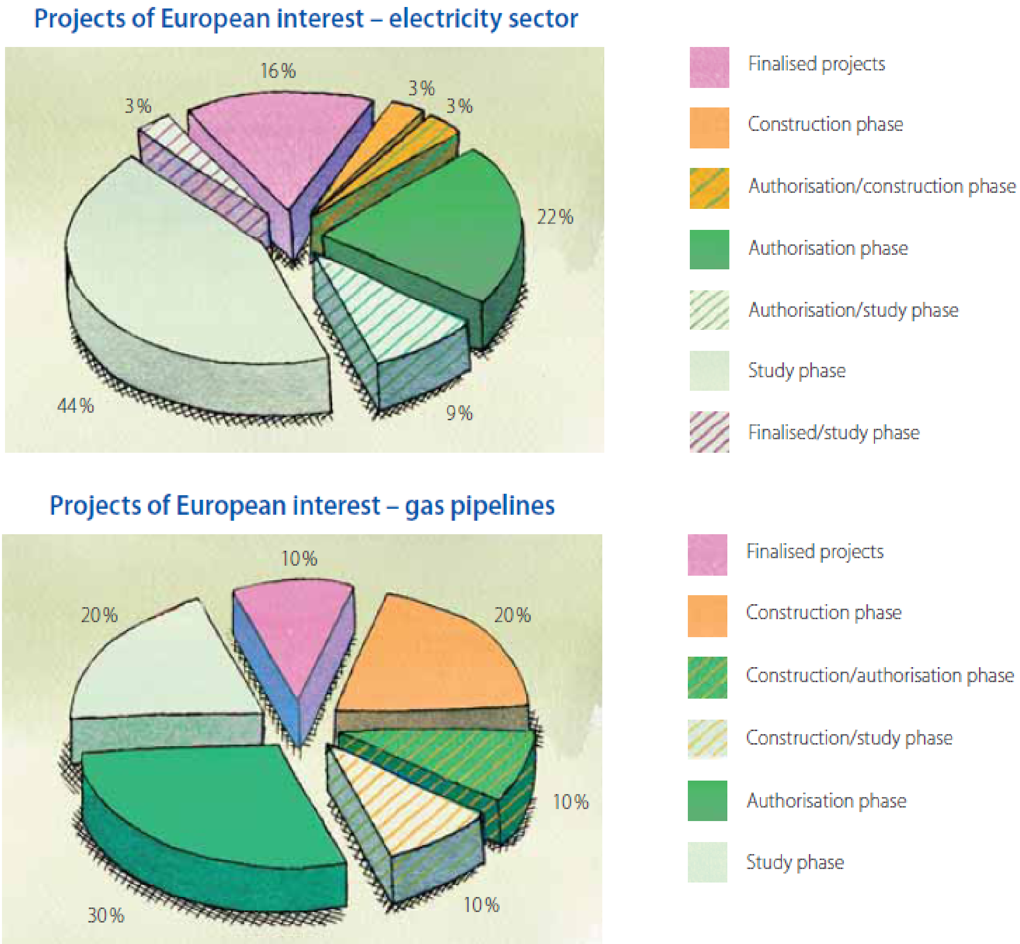
> "*The interconnection levels, particularly in Western Europe, remain below the level of 10% that was agreed upon at the Barcelona European Council of March 15 and 16, 2002. Since then only a little progress has been made, and most of the physical bottlenecks still exist. Consequently the list of priority projects has not changed much since 2002, even if the EU has tried to accelerate market integration by financing electricity transmission projects of European interest*" [CapGemini, 2007: 63].

Though this point is mentioned in various contexts and despite the fact that EU legislation requires the cross-national interconnection of national grid networks, implementation has typically been slow. However, with the integration of increasingly large shares of more distributed small scale and frequently intermittent forms of energy generation (in particular wind and solar power), the ability to ensure security of supply is greatly facilitated by extensive cross-national grid interconnections.

[28] This was an issue for example during negotiations on the EU's 2020 Climate Package concluded in December 2008 and Spain continued make this an issue in recent European discussions during the Spanish EU Presidency. See "Spain Mulls Over Copenhagen and Future Energy Policy" (www.Europolitics.info, Jan. 13th, 2010).

On 4 March 2010, as part of the second package under the European Economic Recovery program, the European Commission agreed to spend 2.3 billion Euros on electricity (910 million Euros) and gas (1.39 million Euros) network grid interconnections[29]. This is certainly a step forward and will go a long way to securing greater interconnectedness in the European energy network. At the same time, there is still quite a lot to be done. A report from [DG Energy 2008] notes that of the current projects under consideration only a very small share have been finalized or are in the construction phase. The question thus remains whether the EU strategy of providing significant financial support will be able to overcome the apparently low level of commitment from many EU Member states.

Figure 6: Projects of European interest



Source: [DG Energy 2008: 10-11]

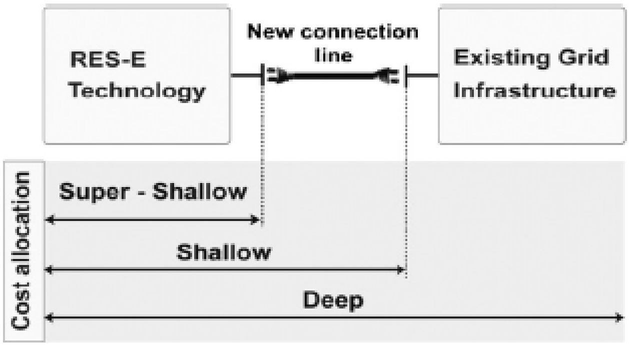
In this regard, the backlog of projects that still need to be completed in order to arrive at an adequate degree of flexibility across EU electricity and gas markets is considerable. Though funding from the European Economic Recovery Package should have a considerable impact in terms of beginning to move projects forward, there are no guarantees this will happen. Consistent monitoring and assessment of progress by the European Commission would be advisable in order to ensure that older bottlenecks posed, for example, by Member state reluctance do not stand in the way of significant improvement.

[29] See European Commission press release (IP/10/231, 4 March 2010).

Grid Connection and Priority Access

Grid connection and priority access must also be improved or guaranteed—in particular for smaller scale RES and low carbon energy generation. Though this issue is already addressed in the EU RES [Directive 2009/28/EC], it is ultimately left up to Member states to implement this plan and develop their own models. Moreover, Member states have considerable leeway to structure the distribution and sharing of grid connection costs as they think appropriate across grid owners and RES producers. Thus, for example, no decisions have been made at EU level regarding the structure of *deep* (paid for by RES developer) and *shallow* (grid reinforcement costs paid for by grid owner/operator). The most advantageous model for RES developers and generators is clearly the "*super-shallow*" model in which all grid connection costs are assumed by the grid owner/operator [see Swider et al, 2008]. Some network operators also require the payment of "*network tariffs*" in order compensate them for the cost of improvement the quality of the grid [CEER, 2009: 22]. Finally, a number of countries allow for the "*pass-through*" of costs to consumers (utilities are permitted to raise prices in line with changes in cost structure) related to grid network improvements related to the adoption of wind power and other RES technologies [CEER 2009: 23]. Since the precise allocation of cost and the degree of "shallowness" could ultimately give rise to market distortions across Member states, making it more advantageous to deploy RES and DER technologies in some Member states than others, it may be advantageous to seek an EU level agreement on this point. Such a strategy could likewise insure that individual Member states are not able to continue imposing cost-related restrictions on market (grid) access. Finally, a model requiring grid operators to assume the costs of grid connection ultimately facilitates the social sharing of attaining the low carbon economy, whereas imposing these costs on RES and DER investors tends in the opposite direction.

Figure 7: Cost Allocation for Grid Connection



Source: [Swider et al 2008: 1837, Fig.2]

Whether more concerted efforts from the EU level will be required in order to promote DER depends significantly on the models individual countries choose. In particular for smaller scale DG units, the imposition of connection costs on RES producers can potentially act as an impediment to the rapid adoption of smaller scale RES technologies, in particular where such costs represent an significant share of overall investment costs. One additional factor to consider is the compatibility of deep cost funding requirements and any impact this may have for the unbundling requirements in energy sector liberalization [Directive 2009/72/EC].[30]

[30] The CEER (2009: 27) report on the integration of wind power points out potential conflicts of interest in particular where offshore wind generators are also required to build their own transmission networks. Such issues are also relevant with regard to the possible development of a European SuperGrid.

The other major issue affecting the adoption of RES technologies is the degree to which countries provide "priority connections" and/or priority access for generated power from RES technologies. According to CEER, this is a regular practice in some countries. As noted by CEER, '*9 Member states provide priority connection of onshore wind over conventional generation and 4 provide a more favourable 'use of system' charging regime for wind generation compared with conventional generation'* [CEER, 2009: 23]. Article 16(2b) of the EU RES Directive does in fact require that Member states provide for, "*either priority access or guaranteed access to the grid-system of electricity produced from renewable energy sources*." In this regard, given that only a very small number of Member states provide such access for RES and DER technologies, very significant steps forward must still be made. In this regard, consistent monitoring of Member state implementation would be advisable.

EU ETS system

As currently structured, the EU [ETS Directive 2009/29/EC] is too restrictive and is only focused on the practices of the fossil fuel-based power sector and high-emitting industrial firms. With greater flexibility across the tradable and non-traded EU ETS sectors, far greater incentives could be provided for the smaller scale DER technologies than is currently the case. In this sense, the EU ETS system misses important opportunities to provide incentives for DG, in particular where energy generation occurs in buildings. This falls in the non-ETS sector. A more flexible and broadly-based system is necessary in order to provide powerful incentives for building-related energy generation and thus smaller scale DG.

Although the ETS system does provide incentives for DG in installations over 20 MW or with emissions over 25,000 tons CO2 (hospitals are excluded), this is still only a relatively small share of total domestic emissions. While the EU ETS system primarily motivates power plants and industrial firms to focus emission reduction efforts on high-emitting carbon intensive combustion installations, a very large share of emissions is associated with building-related energy use and/or smaller scale industrial installations.

The EU Effort-Sharing Decision (Decision No. 406/2009/EC of the EP and Council) does require Member States to make emission reductions in the non-ETS sector. Overall, EU Member States must reduce non-ETS sector emissions by 10%. However, this amount is distributed very unevenly across the Member States, typically allowing most of the New Member States to increase emissions in the non-ETS sector over the period 2012-2020 and requiring the more advanced Member States to reduce emissions. For the period 2008-2012, no effort-sharing agreement exists.

Though revisions to the Effort-Sharing Decision ultimately allow Members states to trade emission reductions in the non-ETS sector across borders (Art 3.4-3.5), there is no allowance for the trading of emissions across the ETS–non-ETS barrier. Flexibility across this barrier, however, would potentially create far greater incentives for individual Member states to pursue significant emission reductions in the non-ETS sector.

Although the strength of incentives to reduce emissions in the non-ETS sector presumably depends on the nature of the incentive system introduced (e.g. the type and nature of national-level strategies to encourage consumers and households to shift to low carbon technologies and raise energy efficiency),[31] the lack of potentially powerful incentives to trade credits resulting from increased flexibility across the ETS and non-ETS barrier likely means that Member states will face far fewer incentives to reduce emissions in the non-ETS sector.

In this regard, **the relatively strict compartmentalization of tasks in the EU's Energy and Climate Change Package of legislation ultimately creates an inefficient degree of inflexibility**. It is not clear, for example, why countries cannot *substitute* or *trade* emission reductions achieved through improved energy efficiency or fossil fuel substitution—whether in the non-ETS sector or elsewhere—for commitments in either the ETS sector or the failure to achieve renewable targets.

For DER, this essentially means that the current focus on the EU ETS model provides only relatively weak incentives for investment in DER-related technologies. Though the EPBD and national-level RES incentive systems may make up for some of this, these models are not free of obstacles. These are discussed further below.

3.4.2. Research Support, the SET Plan and NER300

Given the relative priority and economic importance of electricity and the urgency of promoting emission reductions, more spending of EU research monies on energy and DER (as a share of total research expenditure) seems advisable. However, the relative balance across spending priorities should perhaps be more extensively debated.

The basic intent of the EU SET Plan — to spend significant additional resources on researching low carbon technologies — is generally well-placed. However, the above reservations concerning the relative weighting of the distribution of resources and the relative lack of attention dedicated to smart grid, storage technologies and base load forms of renewable energy generation still apply and require greater consideration.

The SET Plan Roadmap suggests the following breakdown of investments for each of seven separate categories over the next 10 years:

Table 8: Cost Estimates: EU SET-Plan EIIs and the Smart Cities Initiative

European Industrial Initiatives	Total (billions of Euros)
Wind Energy	6
Solar Energy (PV & CSP)	16
Bioenergy	9
Carbon Capture and Storage (CCS)	10.5 – 16.5
Electricity Grid	2
Sustainable Nuclear Energy	5 – 10
Smart Cities	10 – 12
Total	58.5 – 71.5

Source: SET Plan Roadmap [SEC 2009 / 1295: 8]

[31] One such model could involve for example the right of Member States to resell carbon credits to ETS sector firms for emission reductions achieved in the non-ETS sector. Such a model would avoid the problem of requiring individuals to apply for the right to sell certificates and prove emission reductions and would instead place the burden on states to do this on a broad scale. But in order to gain the right to sell such certificates, the State would first have to create meaningful incentive programs for consumers and households in order to encourage investment in meaningful building-related emission reductions and rising energy efficiency.

However, the SET Plan Roadmap also clearly notes that the actual amounts invested may ultimately vary from category to category (2009:7). Note that in this breakdown, Smart grid funding is distributed across two categories (the electricity grid and Smart Cities) but is also shared with other Smart City and electricity grid technologies. Further, geothermal energy production (along with tidal power and small scale hydro) does not even appear as a separate category and also receives quite sparse treatment in the remainder of the document. CCS demonstration projects are set to receive quite a significant amount of funding. Finally, while a significantly large amount of resources have been dedicated to PV and CSP technologies, as noted above, some of this funding could potentially be dedicated to public support strategies facilitating their commercialization.

Funding modalities are mentioned in a rudimentary fashion in "*Investing in the Development of Low Carbon Technologies*" [SET Plan, COM (2009)519 final: 11]. A large share of funding is expected to come out of the **New Entrants Reserve (NER300)**, a pot of 300 million EU allowances set aside in the third phase of the EU ETS system from 2013-2020. Though the precise value of these allowances will not be known until they are actually auctioned, this is still expected to represent a significant share of EU resources. The NER300 plan, currently only in draft form, would distribute resources across the funding of CCS and RES technologies. It is encouraging that geothermal technologies receive considerably more discussion in this document, suggesting that more attention is perhaps slowly being dedicated to this option. On the other hand, the division of the NER300 into only two categories suggests that CCS technologies are likely to get a significant amount of funding from this source.

Finally, other funding modalities include the traditional EU funding programs (such as the Research Framework Program and the Intelligent Energy Europe Program). In addition, the European Economic Recovery program has dedicated significant resources for electricity and gas grid network cross-border interconnections.

The SET Plan does not specifically discuss DER. Moreover, how it will affect DER must remain somewhat unclear. Many of the RES technologies to be funded under NER300, for example, involve relatively large scale installations and in fact the minimum capacity for many of these projects is set at limits well above what we have defined as "small scale" DER or DG. While funding for Smart Grid technologies will presumably have a positive impact on DER, the total amount of resources dedicated to this strategy is not large and will ultimately be divided across a range of competing technologies related to electricity grids and Smart City programs. Solar PV funding, on the other hand, could positively impact DER.

Though the relative distribution of research expenditure across the different DER categories (resources, transmission, distribution, storage, etc.) seems relatively well-balanced, given the tendency to associate RES with intermittent forms of renewable energy (wind and solar power), inadequate attention may have been dedicated to base load forms of renewable electricity generation (i.e. hydro, geothermal, tidal, biomass power production and waste-to-energy generation). Though the potential for increased hydropower may be more limited, the remaining technologies exhibit quite considerable potential. These are striking omissions and deserve greater consideration in research funding efforts. Moreover, they should be far more strongly considered and investigated as potential resources for balancing intermittent renewable energy sources.

Given the potential value of storage technologies as a balancing tool to accompany the large scale integration of intermittent RES and as a backup mechanism for the gaps that decentralized energy systems and demand response are not able to fill, **it is surprising that more resources are not dedicated to their development**.

Finally, **while considerable resources are dedicated to electricity-related technologies, far more resources could also be dedicated to both energy-saving and heat-related technologies.** Though natural gas is only 2/3rds as carbon intensive as coal, it is still a fossil fuel and its elimination from the common energy base for building-related energy use could go a long way to reducing GHG emissions and improving energy security. Moreover, many of the related technologies are already competitive in today's market place. More targeted research on building-related energy use could go a long way to further improve this potential. Funding for the research and development of low carbon transportation represents another deficiency and would benefit tremendously from greater supporting efforts.

In many ways, **the principal question that should be posed is not whether to fund CCS, RES or DER technologies—presumably all of these technologies deserve at least some level of public support—but rather what is the appropriate "metric" for deciding which technologies should receive what share of EU resources**. Defining an adequate "metric" is complicated and is easily rendered more so by the political lobbying pressures of different groups and states. Possibilities for defining a potentially neutral metric that does not take into account political considerations are the following:

- **Greatest potential**: financial support could be distributed based on the likelihood that projects will produce significant returns in terms of low-cost, low carbon energy generation and transmission
- **Highest investment cost**: barriers to entry such as high initial investment costs may also provide a meaningful justification for R&D support. Investments in nuclear fusion technology clearly appear to fit into this category
- **Market failure**: it is frequently argued that R&D support should be provided to technologies that exhibit some potential but in which the private sector is not likely to invest without public funding
- **Near-term solutions**: given the urgency of solving the climate dilemma, technologies that offer more immediate solutions on the basis of proven technologies might be considered more attractive than longer-term hypothetical solutions

When considering an appropriate metric for funding CCS, RES and/or DER technologies, CCS technologies fall in a problematic category. At least in terms of the potential scale and cost of energy generation, a viable CCS technology at reasonable cost could provide significant returns based on the three principal constraints (climate, competitiveness and energy security). However, the relative degree of potential for CCS technologies based on how long it will take to develop and test them is much less appealing. As larger scale demonstration projects are currently just getting underway, these are not likely to provide significant results for some time. Finally, the cost of CCS-based technologies is likely to be far more expensive at future costs than several of the currently available RES technologies at today's costs (e.g. wind power, CSP and geothermal).

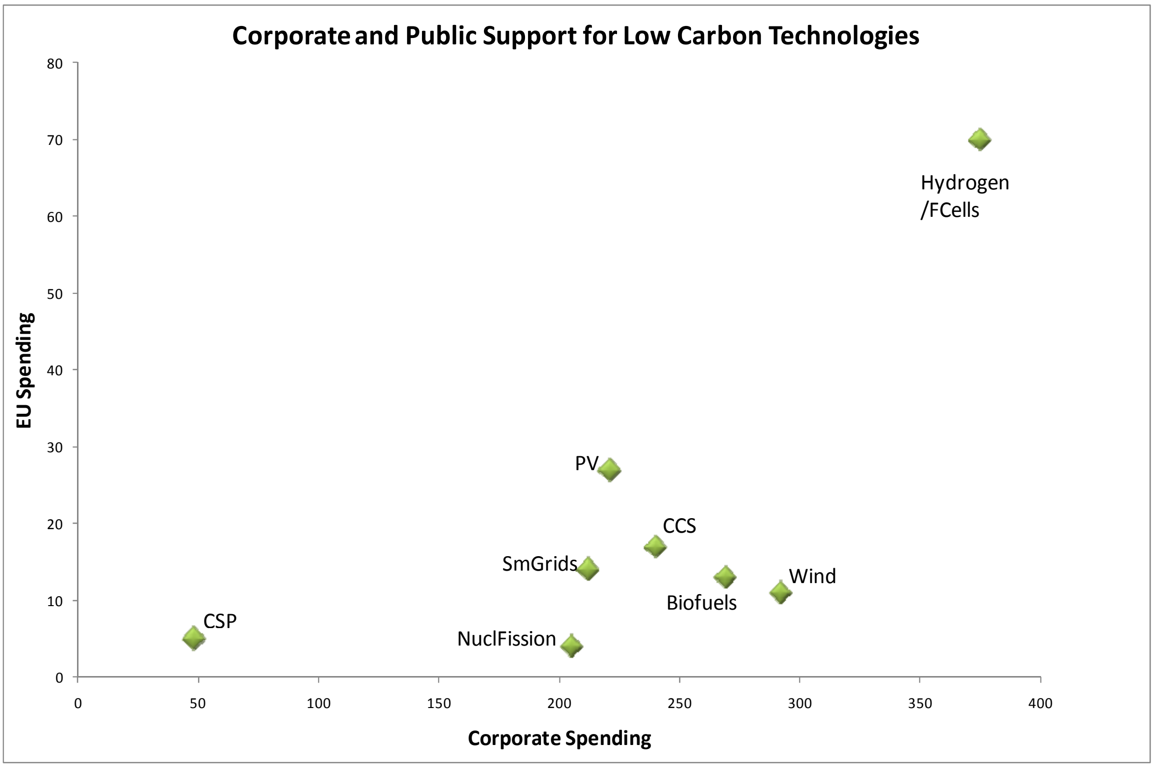
Though many argue in favor of supporting the development of CCS technologies,[32] there are also many downsides. The most important of these are the following: 1) currently there are no large scale demonstration projects (though there are an ever-increasing number of smaller scale projects).

[32] For a good overview of current discussions on CCS technologies, see the Proceedings of the 9th International Conference on Greenhouse Gas Control Technologies (GHGT-9), 16–20 November 2008, Washington DC, USA. These have been published in the first volume and issue of Energy Procedia.

A very recent paper has suggested that the physics of CCS are unworkable and that it would be impossible to sequester anywhere near as much carbon as would be necessary in underground locations [Ehlig-Economides and Economides 2010]. 2) The timeline for the completion of large scale demonstration projects is relatively far off in the future. 3) CCS technology is very expensive and energy intensive. In addition to the estimates provided in an earlier section of this document, other authors have estimated even far more substantial costs [see e.g. Al-Juaied and Whitmore, 2009] suggesting that CCS could cost as much as \$150/tCO2 for early stage plants. 4) CCS would support an industry that is associated with many other additional problems, the costs of which (as is currently the case for CO_2) are not internalized in the price of coal or electricity. Finally, 5) coal-based energy generation (as well as nuclear power) are comparatively water-intensive technologies and are thus likely to be constrained by the effects of global warming and climate change.

Most current RES technologies already provide near-term and proven solutions. While several of these technologies do so at higher cost than conventional fossil fuel-based technologies, this is likely to change with time, both due to the impact of carbon pricing strategies (EU ETS) as well as improvements in technology. In this sense, increased funding could potentially increase the speed at which such technologies become highly competitive with conventional energy sources. While there are numerous projections on when technologies such as rooftop Solar PV and other RES technologies will achieve full grid parity, most of these projected dates are well inside projected dates for CCS.

Figure 8: Corporate and Public Spending



Source: based on 2007 spending data taken from Set Plan, Accompanying Document [SEC 2009/1296: 69].

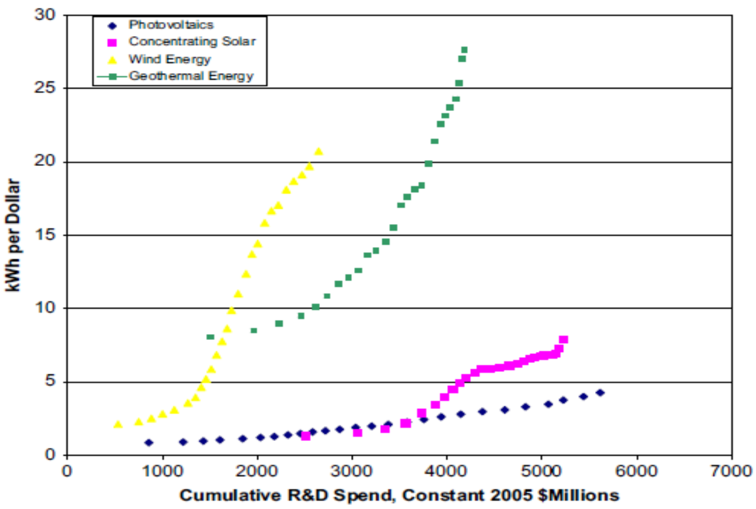
The market failure approach (see Figure 8 above) is also worth considering in this context. Adopting the market failure logic, one should expect to see downward-sloping expenditure curve going from left to right, illustrating that government intervention is high where private sector spending is low. However, as illustrated by Figure 8 above, the opposite is true. Current corporate funding for fuel cell technologies, for example, is already so high the continued justification for public funding is limited.

The private sector appears to think that fuel cells potentially provide real market opportunities and is investing significantly in this strategy, thus potentially negating the need for public sector spending. Private sector investment in Solar PV is not far behind, though the public sector has not reduced its investment efforts in this area either. By this metric, newer technologies such as CSP and smart grids are significantly underfunded. However, the potential and even the near-term viability of these technologies is presumably quite significant.

Support for the development of CHP technologies is ultimately missing from the SET Plan. Though many of these technologies are perhaps somewhat further along in the development process, they are still comparatively new in the commercial sphere and could potentially be developed further. Thus it is curious that CHP technologies, in particular in the context of their importance for DER, are neglected on the research and development side.

One additional "great potential" measure provided by different RES technologies is provided by the measurement of "**technology S-curves**". [Schilling and Esmundo 2009] attempt to provide estimates of the amount of research and development monies spent of different RES technologies and their respective payoff. In this model, the "payoff" is measured in terms of kWh's per dollar. The logic of the S-curve is driven by the concept that initial R&D investments require some time before they generate results. Thus initially progress is slow but takes off after a certain point. Finally, at latter stages of technology development, R&D spending begins to encounter diminishing returns to continued investment and the S-curve begins to smooth out again.

Figure 9: Relative Payoff per Investment Dollar



Source: [Schilling and Esmundo 2009: 1778, Fig. 15]

Though Schilling and Esmundo do not investigate a number of technologies (e.g. CCS, or smart grids), they find a number of interesting results. First, they note that the "payoff" to development spending on geothermal and wind energy is quite high (see Figure 9 above). Payoffs to concentrating solar—still at an early stage of development—are also on the rise. In contrast, investment spending on conventional fossil fuel technologies actually demonstrates declining returns to R&D spending (not depicted here). Moreover, the authors likewise point out that both geothermal and wind power technologies are relatively cost competitive, with geothermal exhibiting a slight advance on wind power (these cost comparisons, along with others, are presented in the cost section below).

The authors argue that with relatively little investment spending, significant returns in technology improvement could presumably be made.

Finally it may be important to distinguish more carefully between the advantages of different types of public support. National level FIT strategies, carbon taxes and investment subsidies, for example, are far more effective at turning technologies into real world applications, i.e. at the commercialization of meaningful technologies. Moreover, FIT strategies in particular are very effective at spurring further innovation as well as getting new technologies out into the marketplace. For technologies already receiving significant private sector investment, an argument could be made for shifting to such market application support strategies and away from heavy public funding of R&D investment.

4. Challenges and Barriers

4.1. Physical and Technical Developments and Challenges

4.1.1. Electricity

Conventional electricity systems have evolved over many decades to enable cheap and efficient distribution of electricity. Increasing the deployment of Renewable Energy (RE) systems requires their integration into the existing infrastructure. Decentralized energy systems will have all the same challenges and barriers as renewable energy. We assess physical impacts on the power supply system regarding control, efficiency, adequacy and planning at the generation, transmission and distribution levels, that are due to variability, degree of predictability (affecting, for example, operating system reserves and generation adequacy), power plant characteristics and location of the resource with respect to demand affecting network issues.

Traditionally power generation, distribution network management and loads have been considered quite independent processes. Along with the increasing amount of DG the traditional approach is gradually changing. A considerable amount of RES consists of DG, but also active energy resources like controllable loads, storage and electric vehicles, which can act both as consumers and sources, will be increased. One of the main barriers for the penetration of active resources at distribution network level is the **complexity of the interconnection process**. From the network management point of view the increasing amount of DG is often considered with reluctance as it brings the complexity of transmission networks to distribution network level. The main reason for the complexity is caused by current methods for managing the distribution networks as well as the features of different active resource components themselves, which are not sufficiently developed to enable easy interconnection. So far loads and customers have been passive from a network point of view. By making the customer connection point more flexible and interactive the demand response functions (e.g. real-time pricing, elastic load control) can be more easily achieved and the efficient use of existing network and energy resources by market mechanisms can be improved. Smart Grids are customer-driven marketplaces for distributed generation and consumers. In summary, the main characteristics of Smart Grids will be:

- interactive with consumers and markets
- adaptive and scalable to changing situations
- optimized to make the best use of resources and equipment
- proactive rather than reactive, to prevent emergencies
- self-healing grids with high levels of automation
- integrated, merging monitoring, control, protection, maintenance, etc.
- having plug-and-play features for network equipment and ICT solutions
- secure and reliable

Technical development of generators

RE plants generate electricity just like any other power plant on a system wide level, but many of the generators have distinctive features compared to conventional generation. The capacities of conversion technologies to extract electricity from RE sources have varying physical dimensions (such as surface area), in order to harness the same amount of energy from selected RE resources. The primary difference in energy extraction capacity arises from energy density, water being a denser medium than air for example.

Some conversion technologies, such as wave energy devices, are capable of extracting the incident energy from an effective surface area many times larger than the actual device.

- As an example, by increasing the tower height and blade surface, wind turbine power has grown from 1 MW to 3 MW and in the future up to 10 MW
- Production of solar electricity can be achieved in either of two ways: The first (concentrating solar power or CSP) uses solar thermal conversion to produce high-temperature heat, which is then converted to electricity via a heat engine and generator. In the second, solar energy is converted directly into electricity in a solid state semiconductor device called a photovoltaic (PV) cell. Both approaches are currently in use. However, further technological improvements will be achieved. For example, much work is under way to improve efficiency and reduce material requirements

Judging from the past track record of improvements, for example, in solar semiconductor devices, one may expect that a steep learning curve is still probable for the future

Increased reserve requirements due to intermittent and unplanned production

The power output from RE generation from hydro, wind, solar PV, wave and tidal fluctuates with the variability of the local resource and in different time scales. Fluctuations can be predicted to various levels of accuracy but do not necessarily correlate with fluctuating power demand. The location of RE generation is determined by the primary renewable resource location and, particularly at larger scale, cannot be easily relocated close to transmission networks and demand centres. A major issue for the integration of RE into a power system is the additional imbalance introduced by variable sources.[33] RE technologies are often referred to as “intermittent”, but this term is considered partly misleading because, when aggregated at the system level and over different types of RE, the total output does not change instantaneously between zero and full power, but fluctuates at a rate dictated by meteorological and geo-physical effects.

In the absence of a perfect forecast, system balancing requirements and costs are increased by random fluctuations and by forecast errors, both of variable RE and of load demand, since these are generally not correlated. Power balancing requirements in large-scale power systems mainly address reserve power in secondary control time scales that is offered on the balancing market. For an isolated system or one with limited interconnection - at various penetration levels up to 10-15% in some areas or higher elsewhere - unpredicted imbalances can be countered with existing reserves [DENA 2005].

Need for forecasting

Predictability is the key to dealing with RE variability. The ability to accurately predict a variable RE resource is significant for bulk commercialization, cost reduction and industrial uptake. From the technical perspective, if RE prediction methods are effective, grid integration and accommodation of variable resources in the system become more manageable from the technical and economic perspective. Aggregated PV generation over a wide geographic area is more predictable using the smoothing effect and tidal variations are fully predictable being diurnal. Estimation of wave characteristics involves less uncertainty than for wind speeds owing to their slower frequency of variation and direct dependence on wind conditions over the wave fetch.

[33] Discussion on variable resources often focuses on wind power because it exhibits variability over a range of time scales (Holttinen, 2009).

Therefore, accurate RE power output forecasting is critical to the economic operation of RE plants in the system, as confirmed by experience in countries with significant penetration. In the absence of accurate forecasting, uncertainty leads to increasing balancing costs [Lange 2009].

Excess production and energy storage

Where RE output exceeds the amount that can be safely absorbed while still maintaining adequate reserves and dynamic control in the system, a part of RE generation may have to be curtailed (for example in low demand, high wind situations). However, it may prove more economic to increase demand under 'demand side management', for example by additional pumping at pumped storage facilities, use of heat pumps and/or water supply reservoirs. Increased inter-connection and improved power exchange rules between neighbouring countries can avoid wasting RE output in such situations.

Ancillary services

Apart from balancing requirements, the power system requires ancillary services. These range from operating reserve and reactive power through short-circuit current contribution and black start capability. All RE plants can provide part of these services noting that if reserve is provided with variable RE, this will come at the cost of lost production, so it will not be the first or most frequent option to deploy. In addition, appropriate equipment should be maintained in the system to provide the ancillary services that cannot be delivered by RE power plants.

System operation at transmission and distribution level

RE generation has implications for the operation and management of the network. Specific combinations of RE production and demand, in terms of level and geographic location, cause changes in the magnitude and direction of power flows in the transmission grid. The effects of these can be mitigated by accurately forecasting renewable generation, combined with monitoring technologies to reduce impacts using the on-line SCADA (supervisory control and data acquisition) information for the RE plant and WAMS (wide-area measurement systems). Operational issues include congestion management priority access of RE plants and priorities in curtailment in critical situations (for example the combination of low demand and high RE production). As a positive impact, RE may keep parts of the system operational in the event of transmission failures which otherwise would cause black outs.

Connection of RE generation to the distribution network introduces similar effects as in transmission grids including changing direction and quantity of real (active) and reactive power flows, which may affect the operation of network control and protection equipment. There is less active management of distribution networks than at the transmission level. Nevertheless, distribution networks have to cope with varying distributed generation levels without reducing the quality of supply. Weak distribution networks may be supported by RE and end-users may be better served because RE can contribute to grid voltage and power quality control. Power generated within a local distribution network can go directly to local users, thereby avoiding transmission costs and line losses.

Security of supply

TSOs impose grid connection requirements, such as interconnection regulations and grid codes, on RE plants just like on any other generator. This is to keep good order in the system and to prevent negative impacts on the network. For example, in countries facing significant wind power development, the specific rules for wind power are continually being refined to allow a larger penetration and at the same time maintain an adequate power supply. Grid codes are country and system-specific, resulting in a wide disparity of requirements that equipment manufacturers, developers and RE plant operators face across the globe. Internationally harmonized connection requirements for RE plants would avoid unnecessary costs for manufacturers and operators but they are very difficult to achieve.

Also in many countries, rules for network connection for small scale RE generators are lacking. Unnecessarily strict demands on connections in the name of security of supply might result in the formation of local barriers, so guidelines preventing this from happening would be useful.

Need for upgrading transmission network infrastructure

High penetration levels of RE may necessitate additional upgrades in transmission and distribution grid infrastructure, as may be the case when any new power plant is connected to a grid. In order to connect remote high-resource site plants to load centres, new transmission lines may have to be constructed. Upgrading transmission infrastructure to handle large penetration of variable RE is a complex process subject to strategic long-term planning which has to proceed through various stages, following the gradually increasing penetration of RE. Transmission systems in several parts of the world have been developed in a compartmental way by being confined within countries or to limited network areas. National TSOs and regulators deal with grid issues, balancing and power exchange in a way that is determined by national legislation, grid topology, geographical situation and historical developments. Relatively low penetration (< 10%) of variable RE in existing networks could add to existing transmission congestion. The extent to which transmission upgrades are required depends on the effectiveness of congestion management and optimization of the transmission system. At higher penetration levels, or in order to access new remote resources, new lines have to be added. Planning methods should avoid the classic ‘chicken and egg’ problem by jointly considering RE power projects and the associated transmission network requirements. At very high penetration levels of variable RE, large-scale storage systems may become economically attractive. Transmission network upgrades are needed for large-scale integration of wind power in many countries.

Flexibility and Aggregators

The realization of the European energy policy’s objectives requires processes and technologies for integration and market-based exploitation of flexibilities and services provided by demand and distributed energy resources, while improving cost-effectiveness, security and quality of supply for all consumers. Especially in order to integrate small customers and small and medium enterprises (SMEs) into markets, the new concept of the aggregator has been created. It is rather new in power systems and even if the practical “implementation” of aggregators may be close to appearing in real-life, the concept is still the subject of research. More specifically, **the main role of the aggregator will be to aggregate the flexibilities and services provided by consumers/producers in order to offer in turn to the other power system participants services of a commercial or technical nature**. Demand side participation is seen as an important mechanism for addressing the issues of improving overall system balance, reducing the reliance on inefficient fossil fuel generation, particularly at peak times and increasing the utilisation of renewable energy sources with variable output.

Demand response (DR) is about flexible -shiftable or curtailable- end-user loads responding to control signals. Shiftable loads are those that can be postponed in time, but their overall consumption does not change, for example washing machines, dryers or EVs. Curtailable loads are loads that can be set to consume less for a (short) time, for example air conditioning or space heating. DR started to come into use in the 1980's, but the unbundling of markets in many places halted progress, especially for smaller end-users without precise meters.

The full business separation between key players (transmission and distribution, trading and generation) in an electricity market has a significant impact on the potential implementation of DR. Full business separation can make it difficult to justify the business case for demand response due to the fact that the potential benefits are distributed across a number of different organisations. In this situation, the role of demand aggregator could become pivotal in gaining access to benefits throughout the value chain.

In terms of barriers, the current lack of existing demand response providers could represent a moderate barrier for new service providers to enter the market. The lack of specific economic incentives for the TSO to reduce costs and also the market dominance of existing suppliers are perceived as a significant barrier to the development of new products. For the successful implementation of demand response concepts, an appropriate pricing model for demand response services will have to be developed.

The balance settlement process highlights the complexity of the relationship between demand aggregators, the customers and their energy suppliers. The actions of demand aggregators have a direct impact on the imbalance of energy suppliers if their customers use less energy than expected (during a particular trading interval) due to demand response actions. The settlement process by which the energy consumption patterns of the customers without interval meters are determined has the potential to present a significant barrier to the development of demand response products. The use of profiles makes it difficult for energy suppliers to capture the value of any changes to the demand profile of their customers. Whilst the roll out of smart meters enables time of use energy profiles to be collected for small consumers, the interval data is not necessarily used for settlement purposes. In many cases, households with smart meters are still settled on the basis of the deemed consumption profile rather than their actual consumption. Therefore, it should be beneficial that, once the roll out of smart metering has been completed, hourly metered consumers should have their electricity meter read daily, thus facilitating settlement based on actual consumption patterns. Smart metering is recognised as a key enabling technology for the implementation of demand response products.

4.1.2. Gas

The technical challenges have to do with producing biogas from local (and renewable) energy sources in a cost-effective way. Biogas must uphold given quality requirements when used as an alternative for natural gas.

Biogas consists of 45-75% methane and 25-50% carbon dioxide (CO_2). Small amounts of hydrogen sulphide (H_2S), nitrogen (N_2), hydrogen (H_2), oxygen (O_2) and traces of ammonia can also be found in biogas. Landfill biogas can include more problematic components than, for example, biogas made from manure or energy crops. Landfill gases are forbidden in some natural gas networks, for example in Austria [ÖVGM 2001]. If the biogas is to be inserted into the natural gas grid, upgrading to natural gas quality is required. This means that the share of methane has to be over a set limit, e.g. 96%. Though natural gas networks have varying restrictions and regulations, natural gas composition is not uniform, exhibiting significant variation depending on its source. [Persson 2006]

Two of the most commonly used -and mature- upgrading technologies are pressurised water scrubbing and pressurised swing adsorption. In addition to investment costs, the upgrading processes also use electricity (electricity energy used matches 3 to 5% of methane energy) and loose methane (1 to 2%). Chemical scrubbing processes lead to half the electricity consumption, but in turn need temperatures of 160°C.

4.2. Economic and Financial Challenges/Barriers

Though many repeatedly argue that cost is a barrier to the more rapid adoption of RES technologies, the discussion of current and future cost projections provides something of a mixed picture and does not necessarily concur with this analysis. Both geothermal and wind power technologies are already more or less cost competitive with at least some of the conventional fossil fuel-based technologies—even without higher prices for carbon credits. Moreover, while all of the RES technologies exhibit declining cost curves over time, most or all of the fossil fuel-based technologies exhibit the opposite trend. Though wind power is a heavily fluctuating renewable power resource, geothermal is a constant base-load power source. While other RES technologies—in particular Solar PV—remain costly, prices have come down considerably over time and rapidly rising capacity means that costs are likely to drop much further in a relatively short period of time. Moreover, national level incentive schemes that provide strong support for solar PV are likely to drive this evolution ever further along the same curve, spurring further innovation, rising efficiency and further reduced costs. CCS technologies, on the other hand, are quite expensive in comparison and ultimately require a relatively high price for carbon credits (from 30-40 Euros per ton) in order to begin to be competitive. Nuclear power is also occasionally seen as quite expensive in the longer term.

Cost is largely a relative descriptive factor. Firms care about the cost of energy because they compare their cost position *relative* to other firms in the world marketplace. If energy is cheaper in one location compared to another, firms enjoy cost and thus market (dis)advantages. Applied unevenly across geographic regions, constraints on the purchase of different kinds of energy can impose increased costs and competitive disadvantages in the region where they are introduced. Internalizing the costs of global warming and/or environmental degradation—through the imposition of carbon accounting and crediting systems (or carbon taxes), such as the European Emission trading Scheme (ETS)—has the potential impact of creating cost disadvantages in regions of the world where these are applied unevenly. Though consumers are likely to care more about rising energy costs because these represent relative welfare losses, estimates of the total amount of welfare losses over relatively long periods of time are quite small.

Without the successful conclusion of a revised Kyoto-style agreement for the period 2012-2020 including all of the major economic market players and countries, cost factors are likely to remain a significant constraint in the development of future energy generation systems. Market players and thus states are likely to remain highly sensitive to cost factors for some time to come. The recent financial and economic crisis has likewise contributed to these concerns. Though one can reasonably expect the repercussions of the financial crisis to be relatively short-lived, it may take some time before economies completely readjust. This will complicate attempts to garner support for rising costs *where these occur* as a result of moving toward the low carbon economy.

RES and Electricity Costs in Germany

Though the German system is often assumed to generate excessive costs due to high feed-in tariffs, the German system has oddly not been terribly expensive (see Table 9 below). In general, based on the report from which the data was taken, Germany produced about 10.4% of its electricity needs from renewable sources in 2005. Of the costs related to the Renewable Energy Sources Act (which sets the feed-in tariffs, row 2 in the table below), the additional cost of electricity consumption was about 1.84 Euros/month in 2005, or 3.4% of the total electricity cost. Moreover, the price differential created by the German feed-in tariffs generated 7 billion Euros worth of investments in 2005 alone. The report cited below predicted that by 2020, Germany would produce approximately 25% of its total electricity needs from renewables.

Table 9: Cost of the RES Act in Germany

	1998	1999	2000	2001	2002	2003	2004	2005*
Electricity bill (EUR/month)	**49,95**	**48,2**	**40,66**	**41,76**	**46,99**	**50,14**	**52,38**	**54,36**
Renewable Energy Sources Act	0,23	0,28	0,58	0,7	1,02	1,23	1,58	1,84
Heat-Power Cogeneration Act	0	0	0,38	0,58	0,76	0,90	0,85	0,93
Electricity tax (eco-tax)	0	2,25	3,73	4,46	5,22	5,97	5,97	5,97
Concession charge	5,22	5,22	5,22	5,22	5,22	5,22	5,22	5,22
Generation, transmission, marketing	37,6	33,8	25,15	25,05	28,29	29,9	31,52	32,90
Value-added tax	6,90	6,65	5,60	5,75	6,48	6,92	7,24	7,50
Cent per kWh	17,1	16,5	13,9	14,3	16,1	17,2	18,0	18,6
Electricity bill in prices from 2000	50,97	48,88	40,66	40,94	45,44	47,98	49,32	50,19

* Avoided costs for electricity covered by the Renewable Energy Sources Act: 3,7 Cent/kWh; Electricity covered by the Renewable Energy Sources Act: 44.003 GWh

** from 2002 pursuant to the new Heat-Power Cogeneration Act (KWKG) that entered into force on 1 April 2002. Increase through reducing burden on manufacturing industry

*** varies greatly regionally: from 2002 1.32 to 2.39 cent per kilowatt-hour depending on size of municipality; some municipalities do not enforce this charge

Sources: German Electricity Association (VDEW), Figures for Renewable Energy Sources Act in 2005 additionally: BMU/VDN"

Source: [German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety's report; "What Electricity from Renewable Energies Costs" January 2007]

It is however easy to overestimate the total impact of energy investments in renewable technologies on total costs (see Table 9 above). The measurement of cost is a complex problem. Moreover, producing broad averages of cost across large geographic regions and periods of time can easily obscure sub-regional variation or recent technological innovations. Although the operational costs associated with different technologies are occasionally high — in particular with wind power due to the high degree of fluctuation in wind availability — these can also be easily exaggerated. Such high costs are impacted just as heavily by the structure and quality of grid network systems as by the intermittent nature of wind power. Several factors contribute, for example, to reductions in the operation costs associated with wind power: the broad geographic dispersion of installations, the presence of an extensive energy transmission network (including access to cross-border interconnections) that can more easily resolve temporary imbalances in supply and demand, as well as the substantial shortening of the time sequences (gate closure times) for submitting supply and demand requests for power. Where response times are very short, the ability to respond rapidly to changes in wind power availability is greatly increased and costs reduced [e.g. Holttinen 2009].

Figure 10: Increase in reserve requirement

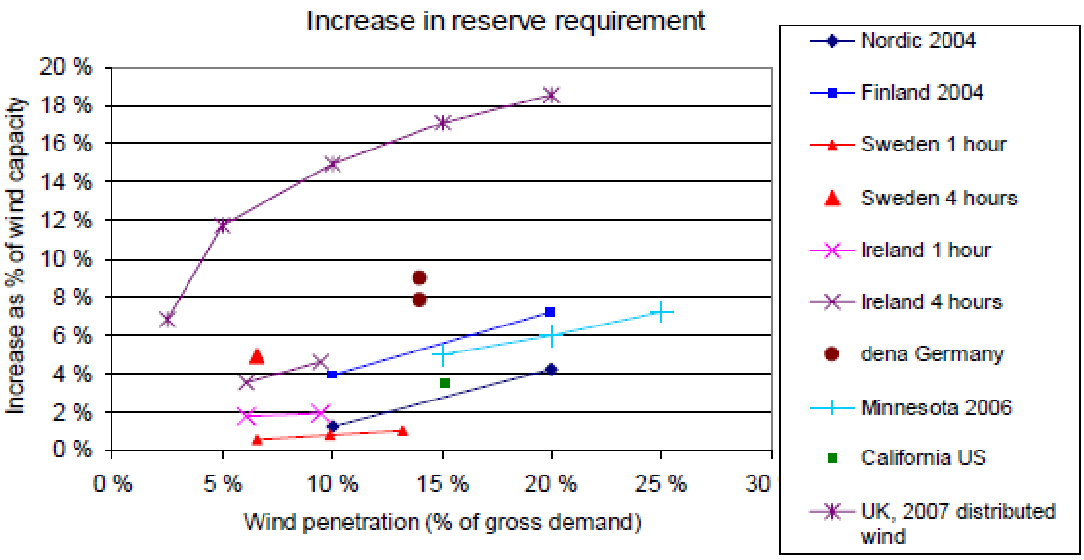


Fig 56. Results for the increase in reserve requirement due to wind power. German Dena estimates are taking into account the day-ahead uncertainty (for up and down reserves separately) and UK the variability of wind 4 hours ahead. In Minnesota and California, day ahead uncertainty has been included in the estimate. For the others the effect of variations during the operating hour is considered For Ireland and Sweden the 4 hour-ahead uncertainty has been evaluated separately.

Source: [Holttinen et al 2009: 170: IEA Wind Task 25]

Figure 11: Gate Closure Times

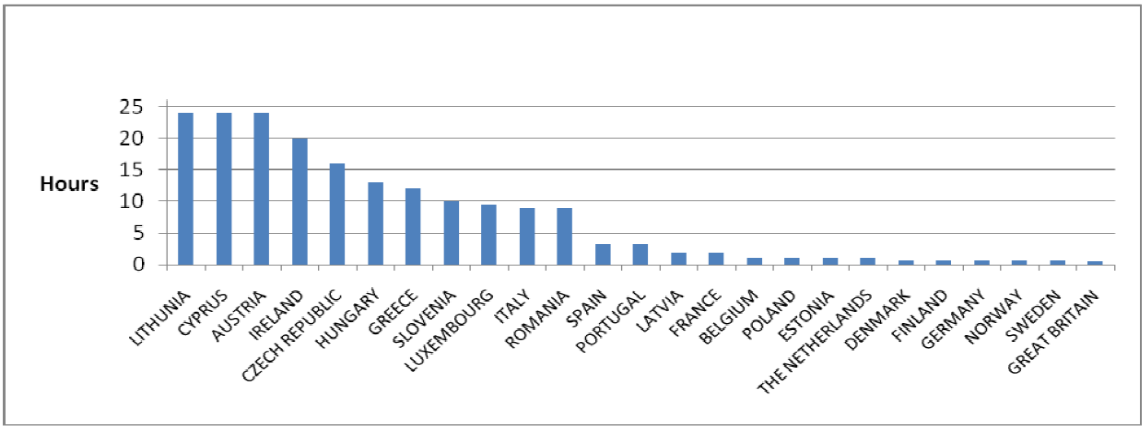


Figure 4: Time between closure of forward market and real-time delivery

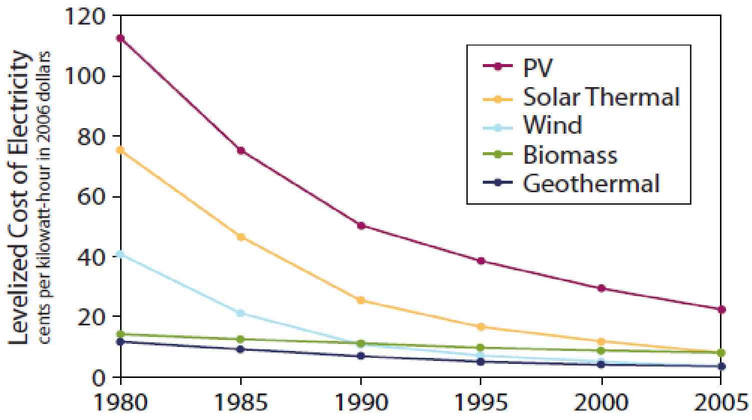
Source: [CEER 2009: 17]

While estimates of the cost of wind power often include operational costs, improvements in the transmission grid structure and its potential geographic extent have substantial impacts on cost. Moreover, while operational costs are often seen as annual costs, transmission grid investments are typically one-off costs. Though such issues clearly raise questions about who should pay for investments in the grid network, it is also problematic to automatically ascribe high operational costs to specific technologies.

Other issues also plague the estimate of costs and the advantages/disadvantages of different technologies. In particular, the construction of very broad averages across a large set of countries and firms easily disguises many important factors regarding technology costs. A good example concerns the representation of geothermal electricity generating technologies. For one, the WEO price estimates for geothermal are based on plant construction time periods of 3 years. However, some of the most recent innovations in the field of modular geothermal power plants suggest that these time periods can be substantially shortened (to as little as six months).[34] Similar issues arise with estimates for constructing concentrating solar power installations. The WEO estimates suggest this takes 3-4 years, while some recent installations in the US have been completed in 3-6 months.[35] More generally, the newest innovations are not easily represented in grand scale costs estimates. Thus, for example, while the cost of concentrating solar power (CSP) is estimated by some to be still substantially above that of conventional electricity generation technologies, the European Photovoltaic Industry Association (EPIA) argues that “grid parity” will be achieved by 2015 for all of Europe and much earlier than this for the sunnier parts of Europe [EPIA, 2009].[36]

Moreover, it is also worth coming back to the issue of Technology S-curves and spending strategies for the promotion of technological innovation. The fact that higher costs exist for certain technologies is, in the long run, hardly an argument against future investments in those technologies. What matters more is the potential rate of change in cost that results from such investments. As illustrated in Figure 12 below, costs have declined quite considerably over time. Though cost declines for geothermal technologies have not been as great, these have also not received as much research funding as some of the other RES technologies.

Figure 12: Declining Cost of RES Technologies



Source: NREL Energy Analysis Office. See *www.nrel.gov/analysis/docs/cost_curves_2005.ppt.*

Note: The levelized cost of electricity includes the annualized costs of capital and operation and maintenance. This graph reflects historical trends, not precise data on annual costs.

Source: [UCS 2009: 76, Fig. 5.7]

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[34] Though the US geothermal power producer Raser Technologies has met with many some difficulties along the way, the modular structure of its generators potentially greatly reduces construction times, potentially to as little as 6 months (www.rasertech.com).

[35] First Solar completed a 10 MW ground-mounted solar PV plant in Nevada in less than six months (see; http://investor.firstsolar.com/phoenix.zhtml?c=201491&p=irol-newsArticle&ID=1238556&highlight=) and a 21 MW solar PV plant in California in three months (see: http://investor.firstsolar.com/phoenix.zhtml?c=201491&p=irol-newsArticle&ID=1368252&highlight=)

[36] There is somewhat remarkable concordance across the various predictions from different sources on the likely target date for achieving grid parity. Essentially the same predictions are made, for example, by BP (2007) and

In order to provide a relatively clear picture of the cost of RES technologies, we provide cost estimates from 4 different sources; Schilling and Esmundo estimates based on data from the US National Renewable Energy Laboratory (NREL), the International Energy Agency's 2009 World Energy Outlook, the Union of Concerned Scientists (UCS) and the Global Abatement Cost Curve from 3C (previously introduced by McKinsey and Vatenfall).

Table 10: Cost of Energy (cents per kWh)

Year	Renewables[a]								Fossil fuels[b]			
	Geothermal		Concentrating solar		Photovoltaics		Wind		Coal	Natural gas	Petroleum	Fossil fuel composite[c]
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower				
1980	13.8	11.3	84.0	69.5	125.0	106.3	51.3	43.0				
1981	13.1	10.6	74.0	57.0	119.0	100.0	47.5	40.0				
1982	12.5	10.0	66.0	46.8	112.5	93.0	43.3	36.3				
1983	11.9	9.4	56.0	38.3	105.0	84.5	38.8	32.5				
1984	11.3	8.8	46.8	27.5	99.0	78.0	36.0	29.0				
1985	10.6	8.1	36.0	24.0	93.0	72.0	31.3	25.3				
1986	10.0	7.5	30.3	21.3	87.5	68.8	28.8	22.5				
1987	9.7	7.2	27.0	19.0	82.0	63.0	25.3	18.8				
1988	9.4	6.9	25.0	17.0	77.0	59.5	22.5	16.8				
1989	8.8	6.3	23.5	16.0	72.0	55.5	20.0	14.8				
1990	8.4	6.3	22.0	15.0	68.8	52.0	17.6	12.5	1.6	2.1	2.6	1.7
1991	8.1	5.9	21.5	14.0	66.0	49.0	15.0	11.3	1.5	1.9	2.1	1.6
1992	7.5	5.6	21.3	14.0	62.5	45.0	13.8	10.0	1.5	1.9	2.0	1.5
1993	6.6	5.3	21.0	13.8	59.0	43.3	12.0	8.8	1.4	2.0	1.9	1.5
1994	6.4	5.1	20.8	13.5	56.3	40.5	11.3	7.6	1.3	1.7	1.8	1.4
1995	6.3	4.9	20.0	13.3	53.0	37.5	9.8	6.9	1.3	1.6	1.8	1.3
1996	6.2	4.8	19.3	13.0	51.0	34.0	8.8	6.3	1.2	1.8	1.9	1.3
1997	5.9	4.4	18.5	12.9	48.0	31.3	8.4	5.9	1.1	1.8	1.7	1.2
1998	5.6	4.0	18.0	12.8	46.0	29.0	7.8	5.3	1.1	1.5	1.4	1.2
1999	5.3	3.8	17.5	12.8	43.8	27.0	7.5	5.0	1.1	1.6	1.5	1.1
2000	5.1	3.8	17.3	12.8	42.5	26.0	7.3	4.9	1.0	2.3	2.2	1.3
2001	5.0	3.7	17.1	12.8	40.5	24.0	6.7	4.7	1.1	2.3	2.0	1.2
2002	4.9	3.6	17.0	12.7	38.0	23.0	6.4	4.6	1.1	1.9	1.8	1.1
2003	4.7	3.4	16.7	12.7	36.0	21.0	6.3	4.5	1.0	2.6	2.2	1.4
2004	4.4	3.2	16.0	12.0	33.0	20.0	6.0	4.4	1.1	2.8	2.2	1.5
2005	4.3	3.1	15.0	11.0	31.0	18.8	5.5	4.3	1.2	3.5	2.9	1.8

Source: [Schilling and Esmundo 2009: 1772, Table 1]. The authors use data from the US National Renewable Energy Laboratory (NREL)

Table 11: Abatement Cost in the US and EU ($ per tonne CO_2)

US Results for 2030

	CO_2 Savings	Abatement Cost
	$MtCO_2$	$ per tonne CO_2
Changes in demand	**337.1**	
Savings from lower emitting technologies	**1 243.5**	**48.5**
more efficient coal plant (excl. CCS)	*238.4*	*13.8*
more efficient gas plant (excl. CCS)	*4.1*	*63.0*
utilising spare gas capacity over coal	*43.2*	*77.3*
through use of CCS	*507.8*	*63.9*
- CCS Coal (Oxyfuel)	*209.3*	*66.4*
- CCS Coal (IGCC)	*269.2*	*60.6*
- CCS Gas	*29.3*	*76.0*
Nuclear	*205.8*	*35.5*
Renewables	*244.1*	*56.1*
- Hydro Conventional	*38.6*	*27.8*
- Bioenergy	*2.3*	*50.8*
- Wind Onshore	*103.8*	*40.2*
- Wind Offshore	*33.3*	*54.4*
- Geothermal	*14.4*	*19.1*
- Solar PV	*25.9*	*179.9*
- Concentrating Solar Power	*24.2*	*61.9*
- Tide/Wave	*1.7*	*52.3*
Total Savings	**1 580.5**	

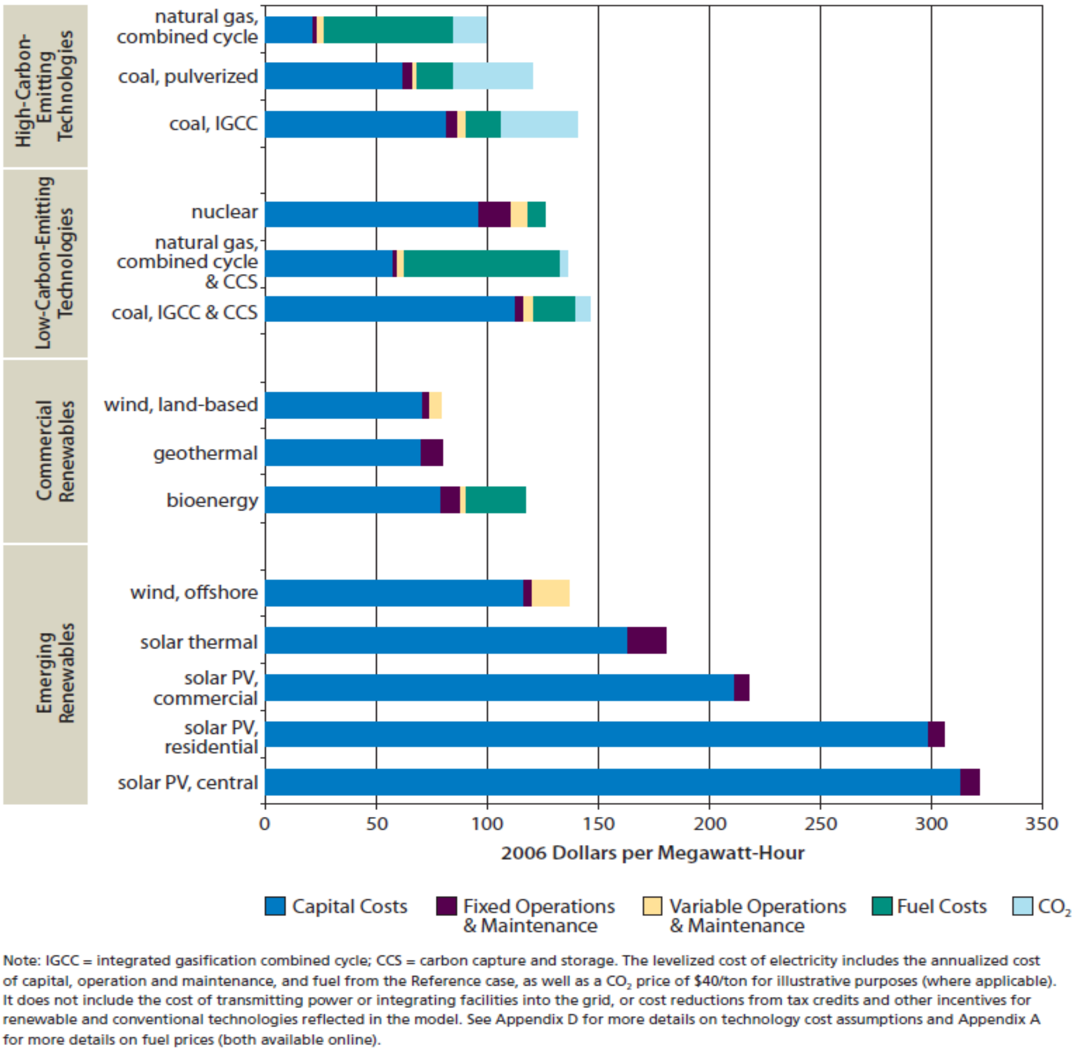
European Union Results for 2030

	CO_2 Savings	Abatement Cost
	$MtCO_2$	$ per tonne CO_2
Changes in demand	**127.3**	
Savings from lower emitting technologies	**660.0**	**54.2**
more efficient coal plant (excl. CCS)	*23.5*	*9.9*
more efficient gas plant (excl. CCS)	-	-
utilising spare gas capacity over coal	-	-
through use of CCS	*158.4*	*61.1*
- CCS Coal (Oxyfuel)	*77.0*	*56.9*
- CCS Coal (IGCC)	*66.4*	*61.1*
- CCS Gas	*15.0*	*83.1*
Nuclear	*252.6*	*39.6*
Renewables	*225.4*	*70.2*
- Hydro Conventional	*16.3*	*32.6*
- Bioenergy	*39.7*	*58.6*
- Wind Onshore	*22.4*	*46.0*
- Wind Offshore	*99.6*	*63.0*
- Geothermal	*7.4*	*27.2*
- Solar PV	*23.0*	*188.4*
- Concentrating Solar Power	*8.2*	*70.7*
- Tide/Wave	*8.8*	*61.5*
Total Savings	**787.2**	

Source: [World Energy Outlook IEA, 2009]

others. Moreover, claims of having already achieved grid parity have been made for sunnier locations, such as Hawaii and California (see e.g.: "Solar Power Edges Toward Boom Time", (www.reuters.com, Oct. 19th, 2007).

Figure 13: Levelized Cost of Electricity, 2006 US Dollars per MWh



Source: [Union of Concerned Scientists 2009: 77, Fig. 5.8]

A number of interesting points should be noted based on this data.

- First, **cost estimates vary substantially** from one to the next.
- However these studies tend to agree that currently, **the two most competitive RES technologies are first geothermal and then wind power**.
- Moreover, in most studies, **geothermal and wind power are typically cheaper than the combination of coal-based power production and CCS technologies** (even at relatively high carbon credit cost estimates).
- While the focus in most studies is on price decline in RES technologies, **fossil-fuel-based electricity prices have been rising** in recent years (see the first table from Schilling and Esmundo based on NREL data). Though the rise in fossil fuel-based prices has been the least pronounced for coal-based power production, prior to the recent financial and economic crisis, the price of coal was likewise on the rise.[37]

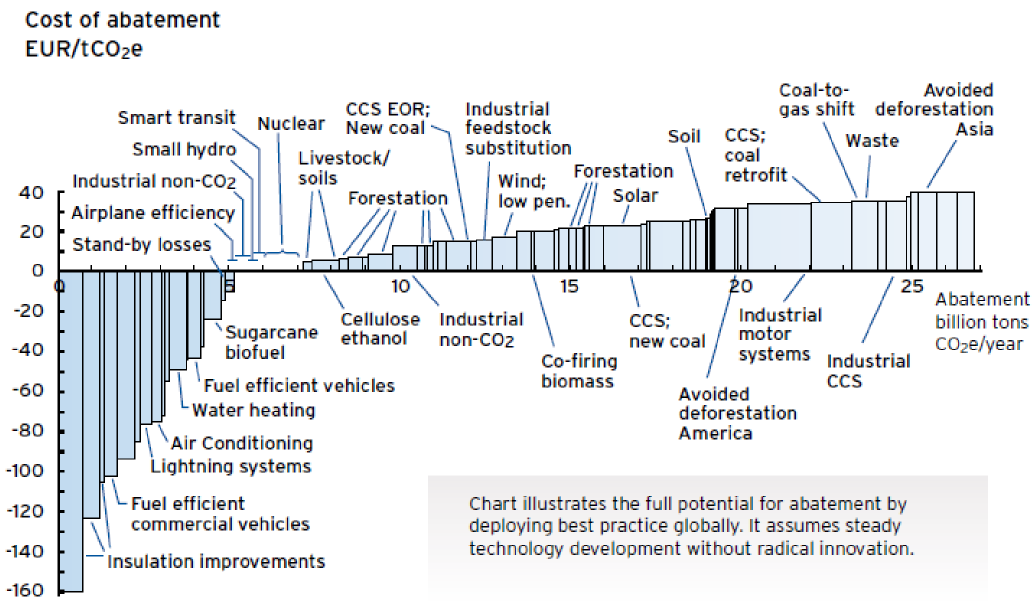
[37] See for example: "Coal, The End is Nigh", (The Guardian, 9 March 2008).

- The **price of RES technologies, however, has declined steadily** and will presumably continue to decline with continued R&D investments, commercialization incentives and the rapid growth of new market entrants.
- Finally, **nuclear power is frequently not thought to be as cost competitive as either geothermal or wind power**.

Not well-represented in these various cost estimates are the specific costs related to the non-RES DER technologies, grid-updating and cross-border interconnections, or the costs of introducing Smart Grids and Smart Metering. Moreover, even where we know the potential costs of individual grid improvement projects, these are rarely expressed in terms that are comparable to the above terminology (e.g. cost, or reduction in cost per kWh). While this would greatly facilitate meaningful comparisons of cost and thus the advantages of introducing various new technologies, these still need to be made available.

One of the principal cost components not frequently discussed is the relative inefficiency associated with the rigidity across the many different EU GHG reduction targets and energy efficiency goals. The basic point is already reflected to some degree in Figure 1 in the introduction: EU Member States face a variety of targets (the RES directive, the ETS directive, the energy efficiency directive and the effort-sharing decision) each of which requires Member State action in specific categories. However, as suggested in particular by the above discussion of the rigidity across the EU ETS and non-ETS sectors, there is little or no flexibility across the basic categories. Carbon credits booked in the non-ETS sector are not fungible in the ETS-sector. Moreover, improvements in energy efficiency and/or emission reductions are not always required in the most cost-effective categories. This last point is perhaps most clearly reflected in 3C's well-known Global Cost Curve (see Figure 14). As reflected in this figure, the highest "negative" abatement costs (investment areas that bring more or less immediate cost-reducing benefits) are not found in the ETS sector where the current EU strategy places most of its effort.

Figure 14: Global Cost Curve of GHG Abatement Opportunities Compared to Business as Usual in 2030



Source: [3C 2009?] Originally developed by [McKinsey and Vattenfall 2008, 2007]

In this regard, it is worth investigating the potential cost that arises from requiring heavy investment in RES technologies or reductions in emissions from more carbon intensive industrial sectors when these may not always provide the most meaningful and cost-efficient solutions for individual Member States. As with the various flexibility mechanisms (the Effort-Sharing Directive and the Guarantee of Origin certificates) that attempt to introduce greater potential to trade carbon credits across Member States, a strategy allowing more flexibility across the various emission reduction and energy efficiency sectors might also provide a meaningful and efficient mechanism for promoting rapid emission reductions. Ideally, a model in which emission reductions resulting from any of the currently targeted areas (the non-ETS sector, RES and/or LULUCF (land us, land use change and forestry)) should ultimately give rise to fungible carbon credits. This could ultimately promote a far more flexible and cost-efficient system.

4.3. SMEs

There are today 23 millions of companies across Europe and 99% of them are Small and Medium size Enterprises (SMEs). Overall, SMEs represent 30% of Europe's energy consumption [Tajthy 2009]. In that sense, their involvement in the deployment of DER at local level is absolutely essential.

In theory, decentralized energy is very much SME-friendly:

- First, the availability of locally-produced energy would make them less reliant on energy market disruptions like price increases and price volatility
- Second it potentially provides additional income from selling excess electricity to the grid
- And third, energy efficiency and DR measures could help bring down their energy costs

Unfortunately, things are not so simple and decentralized energy faces significant barriers in SMEs. A Eurobarometer survey conducted in 2007 showed that comprehensive energy efficiency measures were much less in place in SMEs (4%) than in large companies (19%).

At the same time, the fact that sustainable energy has not really passed SMEs' doors so far means that those economic players represent "low hanging fruit" in terms of potential CO2 savings and adequate policies should be put in place to remove the barriers. The Carbon Trust conducted an advance metering trial in 2007 among British SMEs and demonstrated that those kinds of equipment could allow on average SMEs to achieve 12% of potential carbon savings and to implement 5% of emission saving by reducing energy consumption. And assuming a 20% roll-out rate, it is possible to envisage for the UK a saving of 1.5 MtCO2 per year by 2012 and 2.5 MtCO2 per year by 2016 [Carbon Trust, 2007].

Today, the main barriers to the spread of DEP in SMEs are:

- Lack of awareness: Like a very large portion of public opinion, most SME managers still have a relatively poor understanding of the energy and climate challenges that we face. By and large, they also do not thoroughly realize their exposure as businesses to energy scarcity and higher prices
- Short-term time horizon: SMEs are also intrinsically characterized by a very short-term time horizon. Most of the time, their primary concern is really immediate survival and the mid-to-long-term benefits brought by decentralized energy are very often realizable only in the more distant future. Such projects have to compete with other internal projects that are more urgently needed to stay competitive and that will therefore gain priority

- High capital investment required: In most cases, while profitable in the long run, small-scale renewable energy is still burdened by a high initial capital costs. By adapting to decentralized forms of energy, energy becomes a capital investment rather than what it used to be, a monthly expense. Clearly, only large companies with solid balance sheets can shoulder the financial burden. SME's on the other hand cannot spend their precious human and financial resources on sustainable energy projects that are complex and expensive to develop

Lack of expertise: SMEs very often do not have the necessary in-house expertise to carry out such projects on their own. There is a clear need for the appropriate information, ranging from the legal and policy framework to the economics of DER and the technical feasibility of different solutions. The first step in implementing sustainable energy measures among SMEs would logically be an energy audit. It can be noted that a lot of energy auditing is being performed at the moment (see best practice in the textbox below).

BEST PRACTICE: LIDKÖPING MUNICIPALITY (SWEDEN)
The 3-year Energy Gain project carried out by Lidköping municipality in Sweden won the first prize at the "ManagEnergy Local Energy Action Award 2009". The basic idea was to train 100 local SMEs to become more energy efficient and switch to renewables. The project was divided into two phases: educational and practical. It proved very successful mainly thanks to close cooperation between the local authority and local SMEs. A number of tools were created to help SMEs develop energy action plans and specific training methods adapted to each sector were developed. Sectoral platforms have also been implemented to facilitate dissemination by sharing best practice and knowledge.

The availability and dissemination of energy management systems is also an important aspect. These tools should be sector specific. Their developments require a lot of work and thus are only feasible when done by clusters of similar companies or through projects funded by public authorities. It is important to ensure the sharing of both results and methodologies across comparable companies.

BEST PRACTICE: EMS TEXTILE
EMS Textile is a project financed by the Intelligent Energy Europe Program and lead by a Greek firm called Sigma Consultants Ltd. The objective was to raise awareness and improve energy efficiency in the textile sector in four countries: Greece, Portugal, Spain and Bulgaria. It also aimed at designing an energy management system for SMEs involved in this sector. The project was supported by a communication and dissemination campaign through the internet, the press as well as the organisation of a dedicated workshop and participation in sectoral and environmental tradeshows. This has had a very positive impact on awareness-raising.

ESCOs (Energy Service Companies) may represent one way of overcoming the technical and economic barriers to the spread of decentralized energy among SMEs. [Bertoldi and Rezessy 2005] define an ESCO as a provider of energy services including: energy analysis and audit, energy management, project design and implementation, maintenance and operation, monitoring and evaluation of savings, property/facility management, energy and/or equipment supply and provision of service (space heating/cooling, lighting, etc.). Additionally, ESCOs contractually guarantee the energy and/or savings or the same level of energy services at lower costs. In that sense, ESCOs allow long-term economic benefits to become immediately tangible in the short-term by supporting part of the risk. The technical risk is transferred from the client (e.g. SMEs) to the ESCO. They can either provide financing or assist in arranging it. Their remuneration is directly linked to the energy saving achieved by their client. Historically the business model of energy providers consisted of selling energy to the final consumers: the more energy sold, the more profit. ESCOs now have a different business model: they sell an energy service (as opposed to selling energy as a commodity) and the profits are directly correlated with the amount of "negawatts", thus starting a virtuous circle. ESCOs also intervene in the monitoring and verification of the energy performance of their clients.

Under an Energy Performance Contract (EPC), ESCOs develops an energy saving or renewable energy project for their client. The stream of income coming from reduced energy costs and/or the selling of green electricity is then used to cover the project costs with a margin. The ESCO business is still in its infancy except in Germany, Austria, Hungary and France [Bertoldi *et al.* 2005]. ESCOs are usually large companies or subsidiaries of large companies.

While SMEs should be natural target clients for ESCOs, several barriers are evident. The contract time that usually runs for more than 5 years can be problematic for SMEs. While it provides certainty and visibility about energy prices over a long period of time, it can also be restrictive in some cases for example for rapidly growing businesses that may have to move to another location and may want to avoid being "chained" to a contract with an ESCO. Again lack of awareness in SMEs also plays an important role. SMEs tend to exhibit scepticism mainly because of a limited understanding of energy efficiency, EPC contractual arrangements and the related regulatory framework. The inherently small size of the sustainable energy projects implemented at SME level may also constitute a barrier for ESCOs because it does not allow the same economies of scale as for large clients. A lot of time must be invested but the return is limited compared to larger clients. For financers, the issue is more of the same: they tend to focus on the size and not the number of projects.

4.4. Legislative Challenges and Barriers, Concluding Remarks

On the legislative side, many potential challenges and barriers exist. At EU-level, DEP is present without really being present. Currently it is indirectly linked with a series of directives on the promotion of RES technologies, cogeneration and liberalization of the internal electricity market and the energy performance of buildings. Many of these directives aim at promoting selected technologies (CHP, renewables), thereby promoting a more decentralized and flexible European energy system capable of integrating energy produced by both large centralized facilities and small power producers. Moreover, many of these directives aim at making the energy market more competitive and fair as well as less carbon intensive. However, there are a number of areas where the EU and the Member States could go further in order to promote the proliferation of DER technologies.

Several major issues concerning existing EU level legislation could be addressed. To-date there is no clearly defined strategy on DER or DG at the EU level. DER and strategies to promote the adoption of DER-related technologies are not well-integrated into the EU policy framework and no comprehensive strategy is currently being discussed. Such matters are not facilitated by the fact that many similar but sometimes contradictory terms such as distributed generation, dispersed generation, distributed power, distributed energy resources, decentralized power, decentralized energy systems and decentralized energy production are used to designate are tossed about in haphazard fashion without a very clear sense of what the goals are or should be. It further remains unclear whether the focus of policy efforts should attempt to single out and favour small scale DER technologies over similar large scale technologies (i.e. whether large scale wind farms should be considered a part of DER or not).

Many of the existing incentive systems fall under the purview of state-managed incentive systems, making it difficult for the EU legislative framework to have a real impact on the introduction and adoption of such technologies. For another, many of the EU level strategies seem either not well designed to promote smaller scale DER technologies, or they may even favour the pursuit of larger scale technologies at the expense of DER.

With the window of opportunity provided the Commission by the new TFEU competences, it may be advisable to formulate a clear and comprehensive long-term strategy on DER consistent with the principles of a liberalised energy market and with the goals of EU energy and climate policy.

Finally, current EU-level strategies are occasionally contradictory and/or provide perverse incentives not likely to be beneficial either for the rapid deployment of DER technologies, or for incentives to move toward the low carbon economy. The EU CHP Directive, for example, may conflict with features of the EU EPBD, resulting in surplus heat production, thereby reducing the overall efficiency of the initiatives. Similarly, the EU RES Directive, and in particular the EU-wide Guarantee of Origin model may fail to encourage and potentially even have a negative impact on the development of smaller scale DER technologies. Finally some features of the EU legislative framework could be further improved in order to provide stronger incentives for the adoption of DER technologies. The current EU ETS system likewise misses important opportunities for promoting DER technologies and reducing emissions.

The Third Energy Package

Though the *Third Energy Package* provides an important framework for improving the liberalization of the energy sector, improving grid infrastructure and international cross-border interconnections of electricity and gas grid systems, for regulating the problem of grid connection and priority grid access for RES technologies, the implementation of the *Third Energy Package* must be promoted with consistent and careful monitoring. Moreover—in particular where strategies for grid access may become potential barriers to the smooth integration of RES and DER technologies—both close monitoring and the sharing of best practice implementation strategies should form the groundwork of future efforts.

To-date, only a relatively small number of EU Member states currently provide immediate and free grid access or guarantee priority uptake of renewable energy production. Moreover, Member states are free to set up their own model system. Finally, if practice is any guide, implementation is likely to be slow. Further problems arise with the intent of moving forward with the cross-border interconnections in the European electricity and gas grids. While these are grandiose schemes, Member states still have very far to go before the EU has a highly flexible and integrated grid network. Persistent and careful monitoring at the national and EU levels, as well as sharing of best practice, in particular regarding grid connections and priority access, are likely to be useful tools. For DER technologies, such loopholes in the system represent genuine barriers that need to be resolved.

The CHP and EPBD Directives

The EPBD and CHP Directives may require some additional “*fine-tuning*” in order to ensure the greatest potential output from these strategies. In combination, the CHP and EPBD Directives may ultimately result in surplus energy—in particular heat energy. Strategies for resolving such dilemmas should be devised, in particular before EPBD passage into EU law.

FIT vs. RO and an EU-wide Model for the Promotion of RES Technologies

National and EU-level schemes for promoting RES and DER technologies and the EU-wide Guarantee of Origin strategy do not seem well-designed to promote either rapid RES adoption or DER technologies. Some of the systems have the effect of favouring large scale energy generation systems (in particular large scale wind power installations) and have little impact on the adoption of small scale DER technologies.

This fact alone may well explain why many countries have recently shifted from RO type systems over to the adoption of complementary **FIT systems**. While differentiated FIT systems and carbon taxes seem best suited to the rapid adoption of both RES technologies and smaller scale DER technologies—all the way down to household-based energy generation systems—these strategies have not been adopted in all countries. While the FIT system is the most widespread, the carbon tax is still uncommon in a large number of EU Member states.

The EU Guarantee of Origin strategy is potentially the most contradictory since if favours large scale and relatively undifferentiated RES technologies, and may potentially weaken or even undermine national-level incentives schemes. In the interest of the successful and rapid promotion of DER technologies, it would be advisable for the **EU to consider developing an EU-wide FIT model and the introduction of carbon taxes**. An EU-wide FIT model should, in particular, create the potential for a more *differentiated* strategy promoting a broad range of technologies based on a lowest common denominator of current costs and future potentials. Although the EU has only just finalized the new RES Directive (April 2009), the requirement to review the impact of the Directive by 2014 provides at least one important opportunity to reconsider its potential impact.

Finally, though it may be difficult to introduce a carbon tax at the EU level, the explicit benefit of a carbon tax is its explicit ability to promote greater energy efficiency and low carbon technologies across a much broader range of potential choices. In particular, a carbon tax that complements the EU ETS system and addresses fossil fuel-based energy use in other non-ETS sector areas (building-related energy use, natural gas use, transport) would potentially go a long way to more effective and efficient burden-sharing arrangement across the different ETS and non-ETS sectors. Such a strategy, due to its impact on consumer-based incentives to pursue greater energy efficiency, could also go a long way toward promoting the more rapid adoption of Smart Grid and smart-metering technologies.

R&D

On the research and development end and with regard to the current European Industrial Initiative spending program, more thought could also be given to balance across spending areas. Current **funding strategies** exhibit important weaknesses that should perhaps be resolved. Current funding plans do not seem to focus on those technologies that are the most likely to produce usable and advantageous results.

Though a highly contentious area, the current degree of support for CCS technology development seems exaggerated. Many of the renewable and smart grid technologies are far more developed with far greater potential for producing results. Moreover, several of these technologies—in particular wind and geothermal power production, are generally seen as competitive with conventional technologies. Added R&D resources could potentially have far greater payoffs in these areas. Several technologies appear to be under-supported. In this context, the lack of funding for CSP technologies and the lack of attention dedicated to non-fluctuating *base power* RES technologies such as geothermal, biomass and tidal/ocean power are remarkable. Moreover, the expansion of grid networks and investment in Smart Grid and smart-metering technologies and the management of demand response systems could presumably bring significant long-term rewards, both in terms of increased energy efficiency as well as the greater potential to absorb RES technologies. Greater funding of storage technologies likewise seems advisable.

Though it may be difficult to shift spending priorities at such a late stage, it is worth considering whether more resources should not be dedicated to *proven technologies* with a higher likelihood of producing *significant payoffs*.

EU ETS

Reconsidering the impact of the EU ETS Directive is advisable. This Directive places the principal emphasis of CO_2e emission reductions on the fossil fuel-based part of the power sector and high-emitting firms. Though the Effort-Sharing Decision has placed at least some emphasis on the non-ETS sector, **the fact that carbon credits cannot be bought or sold across the ETS and non-ETS sector divide creates unnecessary rigidity in the system and greatly weakens incentives to undertake investments in areas that are likely to be both more cost-efficient and more favourable to the rapid adoption of DER related technologies.**

Ideally, **energy saving and emission reducing investments in the non-ETS sector should yield serviceable credits** in a **broad EU-wide system**. This would give far greater impetus and potential to the future use of DER technologies than is currently the case. Without this flexibility, most of the EU climate effort will remain focused on larger scale initiatives related to the power sector and high-emitting industry.

5. Forward looking policies – Recommendations

5.1. The need for a comprehensive EU strategy for decentralized energy

Despite an indisputable move towards a more sustainable energy system, the current European legislative framework tends to promote large scale renewable energy sources and frequently fails to support the deployment and integration of small and micro-scale generating capacities. A number of inconsistencies across directives have been noted in the current study with regard to DEP and **we recommend the EU attempt to better integrate the promotion of DER technologies in the overall legislative framework.**

The EU legislative framework provides many positive elements in terms of supporting sustainable energy production and use but does not adequately and specifically address the questions posed by decentralized energy systems. **Thus more attention could be paid to supporting smaller scale DER technologies (in addition to the larger scale RES technologies).** First, **the EU RES Directive is not well suited to the spread of smaller scale DER technologies.** While some national level incentive schemes may provide strong incentives for DER, these strategies are not shared by all Member states and they may ultimately be weakened by the EU level Guarantee of Origin system set out in the new version of the RES directive.

Inconsistencies between the CHP directive and the EPBD have also been noted in the report. In particular the EPBD requires new buildings to achieve “very high energy performance” as of 2021. As a result, the heat demand of buildings is expected to decrease significantly, thus affecting the specification of energy needs especially in terms of heat. CHP development and the incentives used to promote it must take this into consideration. Ultimately, this will imply modifications in the design of CHP units in the years to come (as well as the incentive strategies used to promote them). Currently however this aspect is absent from the CHP directive. The EPBD requirement to construct buildings with a “very high energy performance” may have negative repercussions for surplus heat generated by other systems—in particular CHP and district heating systems. **Therefore, we recommend re-consideration of these inconsistencies across the CHP and EPBD directives—in particular before the finalization of the EPBD.** A consistent legislative framework would facilitate the installation of smaller capacity CHP units resulting in smaller electricity production and an easier and less costly balancing of the electricity grid. Further, in summertime, a much smaller amount of superfluous heat would be produced. As a result, electricity system operators would be protected from superfluous burdens. An alternative strategy for integrating the potential large capacity of CHP units is to build energy storage facilities and through them get round the problem of electricity demand valleys.

Though the EU-ETS offers some incentives for distributed generation by making alternative carbon-based power production more costly, the EU ETS strategy focuses almost exclusively on large emitters and promotes emission reductions from power plants and high carbon intensity industrial installations. The EU Effort Sharing Decision requires Members States to reduce emissions in non-ETS sectors and offers some flexibility to trade emissions across Member States borders in those sectors. **However, the possibility of further increasing flexibility by allowing emission trading across ETS and non-ETS sectors could be an interesting option for the EU to explore.** This would likely provide an increased degree of flexibility and stronger incentives for the promotion and deployment of DER.

5.2. Providing an adequate infrastructure to enable large-scale deployment of DER

The existence of an electricity network that can be easily and readily connected to is absolutely crucial for a strong penetration of decentralized energy resources into the European energy mix. Grid access has been identified as a major non-technical barrier to DEP, with grid connection often representing a legal, administrative and economic hurdle for green energy producers. This is potentially all the more true for small-scale producers who become even less competitive as a result. Additionally, it is important to ensure a competitive and non-discriminatory environment for gaining access to the network. In particular because of the EU's commitment to emission reductions and the low carbon economy, renewable and DG energy producers should receive priority access to the grid. This is not likely to be the case as long as energy network operators and energy producers remain bundled.

These issues are addressed in the Third Energy Package adopted last year by the EU. However, we strongly recommend ensuring the implementation and enforcement of the third energy package adopted last year. **Its implementation should be closely monitored, with best practice sharing across countries.** This legislation is absolutely crucial to creating a level playing field for smaller-scale DEP.

Moreover, the issue of grid connection cost sharing between project owners and network operators should be addressed, in particular for small-scale installations. Member States are provided significant leeway to define and set the terms for the sharing of grid access costs across grid network owners and new energy producers. **More concerted effort and a greater degree of monitoring and coordination from the European Commission will be required in order to ensure that the rules applied by Member States do not negatively impact the development of DER**.

The harmonized rules that will be defined by the European Network of TSOs for Electricity/Gas should provide as much clarity as possible with regards to the sharing of connection costs. With regard to smaller scale DER technologies, the "shallower" the model adopted by individual Member states (i.e. the more responsibility for costs are transferred to utilities), the more rapidly smaller scale DER technologies will be adopted. Moreover, because these costs can be *passed on* by the utilities (but not by the DER technology companies) this model facilitates the "social sharing" of the costs of adopting low carbon technologies and removes potential cost-related barriers to grid access. Given the importance of these technologies, this is presumably desirable.

Grid owners and operators impose grid connection requirements, such as inter-connection regulations and grid codes on RE plants just as on any other generators. Today, these rules are country and system specific, incurring unnecessary costs for manufacturers and operators. **Therefore we advise pursuing the work already started to harmonize the grid connection requirements at national level keeping a close eye on implementation progress and the sharing of best practice strategies. Finally, where this appears advisable (e.g. in the face of persistent barriers to DER) we recommend the EU consider further potential harmonization at EU-level.**

From the grid operator's point of view, the increasing penetration of intermittent RES will place more constraints on the management of electricity supply and demand. As a consequence, inter-connections should be improved as well as power exchange rules both within and across neighbouring countries. Both **significant improvements in the shortening of grid network "gate closing times" and the development of cross-border interconnections should be a priority.**

Cross-border network interconnections will become increasingly important for the smooth functioning of DR and the balancing of intermittent energy sources in the EU energy system. The current state of international cross-border grid interconnections is a matter of considerable concern. Despite the fact that EU legislation requires the cross-national interconnection of national grid networks, implementation has been slow. **In this regard, the construction of the identified projects of EU interest should not be delayed.** The funding made available as part of the EU Economic Recovery Package is likely to have a positive impact on speeding up these developments. However, these efforts may still not go far enough to overcome the slow-moving progress of Member states. **Therefore we recommend the European Commission closely monitor the implementation of this legislation in order to ensure the rapid expansion of a truly interconnected and highly flexible European Grid.** This work will not be complete until one can speak of a truly integrated European Grid, rather than a collection of regional or national-level grid networks.

Demand side participation is a key feature in the management and increasing flexibility of today's smart grids. Smart meters are a key infrastructural component in this regard. The introduction of smart meters has already been implemented for all customers in some countries. If all goes according to plan (and assuming a positive evaluation), Europe is supposed to be 80% smart metered by 2020. Though some countries have earlier targets, in a large number of countries smart-metering is only in the very early developmental stages (some evaluating studies are underway, but implementation has not even begun). **National strategies for accelerating the rapid integration and adoption of smart metering systems should continue to be developed and implemented.**

However, whether national level efforts will be enough to achieve these goals across all EU Member states remains to be seen. **In our assessment, the European Commission could be delegated the task of closely monitoring developments in the implementation of smart meter technologies. This is above all important as a facilitating mechanism for achieving the EU-wide RES target.** Smart Grid, smart-metering and demand response technologies should be promoted and pursued in this context and in order to increase the overall efficiency of electricity networks. Additionally, **greater efforts to achieve the standardization of metered communications seem appropriate.**

In the process of moving towards a smarter and more decentralized energy network, **new economic players and business models** are likely to appear. We think it advisable to further investigate the **growing importance and role of "aggregators"** who integrate demand and supply flexibility across consumers and DG producers and, in turn, offer this integrated flexibility to the power system operators or ancillary services. The new models offered by such aggregators and other yet unknown innovations will make it possible to capture the real economic value of smart grids. Given today's conventional energy mind-set, the true value of smart grids is presumably significantly underestimated and poorly understood. **Intensifying research efforts on smart grids is advisable in order to better identify and remove potential barriers. This could be done for example by setting specific research priorities in the Intelligent Energy Program.** This would facilitate the deployment and implementation of systems dynamically using the options now being made available via smart metered innovation.

5.3. Needs for research, investment & technology development

Finding the right balance for distributing the R&D budget across the basket of low carbon energy technologies is not an easy task. **We suggest using the following set of metrics:**

- Greatest potential
- Highest investment cost
- Market failure, and
- Near-term solutions

Considering these criteria and given the very large degree of uncertainty associated with this technology, the current level of public funding dedicated to CCS is potentially questionable. **The shifting of EU R&D budgets from CCS to RES (including network and storage) and Smart Grid technologies that are capable of providing both near *and* long-term solutions to our energy-climate dilemma seems highly recommendable.**

Moreover, decentralized energy generators generally possess the same technical barriers as renewable energy. **The relative share of EU R&D funding for decentralized energy is too low. We recommend raising it in order to remove the different technical barriers identified—in particular with regard to smart grid and energy storage technologies.**

We have also identified a tendency to focus R&D budgets more strongly on intermittent renewable energy technologies. **We therefore recommend raising the degree of attention dedicated to base load energy sources such as geothermal, ocean-based, biomass, waste-to-energy and perhaps hydro solutions as well as non-electricity-based RES**.

As indicated in the report, energy storage technologies are presumed to play a key role in the decentralized energy network of tomorrow. **In this regard, a higher level of EU public support for research in storage technology would seem advisable.**

Some attention could be paid to the distinction between R&D and commercializing strategies. National level schemes for promoting the adoption of RES technologies are important mechanisms for ensuring that new technologies are put to use and for encouraging new firms to engage in more R&D. **Therefore, for technologies that already have important applications, we recommend shifting to incentive strategies that focus on commercialization (such as the FIT model) and developing strategies and incentive strategies for promoting the rapid adoption and commercialization of storage technologies.**

5.4. Need for coordination and monitoring of incentive schemes among Member States

Some DER technologies are not yet mature. They are generally more expensive and risky than conventional technologies. They are also handicapped by their small size. To deploy them on a large scale, public authorities need to create an environment in which investors and industry can have long-term visibility, stability and reasonable financial investment security. **Supporting schemes are therefore absolutely essential for DER deployment.**

To-date there has been no EU-wide harmonization of regulatory instruments supporting renewables in Member States. The Directive on the promotion of the use of energy from renewable sources adopted by the EU in 2009 only encourages the design and coordination of joint support schemes across Member States. Member States have thus retained a degree of sovereignty in the choice and design of national supporting instruments. In most cases, they have opted for a combination of mechanisms with most countries choosing between FIT and RO (+TGC) as the primary financing tool.

At the time of writing, the vast majority of Member States have chosen the FIT model. However large differences exist across national schemes. Member States like the UK or Sweden have implemented an RO scheme and Finland an investment/tax incentive strategy. Differences across national schemes seem appropriate and should be based on national comparative advantages (e.g. national potential of each RES technology).

The *differentiated* FIT model has clearly demonstrated a better performance than the RO+TGC model both for large-scale renewables and for small and micro-scale installations. **In this regard, the FIT model appears to provide a favourable option to Member states that is well-suited to variation in national level potential for renewable energy generation and also provides a suitable framework for promoting smaller scale DER technologies. Thus our finding is that the FIT model provides the best possible option for the support of DER and RE in general**.

Further, carbon taxes have also proven an efficient consumption-oriented tool for promoting both energy efficiency and the adoption of small scale RES technologies (such as geothermal heat pumps and the shift to biomass-based district heating and CHP systems). Moreover, a carbon tax focused in particular on energy use in the non-ETS sector would have a favourable impact on promoting more efficient building-related energy use. **Thus, a combination of a *differentiated* FIT with a carbon tax is likely to provide the best supporting policy for the rapid and mass-deployment of both large *and* small scale RES and DER technologies.**

Finally, **we recommend evaluating the possibility of implementing an EU-wide scheme comprising both a FIT approach and possibly also a carbon tax despite the obvious political challenges a tax measure on EU-level would encounter. Moreover, we signal our concern regarding the potential that the current Guarantee of Origin scheme is likely to have perverse and negative effects on national level Member State RES and DER promotion schemes. In place of this, we advise introducing a type of 'lowest common denominator EU FIT model' as well as an EU-wide carbon tax**. If well-designed, such a strategy would not compete with other more generous Member state-level FIT schemes. This framework would also ensure that Member States retain a certain degree of flexibility in adapting national-level schemes to national objectives, comparative advantage and other relevant circumstances.

5.5. Needs of SMEs, awareness raising and change in habits

SMEs represent a very significant potential in terms of DG, DR and CO2 savings. SMEs have very little awareness about their energy consumption, DER or energy demand management. The intensification of communication, dissemination and training is absolutely necessary and seems more efficient when carried out at local level by local "trustworthy" (from the point of view of SME's) actors like chambers of commerce or local sectoral business associations where many SMEs are already involved (and especially their top management). Local energy agencies could play a major role by providing support and expertise to those local actors. In order to facilitate this, **we recommend strengthening the existing network of local energy agencies (under the Intelligent Energy Program), enhancing its functioning and providing it with resources adequate to achieving these objectives.**

At the same time, **decentralized energy production information packages with investment and cost calculation models specific to each sector are important tools from the point of view of SMEs.** The development of such tools could for example be one of the priorities of the next Intelligent Energy Program call for proposals to be issued in 2011.

These tools need to be simple, operational and to offer the possibility for sectoral benchmarking and best-practice sharing. The dissemination of the existing and future consolidated tools could be achieved through the network of local energy agencies in cooperation with local players like chambers of commerce or business associations. Dedicated sectoral information campaigns could be organized.

Capital investment is clearly a barrier. DG and DR are perceived as necessitating significant capital investments with no or very long pay-back periods, while SMEs favour investments with rapid returns. **New business models and financial instruments are needed in order to make this kind of investment economically attractive to SME's. Though still in their infancy, the emergence of new players like ESCOs and aggregators may be beneficial. Further research seems advisable to better understand the underlying economics and better identify the barriers. Specific studies could be carried out at EU level on this topic and dedicated budget lines made available for research projects for example through the Intelligent Energy Program.**

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ANNEX: REGIONAL INITIATIVES

Supranational Regional Initiatives

Stakeholders of the EU electricity and gas markets, having recognized the possible advantages of a cross-border trade in electricity and natural gas, have taken initiatives to promote regional energy market integration. EU-wide, **there are seven Regional Initiatives in electricity markets and three in gas markets.**

Electricity and Gas Regional Initiatives

The seven electricity regional initiatives are as follows:

1. Baltic, including Estonia, Latvia, Lithuania
2. Central-East, including Austria, Czech Republic, Germany, Hungary, Poland, Slovakia, Slovenia
3. Central-South, including Austria, France, Germany, Greece, Italy, Slovenia
4. Central-West, including Belgium, France, Germany, Luxembourg, Netherlands
5. Northern, including Denmark, Finland, Germany, Norway, Poland, Sweden
6. South-West, including France, Portugal, Spain
7. France-UK-Ireland

The three gas regional initiatives are the following:

1. North-West

2. South-South East

3. South

The aim of integration of several national markets into a regional one is to minimize barriers to trade within the region and gain experiences to establish an EU-wide single electricity market. The regional market arrangements take account of interactions and the required compatibility with other areas of that region. Although price differences may remain among the individual national markets, it is expected that prices within a regional market will converge. The electricity Regional Initiatives, in the last years, promoted the establishment of cross-border interconnection capacities, an increase in the flow of information (such as available capacity, location of new interconnection points etc.), harmonization of national rules (network access rights, imbalance charges) to each other in order to create a level playing field for market players of adjacent countries and thus create a more efficient market and increase cross-border trade in electricity.

Successful **electricity Regional initiatives** can contribute to relieving network stress and thus can result in a more cost-efficient balancing of electricity systems and in a more level playing field for market players. Thus, for electricity producers including decentralized ones, market access can become less costly and international markets easier to access. The real advantage of these regional initiatives is that they are able and willing to promote cross-border interconnections and greater grid flexibility therefore they are potentially beneficial to the integration of DEP producers.

Gas Regional Initiatives have similar aims, namely the promotion of the creation of an effective regional gas market. In the last years, transparency was enhanced through voluntary commitments from TSOs. They released new data on the availability and use of gas transmission infrastructures. The Initiatives helped harmonize rules between adjacent countries, leading to increased gas trade among regional partners and to more liquid gas hubs. As an effect of the Russian-Ukrainian gas dispute early 2009, the cooperation among the members of Regional Initiatives affected emergency planning so that gas supplies to foreign customers in emergency cases are not stopped. Further proposals by regulators have been better coordinated infrastructure planning and enabling reverse gas flows. In recent years, effort has been made to evaluate the actual needs for infrastructure capacity, necessary for an optimized planning of new investment projects. All in all, the five main priorities of the gas Regional Initiatives are as follows: proposing new interconnection capacity, access to pipeline capacity, transparency, interoperability and security of supply. All these priorities contribute to the establishment of a single EU-wide gas market with optimized investments in the necessary cross-border interconnection points and to a better flow of information regarding availability of gas networks. This could result in a more cost-efficient single gas market. For decentralized energy producers, an increasingly harmonized and transparent gas market with physical interconnection of the national networks can make access to the market/network easier and less costly. As with the electricity sector Regional Initiatives, their gas counterparts have opened up international markets for decentralized gas producers.

Sub-national regional initiatives

Throughout the European Union, there are several municipal cooperations intended to tackle climate change and discuss energy issues. Some of them have been initiated by the European Commission.

THE MAIN GOALS OF THESE INITIATIVES INCLUDE
• changing experiences gained through different energy or climate related actions
• disseminating knowledge and best practices
• promoting energy saving measures
• possibly co-financing projects to install devices using renewable energy like solar panels
• the modernization of urban heat transmission networks
• organisation of workshops, conferences for stakeholders

These initiatives do not build up decentralized energy systems. Rather, their activities result in the establishment of small-scale, sporadic, stand-alone installations using renewable energy technologies. As a result, the decentralization of the energy system takes place but a "system" with its respective interconnections as such is not stressed in the activities of these initiatives. However, the existence of these initiatives has some essential implications for decentralized energy production.

- First, as a result, the use of RES increases. Small scale renewable technologies further contribute to the decentralization of the energy system.
- Second, partner cities, or members of these initiatives are not necessarily located in small regions. Therefore the renewable projects, becoming reality through actions taken by the initiatives, are not connected on a regional level but rather on a national level (simply through the national or cross-border electricity grid for instance). One of the most important barriers, as stated by the leaders of the initiatives, is the lack of knowledge in the relevant municipalities.
- Therefore, as a third implication, we think that the most important result of these initiatives is the dissemination of knowledge and best practice, as well as the continuous exchange of experience.

However, such initiatives and partnerships could be further encouraged. Cooperation on a much lower level should be incentivized. Especially in the case of biomass or geothermal-based electricity and heat generation (CHP and district heating), cooperation involving small numbers of 10-15 small villages could result in the greater penetration of DEP. Biomass could be collected from the nearby area and biomass-based district heating systems could be the result of cooperation. Similarly, financing a geothermal plant (either only for heat production or for CHP) is easier if several municipalities are involved. Another possibility is to build a biogas-based energy production unit. It can be established through the selective collection of (green) waste and the use of agricultural and livestock farming by-products collected on a (10-15 km wide) regional basis. All these projects could result in job creation in the rural areas, a relief of the national energy grids and a more efficient production of heat and electricity.

All in all, the EU-promoted initiatives are a good first step, resulting especially in the dissemination of good practice and knowledge. Thus far, however, they are not aimed at creating municipal-level cooperation for establishing decentralized energy "systems" but rather at the sporadic use of renewable energy. The creation of decentralized energy "systems" would require a cooperation of smaller numbers of adjacently located villages. Cooperation with higher levels might also help to facilitate the integration of decentralized energy "systems" in a greater level of interconnection.

NOTES

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