SMART ELECTRICITY NETWORKS
based on large integration
of Renewable Sources
and Distributed Generation

von

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We are moving towards a sustainable internal electricity market in the European Union with a more diversified generation structure in which small units will seek integration into the electricity grids.

The most distinguishing feature of future electricity grids in Europe will be the ability for the users to play an active role in the supply chain.

In this transition, new markets will emerge to cover generating capacity, reserve capacity and ancillary services. Some of them are already currently handled by informal trading systems; others will be based on the fully potential that smart energy devices can provide when they are assembled together in a system.

The trends and challenges described here will contribute to this change by building a new electricity model that makes the existing one obsolete while recognising today's reality.

Manuel Sánchez Jiménez
June 2006

To my wife and my son,
to whom I promised this a few years ago.
They fully supported me to conclude it
during weekends and holidays.
I promise I will not do anything like this again!

To my parents,
who would have liked to see it finished.

Zusammenfassung

Das Grünbuch 2006 der Europäischen Kommission "Eine Europäische Strategie für nachhaltige, wettbewerbsfähige und sichere Energie" unterstreicht, dass Europa in ein neues Energie-Zeitalter eingetreten ist. Die vorrangigen Ziele europäischer Energiepolitik müssen Nachhaltigkeit, Wettbewerbsfähigkeit und Versorgungssicherheit sein, wobei sie eine zusammenhängende und logische Menge von Taktiken und Maßnahmen benötigt, um diese Ziele zu erreichen.

Die Strommärkte und Verbundnetze Europas bilden das Kernstück unseres Energiesystems und müssen sich weiterentwickeln, um den neuen Anforderungen zu entsprechen. Die europäischen Stromnetze haben die lebenswichtigen Verbindungen zwischen Stromproduzenten und Verbrauchern mit großem Erfolg seit vielen Jahrzehnten gesichert. Die grundlegende Struktur dieser Netze ist entwickelt worden, um die Bedürfnisse großer, überwiegend auf Kohle aufgebauten Herstellungstechnologien zu befriedigen, die sich entfernt von den Verbraucherzentren befinden.

Die Energieprobleme, denen Europa jetzt gegenübersteht, ändern die Stromerzeugungslandschaft in zwei Gesichtspunkten: die Notwendigkeit für saubere Kraftwerkstechnologien verbunden mit erheblich verbesserten Wirkungsgraden auf der Verbraucherseite wird es Kunden ermöglichen, mit den Netzen viel interaktiver zu arbeiten; andererseits müssen die zukünftigen europaweiten Stromnetze allen Verbrauchern eine höchst zuverlässige, preiswerte Energiezufuhr bereitstellen, wobei sowohl die Nutzung von großen zentralisierten Kraftwerken als auch kleineren lokalen Energiequellen überall in Europa ausgeschöpft werden müssen.

In diesem Zusammenhang wird darauf hingewiesen, dass die Informationen, die in dieser Arbeit dargestellt werden, auf aktuellen Fragen mit großem Einfluss auf die gegenwärtigen technischen und wirtschaftspolitischen Diskussionen basieren. Der Autor hat während der letzten Jahre viele der hier vorgestellten Schlussfolgerungen und Empfehlungen mit Vertretern der Kraftwerksindustrie, Betreibern von Stromnetzen und Versorgungsbetrieben, Forschungsgremien und den Regulierungsstellen diskutiert. Die folgenden Absätze fassen die Hauptergebnisse zusammen:

Diese Arbeit definiert das neue Konzept, das auf mehr verbraucherorientierten Netzen basiert, und untersucht die Notwendigkeiten sowie die Vorteile und die Hindernisse für den Übergang auf ein mögliches neues Modell für Europa: die **intelligenten Stromnetze** basierend auf starker Integration erneuerbarer Quellen und lokalen Kleinkraftwerken.

Das neue Modell wird als eine grundlegende Änderung dargestellt, die sich deutlich auf Netzentwurf und -steuerung auswirken wird. Sie fordert ein europäisches Stromnetz mit den folgenden Merkmalen:

– **Flexibel: es** erfüllt die Bedürfnisse der Kunden, indem es auf Änderungen und neue Forderungen eingehen kann

- **Zugänglich:** es gestattet den Verbindungszugang aller Netzbenutzer besonders für erneuerbare Energiequellen und lokale Stromerzeugung mit hohem Wirkungsgrad sowie ohne oder mit niedrigen Kohlendioxidemissionen
- **Zuverlässig:** es verbessert und garantiert die Sicherheit und Qualität der Versorgung mit den Forderungen des digitalen Zeitalters mit Reaktionsmöglichkeiten gegen Gefahren und Unsicherheiten
- **Wirtschaftlich:** es garantiert höchste Wirtschaftlichkeit durch Innovation, effizientes Energiemanagement und liefert „gleiche Ausgangsbedingungen" für Wettbewerb und Regulierung

Es beinhaltet die neuesten Technologien, um Erfolg zu gewährleisten, während es die Flexibilität behält, sich an weitere Entwicklungen anzupassen und fordert daher ein zuversichtliches Programm für Forschung, Entwicklung und Demonstration, das einen Kurs im Hinblick auf ein Stromversorgungsnetz entwirft, welches die Bedürfnisse der Zukunft Europas befriedigt:

- **Netztechnologien, die die** Stromübertragung verbessern und Energieverluste verringern, werden die Effizienz der Versorgung erhöhen, während neue Leistungselektronik die Versorgungsqualität verbessern wird. Es wird ein Werkzeugkasten erprobter technischer Lösungen geschaffen werden, der schnell und wirtschaftlich eingesetzt werden kann, so dass bestehende Netze Stromeinleitungen von allen Energieressourcen aufnehmen können.
- **Fortschritte bei Simulationsprogrammen** wird die Einführung innovativer Technologien in die praktische Anwendung zum Vorteil sowohl der Kunden als auch der Versorger stark unterstützen. Sie werden das erfolgreiche Anpassen neuer und alter Ausführungen der Netzkomponenten gewährleisten, um die Funktion von Automatisierungs- und Regelungsanordnungen zu garantieren.
- **Harmonisierung der ordnungspolitischen und kommerziellen Rahmen** in Europa, um grenzüberschreitenden Handel von sowohl Energie als auch Netzdienstleistungen zu erleichtern; damit muss eine Vielzahl von Einsatzsituationen gewährleistet werden. Gemeinsame technische Normen und Protokolle müssen eingeführt werden, um offenen Zugang zu gewährleisten und den Einsatz der Ausrüstung eines jeden Herstellers zu ermöglichen.
- Entwicklungen in **Nachrichtentechnik, Mess- und Handelssystemen** werden auf allen Ebenen neue Möglichkeiten eröffnen, auf Grund von Signalen des Marktes frühzeitig technische und kommerzielle Wirkungsgrade zu verbessern. Es wird Unternehmen ermöglichen, innovative Dienstvereinbarungen zu benutzen, um ihre Effizienz zu verbessern und ihre Angebote an Kunden zu vergrößern.

Schließlich muss betont werden, dass für einen erfolgreichen Übergang zu einem zukünftigen nachhaltigen Energiesystem alle relevanten Beteiligten involviert werden müssen.

Erklärung

Hiermit versichere ich, dass ich die vorliegende Dissertation selbständig und ohne unerlaubte Hilfe angefertigt und andere als die in der Dissertation angegebenen Hilfsmittel nicht benutzt habe. Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten oder unveröffentlichten Schriften entnommen sind, habe ich als solche kenntlich gemacht. Kein Teil dieser Arbeit ist in einem anderen Promotions- oder Habilitationsverfahren verwendet worden.

Manuel Sánchez Jiménez

Kassel, June 2006

CONTENT

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Summary

The European Commission's 2006 Green Paper "A European Strategy for Sustainable, Competitive and Secure Energy" emphasises that Europe has entered a new energy era. The overriding objectives of European energy policy have to be sustainability, competitiveness and security of supply, necessitating a coherent and consistent set of policies and measures to achieve them.

Europe's electricity markets and networks lie at the heart of our energy system and must evolve to meet the new challenges. Europe's electricity networks have provided the vital links between electricity producers and consumers with great success for many decades. The fundamental architecture of these networks has been developed to meet the needs of large, predominantly carbon-based generation technologies, located remotely from demand centres.

The energy challenges that Europe is now facing are changing the electricity generation landscape in two aspects: the drive for lower-carbon generation technologies, combined with greatly improved efficiency on the demand side, will enable customers to become much more inter-active with the networks; on the other hand, the future trans-European grids must provide all consumers with a highly reliable, cost-effective power supply, fully exploiting the use of both large centralised generators and smaller distributed power sources throughout Europe.

In this context, the information presented in this thesis is based on topical issues with great influence in present technical and policy discussions. The author has widely discussed during last few years much of the conclusions and recommendations presented here with representatives from industry, transmission and distribution system operators, research bodies and regulators. The following paragraphs summarise the main outcomes:

This thesis defines the new concept ahead based on more customer-centric networks and investigates the drivers, benefits and obstacles for the transition towards a possible new model for Europe: the ***Smart Electricity Networks*** *based on large integration of renewable sources and distributed generation.*

The new model is presented as a fundamental change which will have a significant impact on network design and control. It calls for Europe's electricity networks to be:

- ***Flexible:*** *fulfilling customers' needs whilst responding to the changes and challenges ahead;*
- ***Accessible:*** *granting connection access to all network users, particularly for renewable power sources and high efficiency local generation with zero or low carbon emissions;*
- ***Reliable:*** *assuring and improving security and quality of supply, consistent with the demands of the digital age with resilience to hazards and uncertainties;*
- ***Economic:*** *providing best value through innovation, efficient energy management and 'level playing field' competition and regulation.*

Its embraces the latest technologies to ensure success, whilst retaining the flexibility to adapt to further developments and therefore it will request a bold programme of research,

development and demonstration that charts a course towards an electricity supply network which meets the needs of Europe's future:

- ***Network technologies*** *to increase power transfers and reduce energy losses will heighten the efficiency of supply, whilst power electronic technologies will improve supply quality. It will create a toolbox of proven technical solutions that can be deployed rapidly and cost-effectively, enabling existing grids to accept power injections from all energy resources.*
- ***Advances in simulation tools*** *will greatly assist the transfer of innovative technologies to practical application for the benefit of both customers and utilities. It will ensure the successful interfacing of new and old designs of grid equipment to ensure interoperability of automation and control arrangements.*
- ***Harmonising regulatory and commercial frameworks*** *in Europe to facilitate cross-border trading of both power and grid services, ensuring that they will accommodate a wide range of operating situations. It will establish shared technical standards and protocols that will ensure open access, enabling the deployment of equipment from any chosen manufacturer.*
- *Developements in* ***communications, metering and business systems*** *will open up new opportunities at every level on the system to enable market signals to drive technical and commercial efficiency. It will enable businesses to utilise innovative service arrangements to improve their efficiency and enhance their services to customers.*

Finally, it is remarked that for a successful transition to a future sustainable energy system all the relevant stakeholders must become involved: governments, regulators, consumers, generators, traders, power exchanges, transmission companies, distribution companies, power equipment manufactures and ICT providers, etc. at regional, national and European levels.

Scope of the work

A high quality, efficient and secure electricity supply represents one of the most crucial elements for Europe's competitiveness in the future. It is widely accepted in Europe that the design, operation and trading of our electricity infrastructure will undergo fundamental changes during next two decades. The driving forces of such changes are the completion of the internal market, security of supply and environmental concerns.

The implementation of a European internal market and liberalization will lead to the unbundling of production, transmission and distribution with the aim of providing electricity to consumers in a cost effective way. This change will lead to the creation of new markets for electricity and power quality.

Socio-economic transition towards sustainable energy systems has taken a 'no-return' path. It is based on a durable integration of renewable energy sources and other new and innovative efficient technologies –such as fuels cells, micro turbines, combined heat and power (CHP), etc- aiming to reduce the emission of greenhouse gases and contributing to security of supply, which is in line with the European targets of doubling the contribution of renewables and cogeneration by 2010 – further improving the use of energy and energy efficiency.

Most of the renewable energy sources and CHP plants are dispersed and connected to the low or medium voltage distribution grid. The fluctuating character of solar and wind resources, the dispersed power injection into all grid levels and emerging markets will lead to a radical change in the grid design and its operation. It will also allow consumers to react on supply and thus to allow for a very much higher degree of flexibility in the electricity system ranging from production to consumption. New business opportunities will emerge based on a wider market for electricity and other services.

Existing network infrastructures will be used during the next two decades. In order to keep the existing high level of quality supply, new concepts and components for the future must be carefully prepared now. It needs the validation of recent developments and future technological perspectives ranging from power electronics and information and communication technologies up to the creation of adequate policies and regulatory frameworks.

Much of it already started early 2002 through European projects such as those in the ***EU Research Cluster on Integration "IRED",*** *http://www.ired-cluster.org/. The first pilot plants to prove the feasibility of such innovative concepts are being set up and an exchange of results of similar experiences worldwide began in December 2004 with the "First International Conference on Integration of Distributed Energy Resources", organised with the active guidance and support of the European Commission, Canada, the US and Japan.*

In addition, the first steps towards co-operation among all European stakeholders in the sector were taken in May 2005 under the leadership of the ***Technology Platform for the Electricity Networks of the Future - SmartGrids****. The author of this thesis has contributed very actively and enthusiastically to write and publish the SmartGrids Vision paper for the future European electricity networks, which has been issued in April 2006.*

The objective of this thesis is to describe the vision and investigate the trends, benefits and research needs for a new electricity network model –the Smart Electricity Networks- which will allow a durable integration of renewable energies and Distributed Generation by 2020, while contributing to the efficiency, stability, safety and reliability of the European electricity transmission and distribution supply system.

1 Rationale and structure

With this objective in mind, the starting point is the analysis of the cultural, technical, economic and policy elements driving the present electrical systems, the way the market and technologies are regulated and operated in the EU, the opinion of stakeholders and the present evolution from monopoly to liberalisation. These factors, together with environmental and energy dependence issues, expected benefits, etc. are described in **Sections 2 to 3**.

Considering the increasing influence of the European policies and legislation in the energy sector –i.e. internal market, security of supply and climate change-, **Annex 1** gives a summary of the most important European policy documents affecting DER, EU adopted legislation as well as new elements under preparation.

Section 4 emphasises the absolute lack of standardisation suffered in this field, probably because it is quite recent, or most probably because it has not been integrated into present markets so far, or both. It begins with a summary of the different concepts for the same technology or, vice versa, different definitions for the same concepts used so far in Europe and the US. A "consensuated" definition for DER and DG is presented in this section. Finally, a summary of the potential costs/benefits and barriers found in recent key studies and surveys carried out in Europe and the US is presented.

Section 5 opens the discussion of potential challenges for the electricity networks by 2020 and beyond. It gives special emphasis on the extreme importance of "integrating" Distributed Resources into the future networks, rather than "connecting" them to the networks. It concludes with final remarks on technology trends and critical development ahead.

Section 6 is the "visionary" part of this work. It presents the concepts for the "new way", its feasibility and the specific challenges lying ahead, based on experiments carried out in Europe and on running RTD projects.

And finally, **Section 7** deals with the identification of main messages on further efforts and support needed to make the integration of RES and DG a reality by 2020. It is far from being a "road-map", but it sets the basis for a possible European RTD Strategy for the first quarter of this century, which is a key task undertaken by the recently created European Technology Platform for the Electricity Networks of the Future.

2 Evolution of the electricity systems and technologies in the EU

"The biggest force for changes in the electricity systems since last century has been the changing of economics of the power industry. Central power plants stopped getting more efficient in the 1960's, bigger in the '70s, cheaper in the '80s, and bought in the '90s. They had come to cost less than the grid and had become so reliable that nearly all power failures are originated in the grid, which explains the technological reasons why gargantuan power plants will make little financial sense in the future".

Amory Lovins, in his book "Small is Profitable".
Rocky Mountain Institute. Colorado, 2000

Today's electricity supply network is based on large central power stations transmitting power via high-voltage transmission systems, which is then distributed to medium or low-voltage local distribution systems. The overall picture is that the power flows in only one direction and it is dispatched and controlled by predetermined actions from the power dispatching centre(s).

This unidirectional design was based on ideas of economies of scale in large centralised generation and the geography of national sources for generation, based on large hydro, coal mines, dumps, rivers with cooling water for central stations, etc. It was accompanied by the corresponding development of the appropriate technologies for central power plants and network management.

A monopoly national or regional body commonly runs today the Transmission and Distribution systems whilst the generation sector may be a competitive part of a vertically integrated utility. History has demonstrated that electricity supply systems have a very long lifespan, because of the large investments and the pattern of systems development; therefore, it can be assumed that for the next 20 years all existing networks will still exists and be used. The crucial variable for the system development is the level of balancing of supply and demand; and in the future, supply and demand should be balanced on regional, national and also European level.

The aim of this section is to analyse the dynamics of the historical development electricity supply systems in Member States in order to extract insight on market and technologies that can help us in later sections to build medium to longer-term scenarios.

2.1 Electricity supply systems development in Member States

Looking back on the history of electricity, it is possible to distinguish the following three main periods in the development of electricity supply systems at national level [1]:

- 1880-1920: Introducing electricity in Europe.
- 1920-1970: Scale increase and expansion.
- 1970-today: Hybrid systems.

These periods give only an indication of the timeframe. Although there have been marked differences between the different European countries in this regard, each period selected was characterised by interrelated elements such as leading concerns or critical problems, dominant factors and actor groups who formulated these problems and put them on relevant agendas, conflicts and negotiations with other actors, and dominant designs of the supply systems.

2.1.1 Introducing electricity in Europe: 1880-1920.

Since the beginning of utility services, the driving force of actors in this new and promising energy carriers business was earning money by selling electricity. Thomas Edison and his research group in the US developed this original concept of "utility company" [2]: supply electricity to the public as a potentially profitable business modelled after the gas companies

The concept was presented at the international exhibition in Paris in 1881, and was soon imitated in Europe by very diverse types of players, ranging from commercial companies to municipal governments often more interested in the profit of this business than in the extremely important social benefits offered by this new invention.

Significant developments occurred at the dawn of the twentieth century in Europe. Using low voltage direct current electricity, the range of these local systems was limited to a couple of kilometres, but this was not a problem in these days since densely populated inner city areas were the target group. Simultaneously, the commercial concept lead Edison to found a number of companies for patent holding, licence selling and equipment production for the purpose of producing and selling electricity locally. They would increasingly expanded to entire urban and rural "districts" by means of higher voltage, alternating current transmission, locally transformed –if needed- to user voltage in factories, households and offices.

As a result of this, the electrical map of Europe displayed a scattered variety of local and district systems where **Distributed Generation (DG)** was the predominant supply system; however, it was hardly under pressure of the emerging centralised systems in this period.

2.1.2 Scale increase and expansion: 1920-1970.

The predominant vision during this period in Europe was the creation of a nationally integrated electricity supply system to make electricity available everywhere in the country, in spite of the more and more fragmented electricity supply structure. The advantage of such a vision was formulated in terms of national-economic advantages of a national scope. It was the beginning of the central power production economy, represented in Figure 2.1, which was based on the following four economic arguments for large integrated networks:

- Concentration of production in a very few, but very large power plants, in which large turbo generators produced electricity at a very low price per unit.
- Power plants situated near mining sites or at hydropower sites should be integrated as sources of very cheap electricity.
- As all these power stations were interconnected into a single system, the entire system could save on investment in backup units.
- Load managers could tune the overall electricity production needed anywhere in the system.

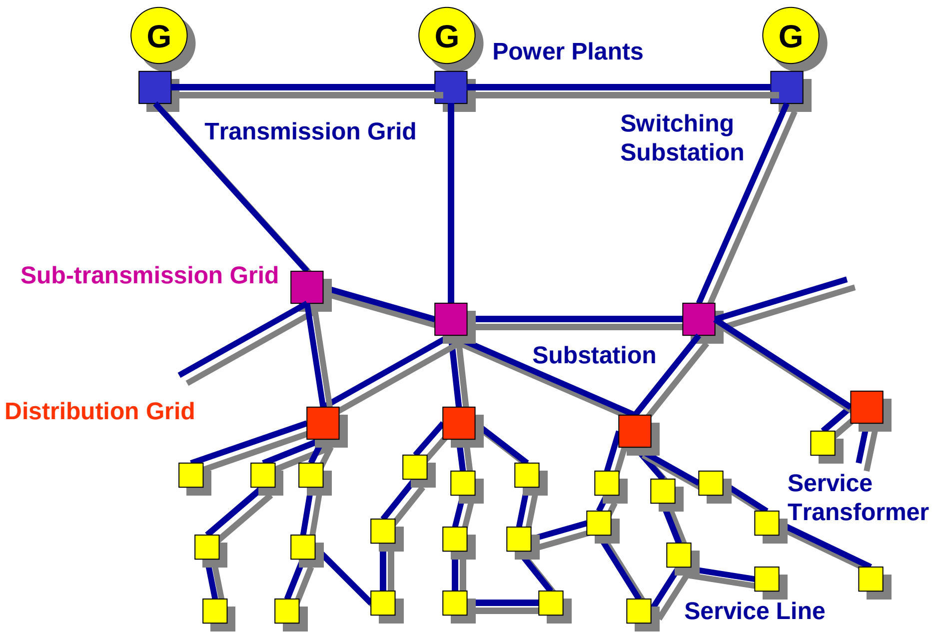

Figure 2.1. Central power production economy and networks are based on a genuine economy of scale: " the bigger, the less investment per kW". It does not overlook, however, larger "diseconomies" of scale in the power stations, the grids, the way both are run, and the architecture of the entire system

This new vision became widespread in modernising nations, and by the 1920s it was seen as the way to run a utility company. Small-scale systems became, at least for the moment, a "loser in history" as scores of companies were forced to shut down their units and turn to low-cost utility power [3].

The implementation of such a vision -based on economic arguments- requested an extremely important role of State governments in the construction of these systems, as existing players were unlikely to co-operate voluntarily. The new technical and institutional/regulatory rules vary from country to country, but such a scheme was implemented in most countries before the Second World War (e.g., France, Germany and UK) or immediately after (e.g. Denmark, The Netherlands, Spain and Sweden). However, the process did not take place automatically; it was the result of persistent efforts of important actors who established new institutional frameworks to stimulate the desired changes. In France, UK, Spain and Sweden the national government built the new infrastructure, in the Netherlands small utilities had already been ousted by larger utilities, which subsequently co-operated to build a national grid whilst keeping the national government at distance. In Denmark small utilities were integrated in larger ones and thus had become co-owners of the centralised system.

The “build-big” approach was also furthered by the broad consensus that generation, transmission and distribution of electricity should be defined as a “natural monopoly”; one firm supplying all customers in a given area was viewed as the most economical path to electrification. Governments in Europe and overseas began to create monopolies by granting concessions for the sale and distribution of power, while establishing regulations to ensure that the companies did not use their monopoly positions to increase profits or deprive customers of the low prices that resulted from the system’s economies of scale. Monopolies were also forced to provide a secure power supply and offer the same prices to customers of the same class –commercial, residential or industrial- in order to guarantee cheap, reliable electricity supply [4].

The increasing economy of scale revolution was conceived as the privileged development route for many countries and their national economies. These changes implied a new type of electricity transport system. As new power lines were built to interconnect existing systems –and their existing distribution networks- to fewer and larger power plants, a hierarchy of transport network –i.e. primary grid, secondary grid, tertiary grid, etc- emerged to route electricity from centralised power station to consumers. These networks, which interest us as potential input locations for **renewable energy sources (RES)** and DG, were constructed with the completely different objective of routing centrally-produced electricity and were imposed on existing electricity supply configurations by either increasing capacity or changing **Direct Current (DC)** to **Alternating Current (AC)** distribution networks.

Already at a very early stage, border-crossing connections were established in Europe. Switzerland played a special role in this field in continental Europe. Due to its geography and abundant availability of hydropower, connections with Germany, France and Italy were established. Another early example was the construction of a sub-marine cable between Sweden and Denmark in 1915. The number of international connections would gradually increase before the Second World War, but there was no systematic coupling of networks spanning more than one country.

Electricity became one of the biggest businesses in many nations and international collaboration in this field became very important to discuss experiences and good practices, identification of RTD and support needs, create working groups for standards, etc. The first international organisations in the field of energy were founded during this period:

- The International Electro-technical Committee, founded in 1906, aimed to discuss and agree on standards and requirements for electro technical equipment and machinery, power cables and lines.
- The International Union of Producers and Distributors of Electrical Energy, the organisation of the electricity industry, was founded in 1925.
- The first World Power Conference in London, held in 1924, was the first of a still existing series of international conferences, which in 1971 changed its name to World Energy Council. During these conferences, engineers and visionaries started to propose electricity networks for Europe in the same way as their predecessors had

done on a national level.

– Without entering into more details now, it should be also mentioned the creation of the European Coal and Steal Community and Euratom by the European Economic Community (EEC).

– The Organisation for European Economic Cooperation (OEEC, now the Organisation for Economic Co-operation and Development, OECD) took the initiative of creating the Union for Coordination of the Production and Transmission of Electricity (UCPTE) in 1951. The Scandinavian countries and Denmark formed Nordel in 1963, a comparable organisation. The main purpose of these organisations was to improve the interconnections between countries in continental Europe.

– The International Council on Large Electric Systems (CIGRE) is involved in the process of adjusting and improving international connections.

An agreement was reached on 380 kV as the standard for main interconnections in Western Europe and exchange agreements on interconnections were established with UFITPE (connecting France, Spain and Portugal), SUDEL (with south-eastern Europe through Yugoslavia), the CDO (Eastern Europe, now Centrel through Austria) and Nordel and Finland trough the Soviet Union. Exchanges, however, remained in the range of a few percent of total electricity consumption during the 1950s. The main function therefore was providing back-up capacity in case of failures or shortages.

Consumption and installed capacity of electricity expanded rapidly, especially in the 1960s. In most Western European countries consumption doubled between 1960 and 1973, with some countries (Denmark, Ireland, Finland and Spain) showing even higher growth ratios. In plans designed to meet these demands large nuclear power stations figured prominently, but the standard 380-400 kV connections started to look insufficient in the perspective of the industry and the organisations involved.

The technological development was driven by the postulate of the economic theory of that time: set-up economies of scale by installing larger units. The economies of scale arguments in production and transmission were especially strong in the 1950s and 1960s –the beginning of the nuclear paradigm- and reaching a peak during the 1970s: in the 1920s, the most cost-effective size of thermal power stations was almost 30 MW; in the ‘30s, around 60 MW; in the ‘50s, this size had already reached 180 MW; and by the ‘70s the size was around 1000 MW. Hence the technical development primarily focused on up scaling or improving the efficiency of an already widely used technology. Reliability has been another major argument for system expansion and although in the first place it was an engineering argument, governments quickly adopted it. This period ended with the wide-spread opinion that “central systems were the cheapest and the most reliable systems”**.**

2.1.3 Hybrid systems: 1970 – today.

The 1970s constitute a new turning point in the history of electricity supply. The oil crisis in the beginning of the 1970s had an important influence on the field of power systems. Energy became an important issue on the European economic and political agenda. The crisis demonstrated very effectively that most Western economies depended heavily on fossil fuels abroad. To reduce this dependency, some governments increased their support for research and the development of non-fossil fuel power resources (see Figure 3.2 in section 3.1.1.4) resulting in, for example, the founding of the **International Energy Agency (IEA)** in 1974. In countries like France and Sweden, however, nuclear power generation soon became an important factor for the nation's power supply.

In many countries, the energy crises and the increasing counter-culture opposition to technocracy, centralisation and scale increase –and in particular nuclear power- inspired governments to change policy.

In the early 1980s this change became entangled with environmentalism and neo-liberalism. During the 1980s and 1990s, governments and administrations at regional, national and European level were now concerned with new arguments:

- diversification of energy sources, to reduce dependency on oil,
- energy saving , for which auto-production in the form of industrial combined heat and power production was one of the many strategies used alongside energy saving campaigns addressed at households,
- the stimulation of renewable energy sources as the inherent transition to sustainable energy systems, reducing environmental impacts and adding economic values,
- more market orientation and liberalisation of energy markets,
- privatisation and deregulation (redefining the rule of the government).

Efficiency limits, environmental concerns, energy crises, overcapacity and the billions of Euros lost by nuclear plants indicated that the "bigger-is–better" approach entailed certain "diseconomies of scale".

Many national and European administrations sought to stimulate new developments for a new scenario by increasing research and development (R&D) efforts and adopting new regulatory and legislative measures.[1] As a consequence, the shape of the electricity supply system started to develop in the direction of a "hybrid system" hosting centralised as well as decentralised generation units in one single system.

These technical changes were imposed on the existing system which remained basically intact; large power units were expanded and adapted to environmental demands; and new small units were inserted, while transmission networks were only marginally adapted.

Looking ahead, there are two possible directions for the development of networks in the future:

1. The "connecting" scenario: moving upwards in reverse of the current trend. A shift to a European electric super highway system of transmission lines, combining and connecting very large scale power stations (fusion reactors in the long term) and large storage capacity embedded with interconnections to national and regional networks.

[1] Although there are considerable differences from country to country, the main European Institutions (Council, Parliament and the Commission) have played a crucial role during this period. This topic will be discussed in Section 3.

2. The “integrated” scenario: continuation of the current hybridisation of electricity supply with an increasing integration of RES and DG into the overall system operation and system development (e.g. new but cleaner technologies, introduction of European interconnections, etc).

The challenges and benefits of both scenarios will be further discussed in Sections 4 and 5.

2.2 Today’s Transmission and Distribution Networks

Figure 2.2 shows the three types of electricity networks traditionally distinguished:

– Transmission and interconnection networks: these networks link the main generation centres to the consumption areas. The voltage level depends on the country, but normally the voltage level is established between 220 and 800 kV (e.g. 765 kV in South Africa).

– Sub-transmission networks: they receive the energy from the transmission networks and their role is to conduct the electricity to the small towns, cities or important industrial customers. The voltage level of these networks is between 45 and 160 kV.

– Distribution networks: they supply the domestic customers and the medium-size industrial customers. The voltages are between 4 to 45 kV for the medium voltage and some hundreds of volts for the low voltage (400/230 V)

2.2.1 Transmission and interconnection lines

The geographical distance between production sites and consumer centres, the irregularity of consumption and the impossibility of storing electrical energy create the need for an electrical network that is able to direct and transmit electricity across large distance. The object of this network is threefold:

– A “transmission” function with the aim of carrying electricity from producing large power stations to the main consumer zones.

– A “national interconnection” function that manages the product distribution by relating the production to the geographical and time-dependant nature of the demand.

– An “international interconnection” function that manages the energy flow between countries dependant on programmed exchanges or as backup.[2]

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[2] The economic power ratings of such interconnections are often small in relation to the installed capacity of the systems to be interconnected; in such cases an AC tie line may not be able to cope with the power flow and stability control problems. Direct current or HVDC (high voltage direct current) links are used for exchanges between countries, exclusively on a transmission network level and for bulk-energy transfers. Such intercontinental and even continental links exist, for example a link between France and England at (2000MW/270kV) or the link between Italy and Sardinia via Corsica (300MW/200 kV).

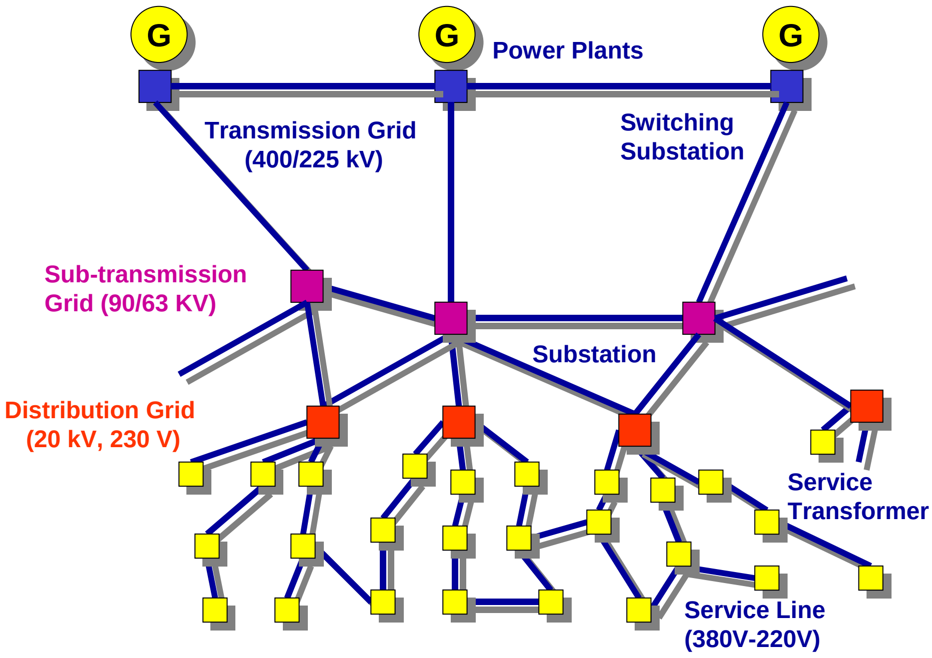

Figure 2.2 The electricity networks structure of today. Voltage levels are different from country to country. This figure shows the case in France: 400/225 kV for transmission, 90/63 for sub-transmission, and 20kV/230V for distribution. Grids might be operated bi-directional, especially in the transmission region, but the communication is today unidirectional.

In general only a few customers with a high consumption are connected to these transmission networks, which are essentially of overhead-line structure. The voltages are normally between 225 kV and 400 kV. The use of such high voltages is tied to cost-saving objectives -line losses by joule effect are inversely proportional to the square of the voltage.

The safety aspect is fundamental for these networks. Indeed any fault at this level can lead to important supply failures for all consumer units. The electrical energy is permanently monitored and managed from a control centre.

2.2.2 Sub-transmission networks

Normally, the sub-transmission networks are organised in a loop to reinforce the security of the system. But the real aim of these networks is to carry electricity from the transmission network to the “big consumer” centres, which are a few high-consumption private customer units supplied directly with High Voltage (HV, e.g. above 10 MVA such as ceramic industries; chemicals; rail transport) or other services from the public sector with access to the Medium Voltage (MV) network.

The structure of these networks is generally of overhead-lines (sometimes underground cables near urban areas). Obtaining permissions for new overhead-lines is taking more and more time due to a large number of environmental impact studies and social opposition issues. As a result, it is more and more difficult and expensive for sub-transmission networks to reach high population density areas. The protection systems are of the same kind as those used for transmission networks and the control is regional.

2.2.3 Distribution networks

2.2.3.1 **The MV network**

The object of this network is to carry electricity from sub-transmission networks to points of medium consumption (e.g. in Spain, higher than 250 kVA). These consumer points are either the in public sector with access to MV/LV public distribution substations or the private sector, with access to delivery substations for medium voltage consumption users. The number of customers is only a small proportion of the total number of customers supplied directly with LV. They are essentially used for tertiary sector such as hospitals, administrative buildings, small industries, etc.

The structure is of overhead or underground type. The voltage levels in these networks ranges from a few kV to 40 kV. The operation of these networks can be carried out manually or more frequently by remote control from fixed/mobile control centres, which are different to those used on transmission and sub-transmission grid.

2.2.3.2 The LV network

The object of this type of network is to carry electricity from the MV network to points of low consumption (e.g. less than 250 kVA in Spain). It represents the final level in an electrical structure. This network enables supply to a very large number of consumers corresponding to the domestic sector. Whether of overhead or underground structure, they are very influenced by environmental issues. Voltages in these networks are between 100 and 400 V. Such networks are often operated manually.

2.2.3.3 Layout of different distribution networks

Distribution networks use two basic layouts.

Radial layout. This layout can also be called antenna-type. Its operating principle is based on using a single supply line. This means that all consumer units in such a structure only have one possible electrical feed path. This layout is particularly used for MV distribution in rural areas. Indeed, it enables easy and low-cost supply to low-load density consumer units with a wide geographical dispersion. A radial layout is often used with an overhead type distribution system.

Open loop layout. Its operation principle uses several lines of supply. This means that two possible electric paths can supply any consumer unit on this structure, each path is activated at any time, back up is provided by the possibility of using the other loop. This layout is often employed with an underground-type distribution system and in highly populated urban areas.

2.3 Today's Control and Communication Systems

2.3.1 System monitoring and control

Electricity networks are dynamic systems with unavoidable failures or disturbances. Protective devices, restoring the system to normal within a few cycles and avoiding further control actions, solve many of them. Others may cause transient oscillations that can last for several seconds, producing large oscillations in power flow, abnormal voltages and frequency and subsequent tripping of plant items. In this case an Energy Management system (EMS) is needed to operate and control the network in real time. It includes communication facilities to capture the current state of the system and to instruct generating plants and other controllable system components. Figure 2.3 shows the four levels form in the hierarchy of a power system with EMS:

- Level 0: network and substations; this covers switchgears, interconnections, service lines, service transformers, etc.
- Level 1: local controls or substations; these include protection relays, tap-change controllers and compensator controls with operating channels to level 0 units. Level 1 controls often comprise digital/electronic devices for voltage and current measurement, interlocking and facilities for receiving and sending data up to the next level.
- Level 2: area controls; man-machine interfacing at this level enables both control and maintenance; so the whole system can be kept in reliable and efficient condition.
- Level 3: Supervisory Control and Data Acquisition (SCADA). It is a single control centre that accepts data from the various level 1 collectors and displays it in a meaningful way to the control operators. With powerful computer processing, the SCADA feeds into an Alarm Management subsystem to supplement automatic relay operation and to give warning about any system abnormality that cannot be detected at levels 1 or 2.

The data measurements and device positions are collected in the control centre in short time intervals (from 5-10-15 seconds to 1 minute) by on-line digital processors. SCADA data includes real-time data from switchgear, isolators and other connectors. The EMS processes these data on-line and, using mathematical methods and voltage measurements at pre-selected network positions, it determines the state of the system. Such a procedure is called "state estimation" and enables the control of the system.

The incoming data must be checked for further utilisation: contingency checking, economic scheduling, automatic frequency control, etc. This process is called data validation.

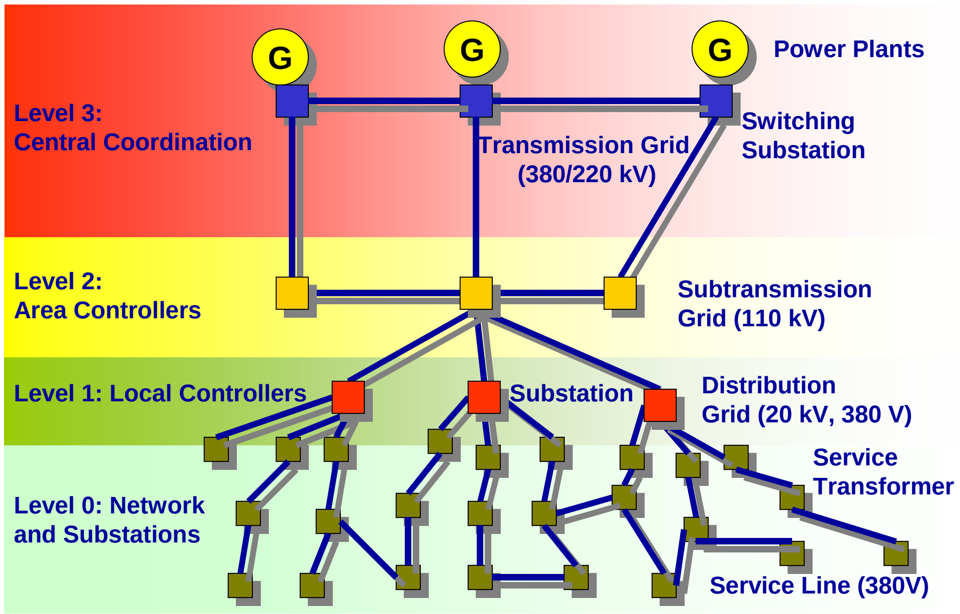

Figure 2.3 Hierarchy of controls required for an Energy Management System (EMS)

2.3.2 **Data transmission methods and protocols**

Data transmission for network control requires the use of one or several equipment, such as paired wires, coaxial cables, radio waves, optic fibre, and power line carrier systems. The choice of one or another depends on various criteria, such as the amount and frequency of information to be transmitted, the type of information, the speed requirement for exchanges, the transmission distance and other geographical constrains, costs, etc. In practice, an electrical energy distributor will always use various methods based on the importance of the data to be transferred:

- Specialised lines for control of important installations HV/MV substation.
- Radio-electrical or telephone links for control of secondary installations (remote controlled MV/LV substation.

2.4 Electricity market transition

The development and strengthening of the current electricity market model has been based on unidirectional flow of power and, probably for technology reasons in some cases and economic reasons in many others, it is based mainly on time invariant tariffs and limited real time status information on load management. Technically, it is designed to be efficiently operated by a single actor in control of all available generation and transmission capacity, but it seems to be unsuitable for the challenges of a real open market. Furthermore, as it will be discussed in later sections, it seems inappropriate for matching the increasing demand in electricity –around 2% per year in the EU15- and the emerging environmental requirements.

Today's market actors, emerged from the ashes of the old-fashioned utilities, are electricity suppliers, electricity traders, electricity retailers, **Transmission System Operators (TSOs)**[3] and **Distribution System Operators (DSOs)**[4]**.** The other important market actors are final customers, equipment manufacturers and engineering companies. Compared to all other actors, TSOs and DSOs are in a special situation. The business of transmission and distribution is characterised by *natural monopolies* within the geographical areas in which T&D Operators are active. Not being in competition, their tariffs are controlled by national regulators, and thus further regulation of the sector is required to achieve the complete internal energy market. Many experts agree that the current transition in the electricity sector did not start in the 1990s but as early as the 1970s and will not be completed for the next two decades.[5]

As in many other businesses, the liberalisation of electricity markets should be good for consumers, who will enjoy lower prices and more innovative services in the long run. Figure 2.4 shows the market flow diagram for the Nordic Pool, which was the earliest example of electricity market liberalisation in Europe. More and more countries –e.g. Germany, UK, etc- have followed, opening their electricity markets according to this model. As energy markets are liberalised, on-line energy-trading markets develop, and individual consumers win the right to select their energy suppliers.

In theory, a liberalised market is synonymous of perfect competition, perfect information and no externalities. However, in practice, real-time metering is not widely available, mainly due to the present technical limitations and high costs of implementing a feasible system that would achieve this. The lack of real-time pricing does not allow consumers to react to electricity prices on time, which is synonymous of fear of market competition. The effect is well known: keep a highly rigid demand.

As it will be presented in next sections, modern **Information and Communication Technologies (ICT)** will allow real-time pricing schemes and on-line settlements of contracts, making the operation of energy suppliers and consumers aware of a more complete and wider market context. On the other hand, more information flow –including for example forecasting inputs- makes these market actors more aware of energy use and also allows strategies favouring the use of more cost-attractive renewables.

[3] According with COM(2003)740, Transmission System Operator means a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the transmission of electricity.

[4] According with COM(2003)740, Distribution System Operator means a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing for distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity.

[5] Liberalisation of energy markets is part of the European energy agenda. The creation of the European market and the removal of institutional barriers -one of the objectives of the liberalisation process- will give a strong impetus to the expansion of the European dimension of electricity networks. The creation of an internal European market presupposed the possibility of large-scale exchange of electricity in Europe, which will certainly has an impact on the development of national electricity networks during next decades.

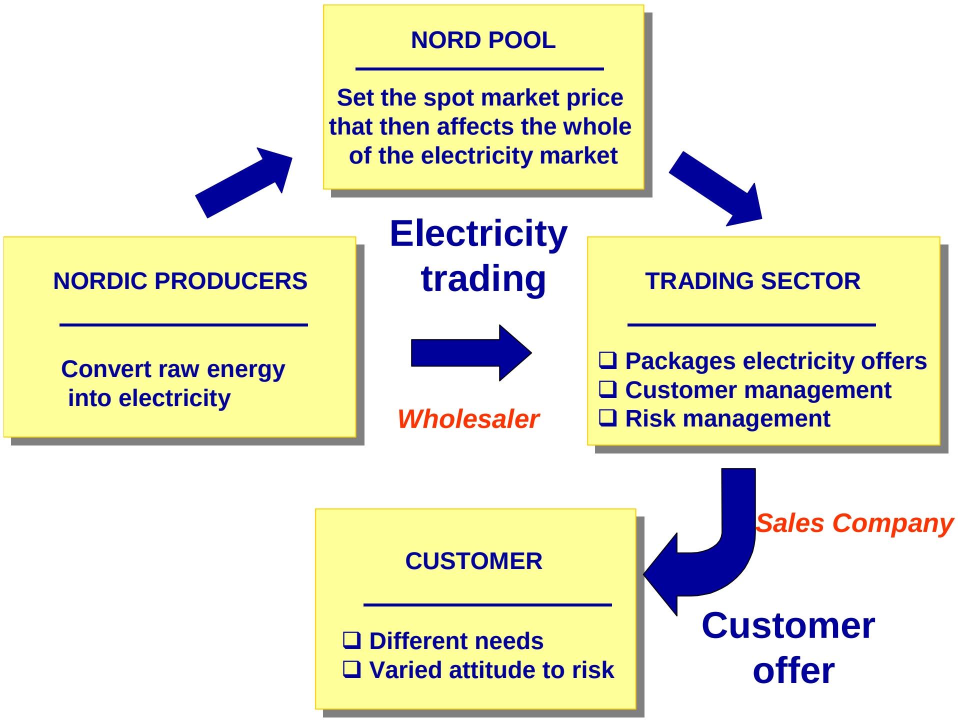

Figure 2.4. Liberalisation created clearer rules for the game. The Nord Pool is a good example of the value chain in the electricity industry of today. In the future, real time pricing will allow consumer to react to electricity prices on real-time and on-line settlements of contracts, completing a real market among all actors involved. To manage power demand, all customers might be equipped with smart meters that can report moment-to-moment power use to the utility; these technologies enable customers to participate in a voluntary demand response program which gives them credits on their bills for limiting power use in peak demand periods or when the grid is under stress. Smart appliances accomplish this automatically, so customers do not have to make manual adjustments, though they can override the system if they wish by controlling their appliances over the Internet.

In this new market environment, one can see the emergence of "micro-grids" and "virtual utilities" (see more details in section 6), which allow new actors to combine the individual of micro-generation with the market power that is gained by bundling together their collective generating capacity. Whether run by established utilities, or in competition with these, such virtual utilities or micro-grids would [5] "*result in greater system reliability, lower operating costs, reduced environmental impact and improved overall business.*"[6]

Much as with the Internet, the companies that develop the technology to allow the electricity grid to perform intelligent metering and switching –and position them-selves as "air-traffic controllers" for these streams of electrons- will lead the market of the future.

If this encouraging trend is not somehow derailed, the result is likely to be innovative services and lower prices for consumers, and more capacity to satisfy the world's ever-growing demand for energy.

[6] Although these arguments have been extensively used in the literature, one should reflect critically on the underlying assumptions. It is important to stress that these arguments were developed in an American context, which has a different institutional framework and a slightly different system of supply. Surprisingly however, these arguments were quickly adopted in Europe without much discussion or critical reflection on the issue of whether these arguments were also valid for the European situation. We will further discuss this subject based on recent experiences on projects and their validation at European level in Section 4.

2.5 Technology evolution and trends

Since electricity is not available in the natural environment, the energy sources market and the generation technology chosen by a country plays a crucial role in the domestic economy of this country. Furthermore, technology power decisions taken in one EU country today increasingly affect not only the power quality of neighbouring countries, but also their environment. The term “technology power” in this case has a double meaning: electricity generation as such, but also an economic effect at national and international levels, and great social and environmental influences.

As environmental issues have moved to the forefront during the last years, and as the costs of environmental pollution have become more widely known, investments in research and development in cleaner, more emission-neutral technologies have gained pace, displacing efforts in conventional technologies. These range from catalytic converters in the automobile industry to a new range of fuel cells for the same industry.

The rapid rise of the integrated energy multinational conglomerate is also leading to the rapid growth of technology markets in such fields as photovoltaics, wind energy, fuel cells, combined heat and power (CHP), micro-turbines or electricity storage systems. This will have a profound effect on energy demand- and on the environment.

Recent studies foreseen a substantial increase in renewables and natural gas in the European Union [6]. It is foreseen that the share of renewable in Europe’s electricity generation will double, from 14% now to 28% in 2030. Wind power alone is projected to increase from 36 TWh in 2002 to 480 TWh in 2030, reaching 11% of total electricity generation. This sizeable increase will require a redesign of networks and the raising of substantial financial resources to develop wind energy. The same studies see a pronounced increase in natural gas, from 521 TWh in 2002 to 1458TWh in 2030, doubling the present share and accounting for over a third of the total in 2030.

Based on the same studies, about 40 GW of new nuclear capacity will be built in the period to 2030, mostly to replace old reactors in France. Therefore, nuclear capacity in the European Union is expected to decline from 133 GW in 2002 to 71 GW in 2030, which means that the share of nuclear power electricity generation will fall from nearly a third of today’s demand to 13% in 2030.

Coal-based electricity generation is predicted to increase at modest 0.6% per year. Many of the today’s coal-fired power plants are expected to be retired. New coal plants are expected to be built in the European Union in the second half of the projection period, when natural gas rise, making coal competitive. Based on present research efforts undertaking in this area at European level, new coal plants will be based on much more efficient technology that the current stock.

The following sections provide further descriptions of the different power sectors in Europe and their trends, so to complete the analysis initiated in previous sections.

2.5.1 The coal sector

As far as energy sources for Europe are concerned, it is worth highlighting that Europe's coal sector still remains an important policy, political and industrial driver. The sector, which employed nearly two million Europeans in the 1950s, now employs fewer than half a million. France, Belgium and the UK have undergone a radical restructuring of the coal sector since the 1960s. Germany is currently undergoing major cuts in employment in the sector, and Spain is facing a similar transformation. However, the coal production sector remains important.

Given the large coal resources available, the political imperatives that surround the production of coal, and its historical lead in coal technology, Europe continues to place emphasis on the development of cutting-edge in this sector (i.e. super-critical coal, integrated coal gasification with combined cycle, advanced coal cycle). From cutting-edge fluidised bed combustion, to supercritical gasification, Europe invests more per capita in top line clean coal technology than any other region of the world. This technology is one of Europe's leading exports, especially to Asia. Until the recent Asia Crisis at the beginning of this century, this represented one of Europe's leading export sectors.

2.5.2 Nuclear technologies

Nuclear technology is also one of Europe's major exports. European firms are some of the most competitive nuclear technology exporters in the world. Asia and other emerging and developing economies are becoming Europe's major nuclear export partners.

While a number of Member States have eschewed the nuclear option (e.g. Austria, Italy, Denmark), and while others are moving away from nuclear (e.g. Sweden, Spain and Germany), European Members States and the European Union spend more, per capita, on public research on nuclear energy than any region of the world. Major research on "breakthrough" technologies continues (e.g. fusion nuclear, fission waste management, etc).

The highest proportion of electricity generated in the EU from nuclear energy is in France. The nuclear industry and other proponents argue that in an era of primary concern for emissions, nuclear energy should represent one of the most logical energy technologies to address these concerns.

The future of these technologies in the medium to long-term is difficult to prevent; the success of nuclear fusion experiments, fossil fuel reserves and price volatility and the use of renewable sources will play a crucial factor in Europe. In the short term, the economics of new nuclear power plants does not make sense, but shutting down existing ones might not either.

2.5.3 Gas technologies

Deregulation of gas markets in the US and in Europe and new gas discoveries in the North Sea, each in its own way sets the path for one of the most rapid transformations of energy use in history. By 1999, close to half the homes in the European Union were supplied with gas, while industries, including much of the electricity-generating sector, have switched to natural gas.

Only the relatively low costs of coal, and the costs of converting electricity-generating plants, have slowed the seemingly inexorable march of gas towards “universal” energy supply (i.e. conventional gas technology, oil-fired gas turbine in combined cycle, gas-fired turbine in combined cycle).

European industries and other energy users are likely to become more dependent upon gas as the costs of delivery fall. Growing concerns about climate change (because the unit emission of gas turbine cycles is lower than for other fossil fuels, see Figure 4.1 in section 4), the relative ease of use in final consumption and the prospects of relative plentiful and low-cost supply, are all factors that facilitate shifting energy demand to natural gas.

In the short to medium-term, the gas technology is expected to experience major techno-economic improvements for gas turbine combined cycles and combined heat and power plants as well as an enhanced availability of natural gas.

2.5.4 Renewable energies and new cleaner technologies

Less and less emphasis is being placed nowadays on “breakthroughs” in large-scale technology, and more and more emphasis is being placed on smaller-scale, easier to build (and dismantle) energy systems, from fuel cells and gas combined heat and power, to decentralised renewable electricity systems. Downsizing, localised and decentralised energy production all hold great promise in this new century, and considerable work is taking place to develop such systems all over the word. General technology progress in several fields, especially information and communication technologies, is strongly influencing these technology trends.

Renewable energy technologies are undergoing a major renaissance in Europe:

- European Member States offer more political and economic support per capita for renewable energy technology development and installation than any other country.[7]
- The European Union has set a target of 12% of all primary energy supplies for renewable energy by the year 2010; for electricity, the collective target for the EU25 is 21% by the same year (see section 3.6.1). Some Member States, such as Denmark, Austria, Finland and Sweden have already exceeded this target and have more ambitious targets.
- The major drivers for renewable energy development are the dependence of energy supply and environment, which are key elements for the EU sustainable development objectives. Export competitiveness is also a major driver for Europe’s

[7] With probably the exception of Switzerland, but no global figures were found to compare it with.

renewable energy technology development.[8] Since the 1990s, Europe has installed more wind electricity capacity than all countries of the world combined.

In addition, work on micro-cogeneration (especially the so-called "trigeneration", which combines heat, cooling and power) and **Fuel Cells (FC)** technologies[9] (solid oxide and molten carbonate fuel cells), combined with the emerging technologies that enable easy remote control of electricity flows are opening new opportunities for energy consumers to also generate and supply energy. These combinations are enabling a range of consumers to install plants that meet their heating and cooling needs, and most, if not all of their electricity needs.

With uncertainty decreasing mainly as a consequence of sustained efforts in R&D, these technologies are to become more and more attractive. New advances in renewables, fuel cells and micro-CHP will accelerate these trends, and make such technology accessible to a larger group of consumers, including individual households. This will lead to fundamental shifts in the energy economy and industrial competitiveness, with profound effects on technology demand, and the environment.

In the short term, they can hardly compete with other gas-fuelled technologies, whereas in the longer term it is likely that they find their own market complementary to some decentralised renewables as a preliminary move towards a hydrogen-based economy. Indeed, the massive introduction of renewable energy sources requires the emergence of an energy carrier suitable for the three large primary energy consumption sectors (i.e. power generation, transportation and the residential) and the tertiary sector. This combination of electricity and hydrogen as the two main energy carriers will have to replace, at least in the long term, the traditional model based on fossil-fuel carriers.

[8] Denmark accounts for over 75% of all international wind turbine exports. But Europe is at the leading edge not only in the wind industry, but also in biomass (i.e. biomass gasification for gas turbines), photovoltaic, solar thermal concentrating technologies and solar thermal heat, geothermal and small-scale hydropower.

[9] In general, penetration of FC technologies is estimated at around 1% for 2008, rising to higher percentages with the new liberalisation of the market. The expected power installed may be around 10% in the year 2020. This will particularly concern proton exchange membrane fuel cells for transportation applications (hydrogen fuel cell cars) and other fuel cell technologies operating at higher temperatures for stationary applications (solid oxide fuel cell with co-generation).

3 The electricity system in the present EU framework policy for sustainable development

Energy is the biggest business in the world. There just isn't any other industry that begins to compare.

Lee Raymond, Chairperson of Exxon Mobil.
Platts Energy Business & Technology. January/February 2004

The Kyoto protocol is only the first step towards achieving a responsible response to challenges facing a sustainable development ….. emission trading is a good initiative but it is not a panacea in the battle against global warming.

David Hammerstein, Member of the European Parliament.
European Voice, 20-26 January 2005, page 19.

All experts agree that decentralised energy production is the most efficient way to make production of electricity happen as close as possible to the points of consumption in order to minimise stability risks to the grid management and thus insure security of supply.

Claude Turmes, Member of the European Parliament.
Rapporteur of the electricity liberalisation Directive, October 2003.

Europe's energy supply today is characterised by structural weaknesses and geopolitical, social and environmental shortcomings, particularly as regards security of supply and climate change. Whilst energy remains a major component of economic growth, such deficiencies can have a direct impact on EU growth, stability and the well-being of Europe's citizens. These three elements provide the main drivers for energy research, within the context of sustainable development, a high-level EU objective.

3.1 Current energy indicators[10]

Despite reductions in energy intensity over recent years, energy consumption in the EU is still rising at 1-2% per year. Energy consumption at world level is due to increase even more sharply (more than 60% between 2000 and 2030), particularly because of growth in demographic giants such as China and India. Electricity's share of total energy is expected to continue to grow from 24% in 1970 to 40% in 2020.

Fossil fuels represent today 78% of the EU energy balance (40% oil-related, 23% natural gas and 15% solid fuels), nuclear energy 16%, and RES 6%. At global level, fossil fuel use is expected to grow even faster than overall consumption. For electricity, Figure 3.1 shows the share of resources for the year 2000, where nuclear and coal are the predominant resources used for power generation in the EU25.

EU external energy dependency is currently 50% and is forecast to rise to 70% by 2030 if appropriate measures are not taken. The cost of crude oil has doubled within the past two years from $25/bbl to $50/bbl, and a new peak of $70.85/bbl was reached in August 2005. The price of gas has followed the same trend which has a fundamental impact on the cost of generating electricity in Europe. It is clear that world oil and gas prices have risen much more quickly than anticipated, and it is evident that the EU dependency on imported fossil fuel has become a threat to economic stability because of the impact of increased fuel prices on the cost base, most notably on the price of electricity.

About 95% of EU CO_2 emissions are attributable to energy consumption. The transport sector (98% dependent on oil) represents one third of this, but accounts for 9/10ths of the growth in emissions.

Non-nuclear electricity generation accounts for a further third of overall CO_2 emissions and the electricity consumption in the EU-25is growing at 2% per year. The electricity produced by renewable energy sources (RES-E) in the EU-25 countries accounted for 394 TWh in 2003, corresponding to a share of 14% in electricity generation (see Figure 3.1). The recent very dry years and the considerable growth of electricity consumption affect the percentage of RES-E in consumption as a whole. One percentage point of the objective on renewable electricity has been missed in the last three years due to the important draughts occurring in Europe.

Global investments required in the energy sector over the period 2003-2030 are estimated at $16 trillion, or $568 billion per year, illustrating the scale of potential new markets opening up for European business. The electricity sector will absorb most future energy investment. This investment will be needed to expand supply capacity and replace existing and future supply facilities that will be closed during this period.

In Europe alone, to cope with increasing electricity demand over the next 30 years, 650 GW of additional power generation capacity, of which 330GW replacing existing plants, will be needed (estimated cost €500 billion), as well as some €500 billion investment in upgrading the electricity transmission and distribution infrastructure.

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[10] Sources used throughout this section include Eurostat, EC publications (green papers and communications), IEA World Energy Investment Outlook, IEA Key world energy statistics, IEA RTD statistics, and WETO report.

There is also a degree of market concentration in Europe, which can reduce competition. At the beginning of 2003, seven companies controlled more than half of Europe’s generating capacity.

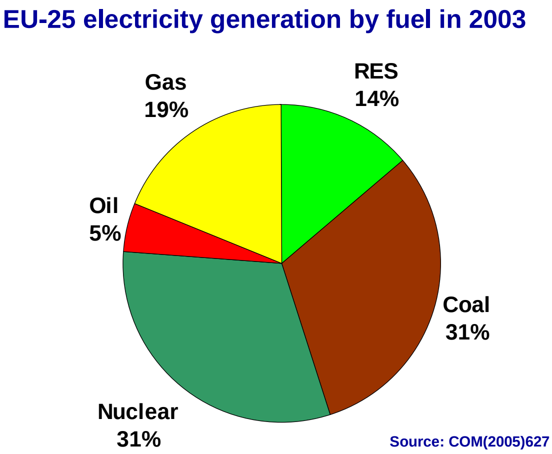

Figure 3.1. Electricity generation by fuel in 2003 in EU25. Source: COM (2005)627, page 19

Regarding energy subsidies and public R&D, Figure 3.2 shows that the level of subsidies in the EU-15 to fossil fuels remains high despite their environmental impacts [7].

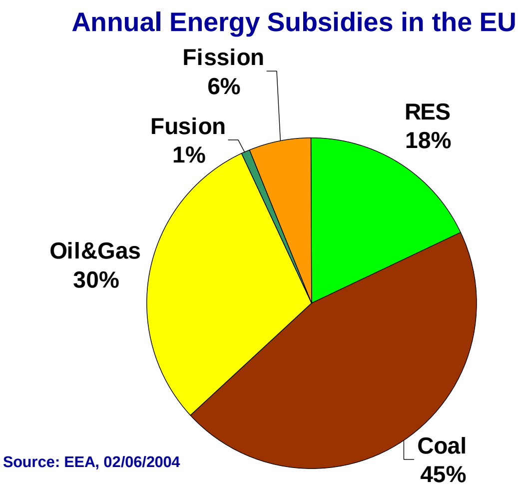

Figure 3.2. Annual Energy Subsidies and Public Sector Energy R&D in the EU-15. The data for 2001 were Energy bill: €700 billion; Energy subsidies: €29 billion; and only €2 billion were expended on R&D in 2001, which is 0,3% of the total energy market. Note that the data for the value of the energy markets are 2 or 3 years before the rise in the oil price, so R&D is now certainly less than 0.3% of the total energy market.
Source: European Environment Agency, “Energy subsidies in the European Union: A brief overview, 2004”, http://themes.eea.eu.int/Sectors_and_activities/energy/reports

There is some evidence to suggest that, in historical terms, renewable energy subsidies in the EU 15 are relatively low in comparison with other forms of energy during periods of fuel transition and technology development[11]. More mature fuels, such as natural gas, continue to benefit from the technological and industrial infrastructure built up during previous decades.

In conclusion, current projections show most of the crucial energy indicators to be moving in the wrong direction, in the EU and even more so worldwide: energy consumption increasing, fossil fuel dependence increasing, import dependency growing (EU), CO_2 emissions increasing (global), energy prices rising and volatile, high subsidies to fossil fuels while support for renewable energy sources is increasing steadily.

3.2 Sustainable development: the European policy for economic growth, security of supply and environment

Energy was not one of the main issues of integration when the Treaty of Rome was signed on 25 March 1957. At that time the six reached one of the ECSC's[12] most valued objectives: making the very first step towards a gradual integration of the Member States, not only on an economic level but also on a political level. However, as we will see later, this type of integration only responded to the preoccupations of those who, at the time, while elaborating the concept of building Europe, had put the accent on a sector-based integration [8]. Indeed, coal was the main source of energy in the first years of the European Community, and energy supply was abundant, cheap and marginal.

Later, in the 1960s, oil replaced coal as it had promising economic perspectives and the boom in nuclear energy followed this. That is when the European institutions first began to reflect on the subject, and to pronounce themselves in favour of adopting common positions in the energy sector, seen as vital for the economies of Member States [9]. However, the absence of a consensus amongst the Member States to develop a common European strategy for energy became clear in the debates preceding the European treaties. The sector-based vision present in the constitutive treaties became the rule until late after the first oil crisis of the seventies [10].

In the 1980s, world oil production increased greatly and even tended to surpass the amounts needed. This caused the prices of crude oil to decrease from 1986 [11], which in turn justified, although only in part, the exclusion of a global energy policy in the treaties resulting from the Single Act.

Only a few years later, the Gulf crisis threw certain oil-producing countries into political instability. Member States became vulnerable to variations in oil prices and to fluctuations in the levels of production. Thus, during the revision process which began in 1990 with the creation of Intergovernmental Conferences, the Commission insisted on the necessity of including a specific provision relative to energy policy in the aim of making the security of energy supply to the Union a community objective and to clarify the rules of community competence in this area. In reality, the idea wasn't new, as the Draft Treaty on the

[11] Results of an US study shows that the nuclear industry received about 30 times more support per kWh output than wind power in the first 15 years of the industry's development

[12] Economic Community for Steel and Coal

establishment of the European Union presented by the European Parliament in 1984 [12] already contained an article – article 53f – granting competence to the European Community in the energy sector with the objectives of ensuring:

– the security of energy supply
– the stability and liberalization of the energy markets in the Union
– the development of sources of alternative and renewable energy
– the adoption of measures for the protection of the environment

A few years later, neither the Treaty of Amsterdam nor the Treaty of Nice had taken the necessary dispositions to ensure a common policy in the energy sector. As a consequence, the terms of the legal provision for this policy were still limited to the modest modifications introduced into the Treaty of Maastricht.

Faced with the passive attitude of the Member States towards granting the EU competence in the energy sector, the community institutions, and especially the Commission, have presented important working documents over the last ten years, indicating the Directives that the EU should adopt in the area. In January 1995 the debate initiated by the Commission itself in 1993 reached its peak with the adoption of the Green Paper on EU policy in the area of energy [13]. This document described the problems that could arise from an absence of a common energy policy and indicated possible solutions.

In 1996, the Commission approved the White Paper entitled "An Energy Policy for the European Union" [14] in which all the main orientations concerning European energy policy are stipulated, as well as the appropriate measures for their implementation, with the following three priorities:

i. <u>Overall competitiveness or the integration of markets</u>

   Integration of the energy market not only means the liberalization[13] of fifteen –at that time- national markets which were still all working according to national models, but *"the complete opening of the markets of electricity and of gas in 2005, accompanied with guarantees on non-discriminatory access to the transmission and distribution networks" [15]*.

ii. <u>Managing external dependency</u>

   In spite of measures adopted by the community institutions since the 1973 crisis the EU's energy dependency is around 50%. This percentage could rise to 70% if today's technologies and sources of energy remain unchanged. That is why in 2000, the Commission published a Green Paper[14] entitled "Towards a European strategy for the security of energy supply" [16]. This paper explains that the security of energy supply is not only a question of reducing imports, but that a series of specific measures are necessary, for example: the diversification of energy sources and technologies; the further development of indigenous and renewable energy sources;

[13] The first key directives in the gradual process of liberalizing energy markets were made in the field of electricity – Directive 96/92/CE, document L27, 30 January 1997 – and gas – directive 98/30/CE, document L204, 21 July 1998

[14] This document describes the structural weaknesses of the European energy supply system and presents the orientations of a long-term energy strategy. The basic motivating factors of this strategy are *"Europe's growing dependence on energy, the role of oil as the governing factor in the price of energy and the disappointing results of policies to control consumption."*

efforts to improve energy efficiency and of generation technologies; and the improvement of relations between the EU and the exterior.[15]

iii. Sustainable development

Sustainable development is a vision of progress that links economic development, protection of the environment and social justice. Energy, at the root of all human activity, holds the key to reconciling these often opposing dimensions. Achieving sustainable development in all regions of the globe is only possible if energy efficiency and renewable energy are taken seriously.

Sustainable development is one of the priorities of the Treaty of the European Union (Art. 2 and 6), and hence in the elaboration of European energy policy. Figure 3.2 shows the three pillars of the sustainable energy policy.

In this line, the European institutions have been making great efforts during last decade to initiate and implement an extremely important set of new instruments to support this new policy. A brief overview of these instruments – already adopted and under preparation- is given in Annex 1. The European energy policy has also catalysed a whole new array of energy-saving technologies, the development of renewable sources of energy as well as the elaboration of a long-term model of production and consumption of sustainable energy. Both lines of action are taken into consideration in the various international agreements signed by the EU, especially the Kyoto Protocol[16] related to climate change.

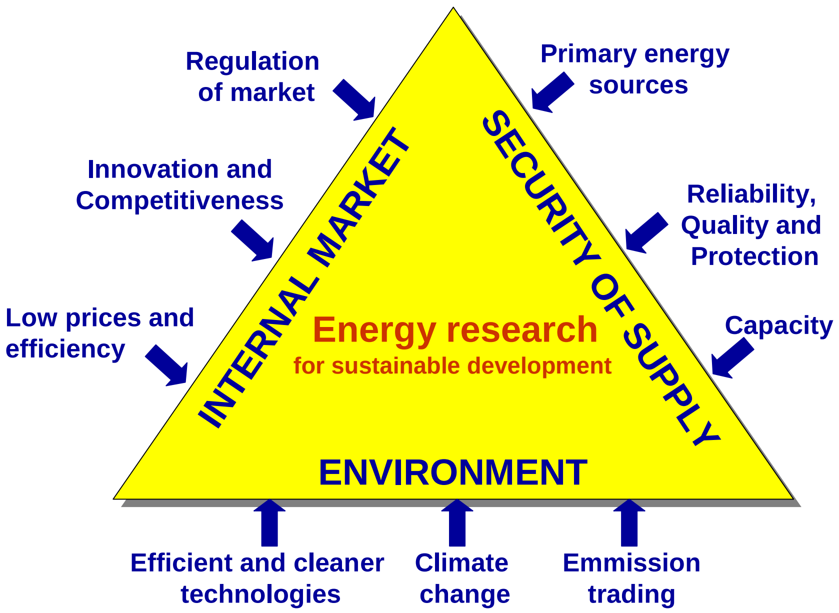

Figure 3.2. European energy framework policy for sustainable development covers society's demands on the energy sector: security of supply, environment and internal market.

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[15] Indeed, the EU is an important actor on the international market for energy products, being the largest energy importer in the world and the second largest consumer. According to the Green Paper, the EU represents 19% of world oil consumption, 16% of natural gas, 10% of coal and 35% of uranium.

[16] In general, the EU emits 14% of total greenhouse gases. In the Kyoto Protocol, the EU pledged that between 2008 and 2012 it would reduce its emissions by 8% in reference with the levels registered in 1990.

More recently, during the Montreal Conference of December 2005, the European Union has signed agreements with the United Nations Framework Convention on Climate Change (UNFCCC) to support the operation of the Clean Development Mechanism (CDM) and the establishment of the International Registry System, which will keep track of transfers of Kyoto emission credits. After this breakthrough achieved in Montreal, present efforts of 180 countries to control the detrimental emissions of CO2 will take on new commitments when the current emissions targets under the Kyoto Protocol expire in 2012, giving the protocol a future. It reassures developing countries that the transfer of clean technologies will continue. It also reassures business that investments in clear technologies will remain worthwhile, and gives researches a sense that the demand for new low-carbon technologies will continue to rise.

A fundamental observation to remark here is that, whatever we will do concerning sustainable energy and curbing demand, we will have to do it with broad international cooperation in mind. Today, when a new EU Constitution is under adoption, the following points regarding policy in the Energy [17] sector and Trans-European Networks [18] are comprise:

ENERGY

In establishing an internal market and with regard for the need to preserve and improve the environment, Union policy on energy shall aim to:

- ensure the functioning of the energy market;
- ensure security of energy supply in the Union; and
- promote energy efficiency and saving and the development of new and renewable forms of energy.

The measures necessary to achieve these objectives shall be enacted in European laws or framework laws. Such laws or framework laws shall not affect a Member State's choice between different energy sources and the general structure of its energy supply.

TRANS-EUROPEAN NETWORKS

- The Union shall contribute to the establishment and development of trans-European networks in the areas of transport, telecommunications and energy infrastructures;
- within the framework of a system of open and competitive markets, action by the Union shall aim at promoting the interconnection and interoperability of national networks as well as access to such networks;
- the Union shall establish a series of guidelines covering the objectives, priorities and broad lines of measures envisaged in the sphere of trans European networks; these guidelines shall identify projects of common interest;
- the Union may support projects of common interest supported by Member States, which are identified in the framework of the guidelines referred to in point (a), particularly through feasibility studies, loan guarantees or interest-rate subsidies; the Union may also contribute, through the Cohesion Fund, to the financing of specific projects in Member States in the area of transport infrastructure; and
- the Union may cooperate with third countries to promote projects of mutual interest and to ensure the interoperability of networks (like the possible synchronous

connection with the Russian electricity network, or the completion of the Mediterranean ring).

Recently, and moving away from the traditional British scepticism about a common EU energy policy, the British Prime Minister has called for better co-ordination to tackle climate change and improve security of supply at EU level. At their meeting at Hampton Court on 27 September 2005, EU heads of state and government discussed a plan presented by the British Prime Minister Tony Blair to create a common EU energy policy. Observers say that this move represents a U-turn by the UK government, who had so far resisted all initiatives to co-ordinate energy policy at European level. In particular, the initiative included the following suggestions:

– Better interconnection between the EU's power grids in order to establish one single grid;
– EU-wide cooperation on gas storage, possibly through an inter-governmental agreement or through ceding national powers to the Commission;
– exchange of information on security of supply;
– maintaining Europe's lead in climate change policies, including the Emissions Trading System (ETS), renewables policy, and the Kyoto commitments

The Commission is already working on it and plans to present a first draft for the spring summit in March 2006. It will be centred on achieving sustainable development, fostering competitive and integrated energy markets, and enhancing energy cooperation with third countries.

The following sections describe the present legislation, activities and recent opinions of major stakeholders.

3.3 Internal market and competitiveness in the EU today

.In order to keep its political and industrial independence, as well as the hundreds of thousands of related jobs, Europe needs a competitive energy industry, for which continuous innovation and R&D are a prerequisite. More than ever, developing and making better use of clean energy technologies, through investing in R&D, will help to meet the Lisbon and Göteborg objectives and reinvigorate and modernise our economy by contributing to technological innovation and increasing European competitiveness.

3.3.1 European integration and expansion of the internal market.

European integration has been a major objective of European energy market liberalisation[17]. With the expansion of the European Union, a range of Directives and laws has been put in

[17] The directive 96/92/EC on the liberalisation of the electricity markets (IEM Directive, Internal Market in Electricity) has triggered a deep transformation of the electricity industry. The monopoly supply structure of the market has been substituted by a more competitive arrangement. The second IEM directive (2003/54/EC) extends the mandate of the first one, and sets firm dates for the full opening of the market (1 July 2004 for non household customers, and 1 July 2007 for all other

place to promote European integration and harmonisation of various Member State laws and regulations. From gas and electricity to renewable energy, Europe is rapidly integrating its energy sector.

Market liberalisation is leading to the unbundling of a range of energy activities and prices. Non-European investors have moved into Europe's energy markets, while European energy players have moved into the Former Soviet Union countries, Asia, Africa Latin America and North America. Europe's electricity sector is undergoing rapid change, not only with shifting ownership, but also with new entrants, particularly in the gas, CHP and renewable energy sectors.

3.3.2 Export competitiveness.

The development of the European energy market is taking place in a global competition environment. International competitiveness is a very important driver of policy within the EU. As shown in Table 3.1, some of the world's largest energy companies (gas, petroleum, electricity, and equipment) are European [19].

Rank 2004	Company Name	State / country	Rank 2004	Company Name	State / country
1	Royal Dutch/Shell	Netherlands	14	China Petroleum	China
2	Exxon Mobil Corp.	Texas	15	ENEL SpA	Italy
3	TotalFinaElf SA	France	16	Electrabel SA	Belgium
4	ENI SpA	Italy	17	Electric Power Co.	Korea
5	Pétrobras	Brazil	18	Centrica plc	UK
6	BP plc	UK	19	The Southern Co.	Georgia
7	Petrochina Co. Ltd.	China	20	Edison Internat.	California
8	Statoil ASA	Norway	21	Dominion Resources	Virginia
9	Repsol YPF SA	Spain	22	RWE AG	Germany
10	Yukos Corp.	Russian F.	23	Endesa SA	Spain
11	LUKoil Oil Co.	Russian F.	24	Occidental Petrol Co	California
12	Exelon Corp.	Illinois	25	Chevron Texaco Co.	California
13	Norsk Hydro AS	Norway			

Table 3.1. The Top 25 energy companies for the year 2002. About 50% of these companies are European

While the sector is capital intensive, and one with a highly skilled labour force, it also accounts for a high level of added value to Europe's economies and competitiveness. Taken together, Europe's energy supply and technology industries account for more added value than any other sector in the EU. Maintaining Europe's competitiveness in this sector is viewed as crucial by a wide spectrum of policy makers, politicians and industrialists and being at the 'cutting edge' of technology, particularly in high quality, energy efficient

customers); furthermore, it extends the level of independence of Transmission and Distribution System operators. See Annex for further information.

equipment, is seen as very important. Since the EU industry is a leader in environmentally clean energy supply and equipment production, the environmental debate may add further momentum to Europe's competitive position. It is perhaps in this area where the energy, environment and technology nexus is so apparent. It is in this area where so much of Europe's research and development is directed, and where so much of its export promotion takes place. Maintaining this competitive position is undisputedly one of the highest priorities in Europe's industrial and market strategies.

3.3.3 Employment and job creation.

Europe has been faced with substantial structural unemployment since 1980. In most EU countries unemployment is currently perceived as the second most severe social and economic problem after the terrorist attacks, which is the first severe problem after the recent attacks in New York, Madrid and London. Consequently, job creation and employment have become major political drivers on the European political scene.

The energy sector is one of Europe's most capital-intensive industries. However, from equipment manufacturing to electricity generation, gas distribution, and petroleum refining, there is little scope for absorbing labour, or creating many new jobs today. Furthermore, energy sector employees are generally highly skilled, which makes it difficult for the sector to absorb labour from other sectors.

The major hopes of Europe's policy makers rest on the expansion of Europe's energy equipment industry, which is one of the most innovative and competitive in the world. There is also some scope for job creation in Europe's expanding renewable energy sector, particularly in the future development of biomass for energy.

To sum-up, sustainable energy policy can create jobs; how many is depending on the sector. But energy inefficiency will not create jobs.

3.3.4 Contribution of Energy research to enhance innovation and competitiveness.

Power generation and distribution is a sector where traditionally much of Europe's research and development is directed. However, the general trend in Europe over last years has been to decrease spending in RTD on energy research. Although relatively constant in monetary terms, the share of the overall budget for energy research in the EU **Framework Programmes (FP)** has been steadily decreasing: the share of nuclear energy research has decreased from 25% in FP1 to about 6% in FP6, whilst the share of non-nuclear energy research has decreased from 20% to around 5% over the same period. The tendency has been similar in Member States, which is in stark contrast to our major competitors, the US and Japan. As an example, the Office of Basic Science of the Department Of Energy in the US alone spends $1 billion a year on energy research. Indeed, public research on energy in the US has increased by 30% between 1997 and 2002.

As seen in Figure 3.3 total public expenditures for energy **research, development and demonstration (RD&D)** in OECD countries have declined further since 1991, although the trend since 1999 has slightly improved. Budgets for total energy RD&D in 2001 were about US$8 billion (53% of the 1980 value) although for renewable energy RD&D they fell to about 34% of the 1980 value of US$675 million.

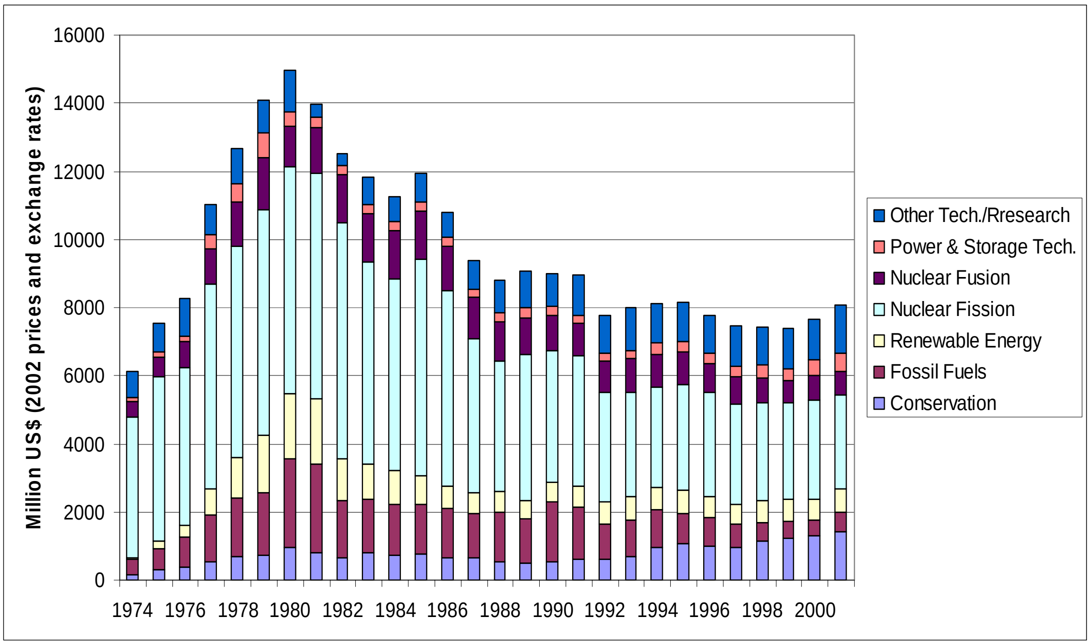

Figure 3.3 ***Government Energy RD&D Budgets in OECD countries [22]***
The major share of global energy RD&D expenditures is in industrialised countries. From 1974 to 2001, the total expenditure of IEA countries for energy RD&D was about US$270 billion. These expenditures were unevenly distributed across the time period. In the first period, energy RD&D spiked from about US$6 billion in 1974 to almost US$15 billion in 1980, falling thereafter to about US$9 billion in 1987. Across IEA countries renewable energy RD&D budgets from 1974 to 2001 were of about US$22,218 billion, which was about 8% of the total energy RD&D funding. During the 27-year period, annual funding for renewable energy RD&D varied from US$0.062 billion in 1974 to US$1.94 billion in 1980, falling again to US$ 0.68 billion in 2001.

The picture is hardly more encouraging in the European private sector, where a combination of vested interests in the current energy system, and increased competition and structural changes in the context of the privatisation process have shifted their strategic focus from long-term security to short-term profitability requirements. Indeed, private research funding has decreased on average from 1.6 ~1.8 % of the industry income before the liberalisation to around 0.2 ~ 0.4 %, with consequent substantial loss of overall know-how and technical competitiveness in the medium term. Today, many ex-utilities no longer have specialized R&D units and a substantial amount of research is subcontracted to several Universities and private research centres. Other parts of research are moving from utilities to manufacturers.

More than ever, results achieved during research/demonstration projects should be efficiently exploited in order to generate qualitative and quantitative impact on social and economic demands.

In the case of EU-FPs projects supported in the energy area, overall lessons learned showed that support measures have an almost immediate impact, while demonstration projects deliver most of their impact, technical and non-technical at the end of the project. Research projects, on the other hand, deliver technical innovation at the end of the project, but then take about five years to deliver the wider socio-economic impacts. The following paragraphs give a summary of the impact of projects in the energy field over the last ten years [20], [21], [22].

3.3.4.1 Environmental and S&T impacts.

Across all types of projects, the greatest impact in the non-nuclear part of the programmes was made on two areas, firstly, the scientific and technical quality of research (93% of projects had an impact, with 30% having a “highly positive impact”) and secondly, on the environment (94% of projects had an impact, a quarter having a highly positive impact concerning the reduction of pollution and CO_2 associated with energy production and use). In general, more than half the projects felt they contributed to moving the EU towards global leadership in their area. In the nuclear part, all projects on management of radioactive waste are contributing to a realisation, in the longer term, of policies aimed at the protection of man and the environment. In the shorter term, radiation protection research is having an immediate impact on the resolving of environmental issues related to background and occupational exposure to ionising radiation.

3.3.4.2 Economic, commercial and employment impact.

Almost half of the demonstration projects and one third of research projects lead to cost reductions. A positive return on investments was expected by the partners in half of the demonstration projects and for one third of the research project partners. Only 38% thought that they had some impact on employment. Moreover, the major hopes of Europe’s policy makers rest on the expansion of Europe’s energy equipment industry, which in some sectors is one of the most innovative and competitive in the world.[18] In this sense, the transfer of expertise from the research environment to the industrial sector and joint development has been improved further during FP5 and is continuing under FP6. For example, valuable new competencies have been developed in industry as a result of work undertaken on challenging technical problems for fusion research. In the shorter term, there is some considerable scope for the creation of jobs[19] in Europe’s expanding renewable energy sector. In the nuclear field, most research is long-term and final objectives, (e.g. the implementation of geological disposal) are only attainable in parallel with political developments, though shorter-term benefits are more apparent than in other areas, specifically radiation protection/installation safety where actions have made direct contribution to general nuclear safety.

[18] For example, the European wind industry produces 90% of the world equipment market. Nine of the world’s ten largest wind turbine manufacturers are based in the EU. The industry employs 72.000 people, up from 25.000 in 1998. Costs per kWh have fallen by 50% over the last 15 years.

[19] A €17 billion annual export business is projected for 2010, creating potentially as many as 350.000 additional jobs (source: 1997 White Paper “Energy for the Future: renewable sources of energy”)

3.3.4.3 Quality of life, education and social impact.

Over half of the projects had an impact on the quality of life, with the short-term impacts of the support measures showing most strongly. The strongest educational impact was achieved with support of measures where direct industrial education and training and dissemination activities were already very effective. Research projects with their postgraduate training dimension had stronger educational impact than the demonstration projects. Education and training is a key impact of the nuclear part of the programme and this has been emphasised especially in FP6 where the retaining of knowledge and know-how is widely recognised as an important element in maintaining a high level of nuclear safety throughout the EU in this sector.

3.3.4.4 Legislative and regulatory impacts

Generally, legislative and regulatory impacts were the lowest (along with employment); however, many renewable and **Rational Use of Energy (RUE)** projects helped to establish a good basis for the development of certain pieces of local, national and community legislation. The Directives in force during recent years concerning renewable electricity, cogeneration and bio-fuels were based on the results of these projects. The energy research strategy (i.e. policy analysis and modelling work) had an extraordinarily high impact in this area, presumably from engaging directly with such issues. In the Euratom Programme, research on radiation protection has a strong link with the extensive legislation [23]-[24] on this topic under the Euratom Treaty (e.g. Basic Safety Standards), and the crucial interplay between the need for research on the one hand and political initiative on the other has been clearly recognised in recent Commission Communications and proposals for new legislation in the field of radioactive waste management and nuclear safety.

3.4 Security[20] of electricity supply in the EU.

In general, countries without adequate reserves of fossil fuels, especially oil, are facing increasing risks to the security of their energy supplies. Import dependence can also lead to unpredictable rises in energy prices, which are a threat to economic growth[21], and volatile prices, a disincentive to make important investment decisions. As explained above, in spite of measures adopted by the community institutions since the 1973 crisis, the EU’s energy dependency is around 50%. Potential future crises in fossil fuel supply, particularly oil, are both foreseeable and avoidable and Europe’s vulnerability to possible economic shocks must be minimised.

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[20] According to the draft COM(2003)740, Article 2 in p. 6, “Security of Supply” means the ability of an electricity system to supply final users in the long term with electrical energy, meeting certain reliability and quality criteria. Security of electricity supply has here a short-term and a long-term aspect. The short-term aspect relates to the power grids’ reliability, while the long-term aspect is linked to investing in adequate generating capacity. Here, long-term adequacy is considered. Inadequacy of supply can result in electricity shortages and service interruptions, and in continuously high and fluctuating electricity prices.

[21] According to the IEA, oil price increases and volatility dampen macro-economic growth by raising inflation and unemployment and depressing the value of financial and other assets, producing losses in the order of 0.5% of GDP for each 10% oil price increase –and oil has risen 50% in the last year alone.

Energy supply forms part of Europe's critical infrastructure and must be secured, in both the geo-political and physical sense. Ensuring a reliable supply of energy in the EU and elsewhere has traditionally been regarded as a prime responsibility of governments. For the electricity sector, security of power supply is in the short term related to system reliability[22].

As a reaction to recent severe blackouts across Europe[23], and considering the fact that European electricity companies operate in a free market -or will soon do so- the Commission proposed a draft Directive designed to improve the security of electricity supply and boost investment in infrastructure in Europe in December 2003 [25]. The proposal requires Member States to define targets regarding the security of their power networks and seeks to step up investment in interconnections between different countries.[24]

3.4.1 Present issues

The rationale behind the draft Directive on Electricity Infrastructure and Security of Supply of 13 December 2003, which is part of a whole 'energy package', is to give incentives to the market to invest in transmission and distribution networks. According to the Commission, there is an increasing risk of interruptions as power demand grows and the strain on the network increases. The Commission proposes the following requirements:

- Member States must have a clearly defined policy to ensure a good equilibrium between power supply and demand.
- Member States must define and meet standards concerning the security of transmission and distribution networks. Failure to comply with the targets could lead to financial penalties.
- Transmission System Operators must submit regular investment plans for cross-border interconnectors[25] to its national regulator.
- Regulators[26] must submit a summary of these investment programmes to the Commission for consultation with the European Regulators Group on Electricity and Gas.

It also includes a right for regulators to intervene in order to speed up the completion of projects.

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[22] Reliability is a key characteristic of a strong electric power delivery system. At its simplest, delivery systems reliability is the measure of whether electricity is available to users. By contrast, Power Quality describes the sustainability of that electricity for servicing electrical loads, and concerns the shape of power waveforms. A widely accepted definition for reliability is comprised of two elements: adequacy- the ability to satisfy market demand at all times, and security- the ability to withstand sudden disturbances.

[23] Blackouts in Italy, Denmark, Sweden, Spain and other European countries since winter of 2003 and the situation is repeating almost every summer in southern Member States

[24] There is no definitive industry statistics that measures the overall reliability in the EU electric power system, although industry surveys are conducted periodically

[25] "Interconnectors" means equipment used to link electricity systems

[26] "Regulators" means the regulatory authorities in Member States, as designated in accordance with Article 23 of Directive 2003/54.

3.4.2 Present positions of stakeholders

The Commission's proposals seem to be highly controversial: while the energy industry welcomes the Commission's approach, environmentalists are calling for alternative ways to deal with supply shortages.

The **Energy Council** on 29 November 2004 adopted a compromise proposal, which would limit the Commission's and the regulatory authorities' role in the construction of electricity interconnections between EU member states. The text deletes some of the most 'interventionist' elements in the draft Directive and simplifies the reporting requirements for transmission system operators.

The **Union for the Co-ordination of Transmission of Electricity** (**UCTE**), representing European power grid operators, believes that in the short term, the EU's power system should remain reliable due to new generation capacity and grid improvements. After 2008, however, a significant decrease in generation margins may lead to an unreliable system. This situation could even be worsened by forthcoming decisions to decommission existing power plants. As a result, UCTE maintains that firm investment decisions are needed to prevent future blackouts in Europe. In particular, UCTE calls for a significant development of the ultra high voltage transmission network in countries with a high share of wind energy (such as Spain and Germany) to cope with unexpected generation peaks [26].

The **Union of the Electricity Industry** (**EURELECTRIC**) has emphasised that a secure electricity supply requires continuing adequate and timely investment across the entire chain [27]. The industry calls for investments to maintain the existing grid and to develop the transmission system. Moreover, in order to cope with increasing electricity demand, EURELECTRIC maintains that some 520 GW installations need to be built in the next 30 years in the EU15, at a cost of over 600 billion euro [28].

FORATOM, the **European atomic forum**, has also emphasised that large interconnected networks are essential. In their opinion, the current network should be improved, in particular by creating more substantial cross-border transmission lines; market rules must encourage grid operators to invest in new infrastructure; and new high-voltage lines are essential between certain countries where bottlenecks occur and where insufficient or poor interconnection is a problem.

The Commission's proposals have sparked an outcry among environmentalists**,** who maintain that the measures are costly, ineffective in improving the security of supply situation, and biased towards the interests of big electricity companies while undermining the EU's efforts to cut greenhouse gas emissions. Interest groups have therefore called for alternative measures such as decentralising power supply, increasing energy efficiency and promoting renewable energy production.

According to **WWF** [29]**,** the Commission "wants to impose on Member States irreversible energy investments on new power stations and high-voltage grid lines that will deeply affect the EU's energy and climate policies".

Greenpeace is also sceptical: the organisation accuses the Commission of reinforcing the largely fossil and nuclear-fuelled power system in place today, rather than driving smaller-scale investment in electricity distribution lines, at the expense of newer, cleaner electricity generation options. "By focusing its efforts on trying to increase interstate competition, the

Commission is ignoring its environmental commitments. This in turn risks creating a single market of dirty power at the expense of a more diverse and environmentally acceptable electricity system," said Greenpeace [30].

Renewables associations **EUFORES** and **EREC**, environment agencies federation **FEDARENE** and cogeneration association **COGEN Europe** also maintain that decentralised and diversified systems would be less vulnerable to accidents (extreme weather conditions, terrorist attacks etc), and would reduce transport needs. They also point out that renewable energy sources and cogeneration are particularly suitable for use in decentralised generation systems [31].

3.5 Climate change

Aside from security of supply issues, the major disadvantage of fossil fuels is that they emit CO_2 when burnt to supply energy. This greenhouse gas contributes to climate change, which is recognised to be one of the greatest environmental and economic challenges facing humanity. But climate change issues should be faced at international level. This is the reason why the United Nations became directly involved in the effort to arrest the deterioration of the global environment, and the Kyoto Protocol was born.

Research is needed to help identify the most environmentally and cost-effective technologies and measures enabling the EU to meet its targets under the Kyoto Protocol and beyond, as discussed recently in the UN Conference on Climate Change at Montreal in December 2005.

3.5.1 Climate change and the European leadership.

The EU is probably the most important world player in the field of clean technologies, and this did not come by chance. Many years ago the public opinion started to be worry, at least in the former EU-15, about the environmental issues and the climate change. As a result, the EU and its Member States have accepted the tightest emissions among developed countries and they are in process of putting in place a wide range of policies, from carbon taxes to energy consumption levies, from renewable energy obligations to energy efficiency obligations, to meet those objectives. So, bit-by-bit a brand new industrial sector developed to face up the needs for a clean environment. Today, this sector is actually built in the EU and it offers its services and products to the rest of the world.

In order to minimise the economic costs of its Kyoto commitments on combating climate change, EU countries have agreed to set up an internal market enabling companies to trade carbon dioxide emissions. Since 1 January 2005, some 12,000 large industrial plants in the EU have been able to buy and sell permits to release carbon dioxide into the atmosphere. The so-called Emissions Trading Scheme (ETS) enables companies exceeding individual CO_2 emissions targets to buy allowances from 'greener' ones. Investments in cleaner technologies can then be turned into profits while helping the EU meet its Kyoto commitments on climate change. Fines of 40 euros per excess tonne of CO_2 emitted will be imposed on companies exceeding their target, rising to 100 euros three years after the entry into force of the Directive. For comparison, the Commission has indicated that prices for carbon allowances are in the 8-10 euros per tonne range[27]. By offering a much cheaper alternative to fines, the Commission hopes that the EU-ETS will stimulate innovation and create incentives for companies to reduce carbon emissions.

The national targets are spelt out, for each individual plant, in a National Allocation Plan (NAP) previously approved by the Commission. Under the EU scheme, companies exceeding their quotas are allowed to buy unused credits from those doing better at cutting their emissions. This unique system has earned the EU the reputation of global leader in fighting climate change but has come under fire from some business circles, who criticise the EU for "going it alone" on the international scene and hampering the industry's competitiveness.

3.5.2 Present issues

During negotiations, EU Member States have obtained a number of exceptions to the EU Emissions Trading Scheme:

- Whole sectors are at the moment not covered, including transport, which alone accounts for a large part of CO_2 emissions. Industries currently covered are electricity, iron & steel, glass, cement, pottery and bricks. In a resolution, the Parliament expressed itself in favour of "incorporating emissions from international flights and shipping into the emission reduction targets of the second commitment period" of the Kyoto Protocol [32].
- Member States can apply to the Commission to opt out individual plants from the system.
- In cases of "force majeure", such as exceptionally low winter temperatures, national authorities can issue additional emissions allowances.
- One key aspect of the system is dealt with in a separate Directive, which links the EU Emissions Trading Scheme with the Kyoto Protocol's so-called flexible mechanisms, Joint Implementation (JI) and Clean Development (CDM). The Directive allows companies to carry out carbon reduction projects outside the EU that can be accounted for in their individual emissions reduction targets.

This 'linking Directive' is expected to offer companies possibly cheaper emission cuts alternatives than at home. The system would foster technology transfers to developing countries (CDM) and other industrialised nations (JI), which have signed up to the Kyoto Protocol.

As the scheme now faces its first real-life test, the debate is already focusing on the revision of the Directive. The Commission announced in January 2005 that it would start a "comprehensive overview with stakeholder involvement" and produce a report in mid-2006. The review will take account of:

- The extension of the scheme to the other gases and sectors.
- The effects of the system on competitiveness, including international competition.
- The impact on electricity prices.

[27] Just half a year later, the price per tonne is above 25 Euro in the free market.

– The harmonisation of national allocation methods for CO_2 emissions that, in its current form, leaves members states with considerable room for interpretation.

However, any thorough review of the directive will need approval by the Council and Parliament, a process which can take several years, meaning it may not be ready in time for the second trading period in 2008. Some businesses end up feeling they are being forced.

3.5.3 Present positions

Environmental groups hailed the EU for putting in place its carbon emissions trading scheme and taking global leadership to tackle climate change. However, they disapproved of the use of the Kyoto flexible mechanisms (Clean Development Mechanism and Joint Implementation), which they think undermines the pledge for emission cuts within the EU. "Rather than using the ETS to add financial value to emissions cuts, companies are likely to simply buy cheap credits from often damaging projects, including large hydroelectric dams" Friends of the Earth Europe pointed out [33].

Industry circles have focussed their criticism on the EU "going it alone" on fighting climate change by imposing costly measures on companies which do not apply to the rest of the world. They argue the system will put the EU at a competitive disadvantage at international level, ultimately leading to de-localisation and job losses with no overall improvement for the environment. A global problem such as climate change, they say, cannot be resolved at EU level but only on a global scale.

Big **power companies**, supported by the European employers' association **UNICE** are pushing for a full use of the Kyoto flexible mechanisms within the EU-ETS to enable them to carry out greenhouse gas saving projects outside the EU. They complain that the current "bureaucratic procedures and restrictive interpretations" impose too many restrictions on their full usage [34].

Other issues are being raised as to the expected impact of the EU scheme on **industry** [35], [36]:

– **Direct costs**: companies will need to invest in cleaner production methods, imposing high direct costs upon some of them. The electricity sector is under particular pressure in this respect and it would need to switch to alternative production methods (coal to gas power stations, for example) or buy massive amounts of allowances to make up for their surplus CO_2 emissions.

– **Indirect costs**: higher electricity prices are expected to be passed on to individual and industrial consumers with likely impact on prices for power-intensive industries. Prices are likely to be held high until more competition is achieved in the EU power market. A coalition of power-intensive industries - including iron & steel, glass, non-ferrous metals, alloys, cement, ceramics, paper and lime - have warned that "in the absence of real competition in the European power market, power companies will seek to charge" their carbon allowance costs to client industries. The coalition has raised the prospect of an "enormous risk of de-industrialisation" in Europe as a consequence.

– **Red tape**: planning and subsequent national reporting requirements imposed on companies are often criticised as too burdensome.

3.6 The “Renewables Directive”

In 1997, the Commission published a White Paper 'Energy for the future: renewable sources of energy - White Paper for a Community Strategy and Action Plan', setting the EU the target of increasing the share of renewable energy to 12 per cent of total energy consumption by 2010. The target for electricity production from renewable sources was set at 22.1 per cent. These targets correspond to the EU commitments under the Kyoto Protocol on the reduction of greenhouse gas emissions.

After lengthy discussions between Council and Parliament, the EU adopted the Directive on the Promotion of Electricity produced from Renewable Energy Sources [37] ('Renewables Directive') in September 2001, based on a Commission proposal of May 2000. This Directive provides an EU-wide legal framework with the aim of promoting and further exploiting the potential of renewable energy sources. The Directive states "a need to promote renewable energy sources as a priority measure", which goes hand in hand with EU efforts to diversify energy sources in order to enhance the security of supply, to protect the environment and to promote social and economic cohesion.

The full implementation of the Directive has a potential to save up to 200 million tons of CO_2 emissions, representing 6 per cent of the EU's emissions in 1990.

Definition of Renewable energy

The Directive defines “renewable energy as all non-fossil sources, including biogases, biomass, geothermal, hydro-power, landfill gas, sewage treatment plant gas, solar and wind”. Electricity is classified as being produced from RES if it is obtained from plants using solely renewable energy sources, as well as the proportion of electricity produced in hybrid plants that use conventional energy sources. A major controversy in setting a definition for the term was the question of whether electricity produced by unsorted municipal solid waste should be included in the Directive. In the end, there was an agreement on only counting the biodegradable part as a renewable energy source.

National targets

The Directive defines national indicative targets for the share of electricity to be produced from renewable sources by 2010. It is up to the Member States to take appropriate measures to promote renewable energy production and consumption in order to reach these targets, and they must issue regular reports assessing the progress made.

According with the Directive, Member States must publish a report setting national indicative targets for renewable electricity, and outlining measures (taken or planned) to achieve these targets, by October 2002 and every five years thereafter.

Support schemes and funding

Member States can choose one of the different support schemes to promote the production of renewable electricity. The Commission have recently published a report on the experience with these schemes at the end of 2005 [38]. The report, which will review the issue again in 2007, found that "*feed-in tariffs, which are fixed prices for green electricity and used in the majority of member states, are currently in general cheaper and more effective than so called quota systems, especially in the case of wind energy*".

The Commission concludes that the compatibility of all different renewable energy support schemes with the development of internal electricity market is essential in the medium to long term; however, due to the widely varying potentials and developments in different Member States regarding renewable energies, a harmonisation seems to be very difficult to achieve in the short term. In addition, short-term changes to the system might potentially disrupt certain markets and make it more difficult for Member States meeting their targets.

Guarantee of origin

The Directive introduces a system of 'guarantee of origin' to ensure that electricity really is produced from a renewable source. Certificates to this effect are to be issued by the Member States and they should be recognised EU-wide. Currently, the implementation of guarantee of origin varies across Member States. According with the Commission, at the end of 2005 only 9 of the 25 Member States have fully transposed this article of the Directive into national legislation and put in place an operational system for issuing guarantees of origin. At present, none of the new Member States has an operational system issuing guarantees of origin.

Most of the EU-15 have passed legislation concerning a system of guarantees of origins, the exceptions being France, Greece and Portugal. However, these countries are in the process of adopting legislation. Of the new Member States, only the Czech Republic, Estonia, Malta, Poland and Slovakia have passed legislation regarding a system of guarantees of origin. The remaining new Member States, with the exception of Latvia, are in the process of preparing or have proposed legislation.

Fair access to the market

In the recently deregulated EU markets this mainly concerns access to the grid. Member States have to ensure that the operators guarantee the renewable electricity access to the grid. They may also provide for pay priority access to the grid system of renewable electricity. Connection charges have to reflect the economic cost and benefits associated with the connection. This is to avoid unfairly high costs for small producers.

In this regards, the Commission recommends –see COM(2005)627- firstly, that the principles of low cost bearing and sharing should be fully transparent and no-discriminatory. Secondly, the necessary grid infrastructure development should be undertaken to accommodate the further development of renewable electricity generation. Thirdly, grids operators should cover the costs associated with grid infrastructure development. Fourthly, the pricing for electricity throughout the electricity network should be fair and transparent, taking into account the benefits and embedded generation.

3.6.1 Today’s share of Renewable Energy in the EU

The Commission Communication “The share of renewable energy in the EU” [39] was published on 26 May 2004 as a first report on the implementation of the Directive by the Member States. The report shows that Member States are not on track for meeting their national indicative targets and the Communication estimates that under current circumstances, a share of only 18 or 19 per cent will be achieved**,** not 22 as foreseen in the Directive. Only four Member States are set to meet their national targets: Germany, Denmark, Finland and Spain. Other countries have recently introduced new legislation, which could enable them to reach their national objectives by 2010. The worst performing states are Greece and Portugal, which have fallen far behind in meeting their targets.

The EU's ten new Member States are subject to the requirements of Directive 2001/77/EC on electricity from renewable energy sources. National indicative targets for the share of electricity from renewable energy in each new Member State are set out in the Accession Treaty. **Taken together, this means that, for the share of renewable energy, the collective target for the EU25 is to reach 21% in 2010**.

Overall, the Commission estimates that additional investments of 10 to 15 billion Euro are required to achieve the 12 per cent target the EU has set itself, coming from the public and private sectors alike. The Commission therefore recommends the use of the successful support mechanisms of Germany, Denmark and Spain to the other countries. This would include feed-in-tariffs, green certificates, market-based mechanisms, tax exemptions etc.

Despite widespread calls for the introduction of a more ambitious target for the share of renewables in the EU's energy mix by 2020, the Commission has decided not to do so. The Communication proposes a "thorough assessment" of calls for a 20 per cent target for 2020, but only expects to set a new target after 2010 in 2007.

The Commission is presently working to produce a first outline of a “Secure, Competitive and Sustainable Energy policy for Europe”, for the spring summit in March 2006. A comprehensive European energy strategy will be presented at the end of 2006 and, both energy efficiency and renewable energy will be major factors in such strategy [40].

3.6.2 Present positions

EURELECTRIC, the Union of the Electricity Industry, has criticised governments for providing "substantial and unlimited" subsidies for renewable energy sources [41]. The association believes that a sustainable growth in this area can only be achieved through a regulatory framework, which complies with the rules of a competitive market. In their opinion, maintaining that support schemes for RES have to be market-based, capital-efficient and designed to avoid market distortions. As foreseen in the Directive, they finally call for harmonisation of RES support schemes.

Electricity grid operators did not immediately react to the Commission report. However, in a position paper dated March 2005, the **European Transmission System Operators** (ETSO) highlighted that integrating renewable energy sources in the electricity grid is "a complex issue embracing grid extension and system stability requirements, balancing mechanisms development and their overall impact on cross border electricity transits". At the time, ETSO said further analysis was needed to assess the impact of renewable electricity on security of supply and on the influence that non-harmonised support schemes have on their integration in the electricity grid.

The **European Renewable Energy Council** (EREC) has reacted to EURELECTRIC’s position reminding that 95% of the European Internal Electricity Market is based on conventional power sources and 5% is based on renewables. EREC [42] is arguing that there are numerous distortions in the 95% conventional electricity market, and competition is far from being effective.

Regarding the EU targets, EREC has been calling for an increase in the overall renewable energy target for the EU to 20 per cent by 2020. A study carried out by EREC [43] has shown that both the overall 12 per cent target and the 22.1 per cent target for electricity production from RES by 2010 can be achieved if specific support actions are taken soon. Moreover, it estimates that a contribution from renewables to total energy consumption of 20 per cent by 2020 is possible.

EREC sees the administrative barriers and grid issues as crucial barriers to further renewables development. EREC does not find the 2007 review necessary.

The **European Wind Energy Association** (EWEA) found the recent Commission recommendations on grid access and administrative barriers in the member states "spot on". However, it found the Commission's 2007 review as "pointless" as it believes harmonisation would not allow countries to fine tune the schemes they have developed in the last few years.

Environmental groups have reacted with dismay to the Commission's latest Communication. They had called on the Commission to introduce a more ambitious long-term target for boosting the share of renewable energy to 25 per cent by 2020. In a joint letter [44] to the Commission, **WWF, Greenpeace and Friends of the Earth** argue that a long-term target is needed to strengthen investor confidence.

EUROCHAMBRES has welcomed the fact that the Commission has abandoned setting quantitative targets beyond 2010. "*In the long run this would impede effective competition in the field of renewable energies and prevent the search for the most suitable and cost efficient technologies in the Single Market*," said Deputy Secretary General Paul Skehan. "*…Furthermore, our organisation is in favour of encouraging Member States to streamline project planning and permission procedures and set up a "one stop shop" for projects.*"

The **International Federation of Industrial Energy Consumers** (IFIEC Europe) points out that it is important to keep a balance between technological progress, security of supply and environmental protection issues. The federation criticises the EU for focusing too exclusively on the development of wind power, as this is based on inconsistent and uncertain weather factors. According to IFIEC, the main concern from the consumer perspective is the issue of consistent and reliable electrical supply to meet high base load demand, and such a focus on wind energy ignores the realities of technical specifics as well as of economic security of supply.

At the **European Conference for Renewable Energy** 'Intelligent Policy Options" in January 2004 in Berlin, participants concluded that the EU should proceed without delay in setting the ambitious target of 20 per cent for 2020, but the Commission has so far been reluctant to implement this new objective.

The **International Renewables 2004 Conference** took place on 1-4 June 2004 in Bonn. Over 100 governments worldwide, who laid down specific international goals, attended it. An International Action plan is expected to mobilise billions of Euros in investments in wind, solar, biomass and geothermal energy; moreover, a shared Political Declaration has been adopted, spelling out the intention of governments to supply one billion people with energy from renewable sources by 2015.

4 Distributed Energy Resources (DER). Definitions, Barriers and Benefits.

Transmission of large flows on long distance is critical for grid safety. In case of fault of one or several elements of the system, generation unit or line, it is desirable that the grid be able to withstand transients of power, voltage and frequency. In these cases, grid safety depends a lot on generation unit performances.

As part of their daily operation, TSOs have to define specifically the unit performances they need to ensure operational safety, taking into account the large number of competing generation companies. They have to re-dispatch the power among their grid. If these performances induce additional costs for generators, TSOs have to compensate them.

The specifications for ancillary services should be harmonised, where appropriate. Depending on their proportion of the generation fleet, distributed generators, connected at medium and low voltage levels, may have a significant influence on the safety of the grid. Therefore, their participation in ancillary services and their design requirements should be examined.

Eurelectric, Task Force Power Outages 2003
Report Ref. 2004-181-0007, page 23

Just a few years ago, the expressions of Distributed Energy Resources (DER), Distributed Generation (DG), Embedded Generation, Distributed Power, etc. were known only among some specialists of technology development. Today these words are widely recognised by a large number of people involved in energy policies, technology and legislation, but there are no universally accepted definitions. It is, however, widely accepted that the use of these concepts introduces totally or partially some of the following benefits: reduces energy transmission losses -estimates of 7% in OECD countries– by helping to bypass 'congestion' in existing transmission grids; enables the use of waste heat -via CHP- improving overall system efficiency; power quality and reliability can also be enhanced; and from an investment point of view, it is generally easier to match capacity increase with local demand growth and with low capital risk

This section presents an overview of criteria, concepts and cost/benefits to connect non-central generation in the EU and the US. Definitions for DER and DG are provide alongside the definition for RES adopted in the Directive 2001/77/EC. Finally, a set of recommendations for reducing present connection barriers in Europe is briefly presented.

4.1 Definition of DER, DG and RES

Many terms have emerged over the last few years to describe power that comes elsewhere than from large power plants exporting electricity into a high voltage network. Table 4.1 shows the results of a questionnaire carried out in the EU, which shows that too many criteria are used for specific country definitions, and it is difficult to extract a common view.

Country	Brief Definition	Connection
Austria	Standardised and modular generation source using RES in a range up to MW	Up to 60kV
Bulgaria	Source less than 10MW, not centrally planned and connected to the Distribution Network	Up to 110kV
Czech Rep.	Source not operated by utility	Up to 110kV
Denmark	Source without agreement between the owner and the TSO	Up to 60kV
Estonia	Source less than 50MW for local consumption and for selling to the utility	From 6-35kV
Finland	Source less than 20MW, not centrally planned and not centrally dispatched, and connected to the distribution network	Up to 20kV
France	Electricity generation plan owned by a third party, connected to the grid	Up to 20kV
Germany	Integrated or stand-alone modular source close to the point of consumption	Up to 110kV
Hungary	Source less than 100MW using RES or co-generation mainly for heating	Up to 120kV
Italy	Co-generation less than 1MW rating and close to the end user	Up to 35kV
Netherlands	Generation not active in system balancing	Up to 150kV
Norway	Source connected to the distribution network	Up to 22kV
Poland	Electricity or heat source connected to the user	Up to 110kV
Romania	Decentralised source less than 50MW rating	Up to 20kV
Slovakia	Source less than 100MW, not centrally planned and dispatched, and connected to the distribution network	Up to 110kV
Spain	Modular generation less than 50MW located at the customer site	From 30-132kV
Sweden	Source connected to the distribution network or to the customer site	Up to 20kV
UK	Source not connected to the Transmission System	England and Wales <132kV Scotland 30kV
Ireland	The definition deals with “small generators” or “embedded generators” but not directly to distribution generation	Up to 110kV

Table 4.1. Specific “criteria” to describe the connection of distributed sources and voltage range of connection in European countries analysed in countries of origin of ENIRDG-net participants [45]

It is clear that there is no consistency among these national "criteria", in which for instance, the size varies from 100MW in Hungary and Slovakia down to less than 1MW in Italy; and connexion limits from 6kV in Estonia to 150kV in The Netherlands. With the present situation one could expect that the connection to the network of new energy producers leads to new definitions, new standards and new concepts that could be harmonised from now on. However, in spite of intensive discussions during last years, new concepts such as Decentralised production, Distributed production, Integrated production, Embedded Generation, Distributed Generation or Dispersed Generation have invaded the electricity networks literature. Among them, Distributed Generation is the concept most recognised internationally for new connections of non-central generation plants. Table 4.2 gives a short non-exhaustive inventory of existing definitions in the literature.

Organisation	Definition of "Distributed Generation"
European Commission [46]	Distributed Generation means generation plants connected to the distribution systems
DPCA [47] Distributed Power Coalition of America	Distributed power generation is any small-scale power generation technology that provides electric power at a site closer to customers than central station generation. A distributed power can be connected directly to the consumer or to a utility's transmission or distribution system.
CIGRE [48]	Distributed Generation is not centrally planned, today not centrally dispatched, usually connected to the distribution network and smaller than 50 or 100MW
IEA [49] International Energy Agency	Distributed Generation is a generating plant serving a customer on-site or providing support to a distribution network, connected to the grid at distribution-level voltages. It generally excludes wind power, since that is mostly produced on wind farms rather than for on-site power requirements.
US-DOE [50] (Department of Energy)	Distributed Generation – small and modular electricity generators sited close to the customer load – can enable utilities to deter or eliminate costly investments in transmission and distribution systems upgrades, and provide customers with better quality, more reliable energy supplies and a cleaner environment.
California Energy Commission [51]	DG is electric generation connected to the distribution level of the transmission and distribution usually located at or near the intended place of use

Table 4.2. A non-exhaustive list of definitions for Distributed Generation.

Again, there is no unique criterion for the signification of Distributed Generation (DG). Very often each organisation, association, working group or author establishes its own definition and from this definition it defines its work. The majority of documents coincide in saying that the DG concept does not correspond to all the electricity producers connected to the grid. In fact DG corresponds to those generators that satisfy some conditions. Generally, the critical parameters used in the DG definitions are:

- The location of the producer and the production system that is positioned in the customers' installations or just outside. This is the case of the definition given by the Energy Department of the United States and by the California Energy Commission.
- The second important parameter to be considered is the connection point to the network. Thus, only the energy sources connected to the distribution network and not to the transmission network constitute DG. This is the criterion employed by European Commission, CIGRE Work Group WG 37-23 and the International Energy Agency.

Based on the analysis of the different definitions described above and considering the co-generation of heat/cool of some of these "devices", which introduces additional benefits, a definition for RES, DG and DER is presented in Table 4.3. The definitions for DG and DER are based on final results of intensive discussions held during the last four years with participants in the EU-FP5 Target Action "Integration of RES and DG". They have been reported in a recent presentations and publications issued by ENIRDG-net and other projects financed by the EC-FP6. We will use them here as the reference definitions for these concepts.

Subject	Definition
Renewable Energy Sources (RES) [52]	**RES designates renewable non-fossil energy sources (wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases)**
Distributed Generation (DG)	**DG is the integrated or stand-alone use of small, modular electricity generation sources, installed within the distribution system or a customer's site by utilities, customers or any other third parties to meet specific capacity and reliability needs in applications that benefit the electricity system, specific end-use customers, or both.**
Distributed Energy Resources (DER)	**DER are Distributed Generation and demand-side measures that provide electricity, thermal and/or mechanical energy. These resources can be located on-site or nearby to users. They can be used to meet base load power, peaking power, backup power, remote power, power quality, cooling, and heating needs. DER include Distributed Generation devices and storage and interconnection equipment needed to interconnect with customers and/or the utility grid.**

Table 4.3. Definitions for RES, DG and DER

4.2 DER opportunities

The greatest potential market for DER is both displacing a large percent of the power supplied by conventional central power plants and reducing the needs for transmission and distribution infrastructures by demonstrating smaller and cheaper ways of providing electricity and, in some cases, further improving overall system efficiency and reducing emissions by using the waste heat. DER provides additional benefits to network operators and customers, as recognised by EURELECTRIC [53] after the power outages in Europe during 2002 and 2003, as well as reduced environmental impacts. The next paragraphs provide further details on these opportunities offered today.

4.2.1 The economic risk and time for permissions

DER began to undermine the justification for monopoly utility control over power generation during the mid-1980s, mainly in the US. During these years, support grew for eliminating monopoly regulation and bringing market principles back into the power sector, or restructuring. Large electricity consumers were particularly intrigued by the shift. Pointing to the cost declines resulting from the restructuring of the airlines and telecommunications industries, they pressed for analogous changes in the power generation sector. Simultaneously, the average size of a new generating unit in the US declined to 100MW in 1992 and to 29 MW in 1994 [54], roughly equal to the electrical sizes of the 1920s. Still smaller sizes, down to 10 and even 5MW – the average size in 1903 – were also beginning to emerge. (see Table 4.4).

Type of Power Plant	Year	Average Scale (kW)
Nuclear Plant	1980	1.100.000
Coal Plant	1985	600.000
Gas turbine CCP	1990	250.000
Single-Cycle Gas Turbine	2000	150.000
Industrial Cogeneration Plant	2000	50.000
Wind Turbine	2000	1.000
Micro turbine	2000	50
Residential CHP	2000	40

Table 4.4. Typical Power-Plant Scales from 1980-2000 [55].

In Europe, the gas turbines cogeneration systems and wind farms were good examples of a trend that would accelerate throughout the 1990s. From the perspective of power generation, the last decade of the twentieth century may have had more in common with the first decade than with the 80 years in-between. Independent power producers – as well as a few local/municipal utilities – were revitalising the concept of generating power at a smaller scale -e.g. cogeneration, wind or gas systems- and nearer to its ultimate point of use. Simultaneously, the responsibility for power expansion in many European countries has shifted from governmental institutions to private investors; and last but not least, a growing public resistance against large power plant projects -especially nuclear plants after the accident in Chernobyl- could be seen everywhere in Europe.

As a direct consequence of these trends at the beginning of the twenty-first century, obtaining the permission to build a big power plant today takes much longer than for building a few small ones, and the economic risks involved are much higher.

4.2.2 DER can contribute to reduction of T&D costs.

An additional benefit from DG units can be derived from the current electricity prices in present European markets. While market prices of power plants induced by fierce competition among electricity producers fell to the range of 35 to 40 Euro/MWh, the costs for delivering the electricity to the final household remained stable, ranging from 50 to 70 Euro/MWh. These T&D costs have increased by about 35% in real terms during the period from 1955-2000 and today represent more than 30% of the total electricity bill [56]. It is estimated that, with increased environmental and reliability requirements and increased personnel costs, the costs of transmission and distribution will increase continuously at similar rate in the coming years.

In addition, there is an increasing capital risk for investors in new T&D infrastructures due to the frequent delays of permissions for building new transmission lines and substations, which can take up more than 10 years -for example, a new 400kV line by the TSO Eltra in Denmark took 4 years for first planning, 6 years for getting the permit and about 1 year to build.

To break this tendency, it is expected that the focus for further development of electricity systems will lie with the reduction of transmission and distribution costs. In this line, data of present experiences should be analysed to "measure" up to which extent DG can contribute to the reduction of T&D costs. It is, however, beyond discussion, that on islands, remote areas and for heavily populated areas with restrictions on grid expansion, DER is a chance for providing reliable electricity supply systems.

DER can also offer additional value to the grid system operators by:

- Deferral of upgrades to transmission and distribution systems.
- Reduction of losses in the distribution system.
- Provision of network support or ancillary services.

4.2.3 Flexibility of operation

Many DER options are flexible in operations, size and expandability. A DER operator can respond to price incentives reflected in fluctuating fuel and electricity prices. Flexible power plants operating during peak periods may be much more profitable than conventional evaluations suggest. The flexibility of DER is difficult to assess in general but may be very important in determining its overall value.

In addition, a DER operator can expand its capacity more readily than a central generator and may do so quickly in response to a rapid increase in demand. Indeed, modular DER can be ordered and installed in weeks -an advantage already recognised by many utilities when they install gas turbines at distribution substations for example. This modularity is extremely important for rural electrification policies in developing countries.

4.2.4 The benefits for the environment

Most of DER technologies show low emissions of harmful compounds (see Figure 4.1). They can further contribute to the reduction of greenhouse gas emissions, as they are capable of matching electricity, heat and environmental demands (see Figure 4.2), as well as contributing to the reduction of import dependence and energy efficiency.

4.2.5 Benefits for the customer

The integration of DER will be accompanied by the proliferation of smart meters, which will measure the flow of electricity in real time, negotiate on-line prices and vary electricity rates accordingly. The interaction with the customer in the future will open new business for the utilities and key economic incentives for the customers.

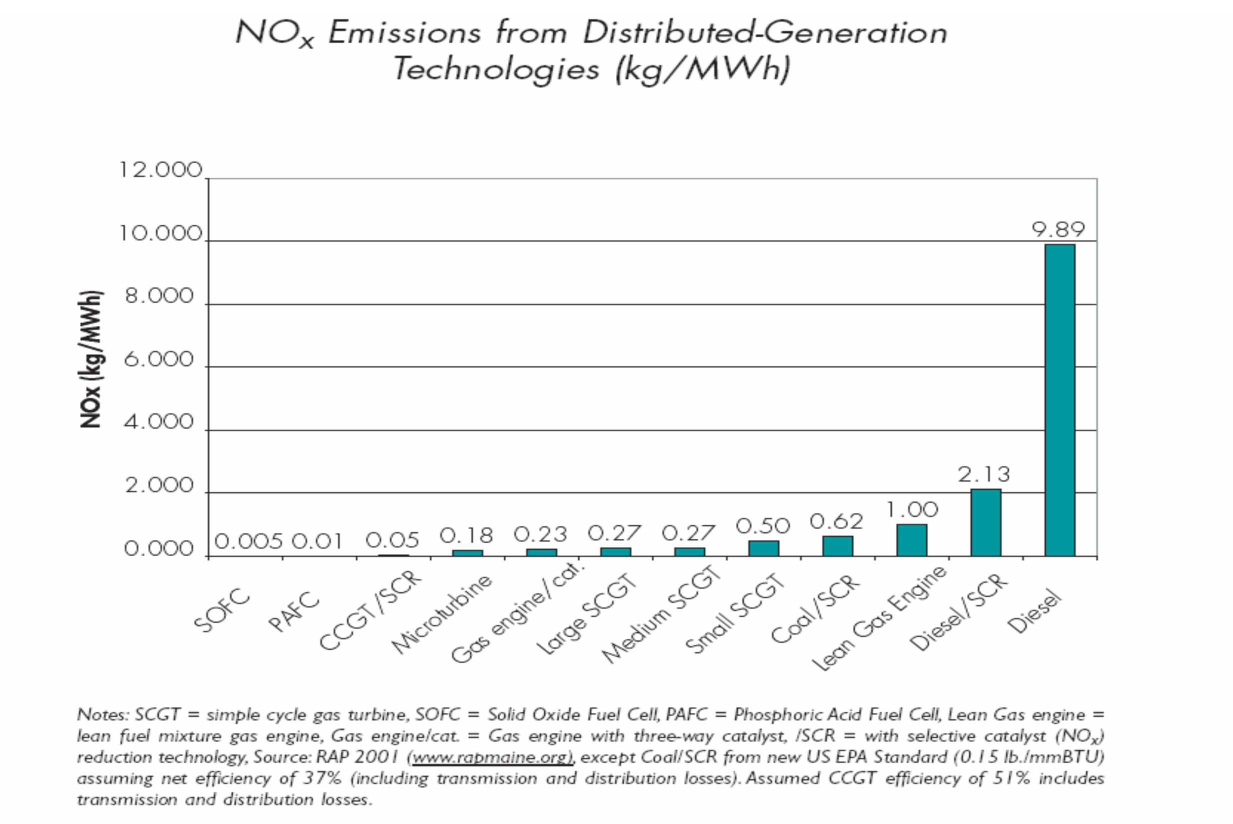
Another advantage from the customer point of view, is the fact that DER provides the possibility of optimising power use and power generation in an integrated way; of increasing the security of supply; and of having an alternative to the volatility of electricity market prices. Another advantage for customers with sizeable heat load is the economical production of both heat and power economically, using low-cost fuel as landfill gas and local biomass.

After price, reliability is the most important consideration in switching electricity suppliers: DER can indeed provide customers with continuity and reliability of supply by restoring power in a short time after an outage. This is extremely important for companies that have a continuous manufacturing process or strong links with the “digital economy” -cellular communication, airline reservations, credit card operations, etc.- for which outages from the grid would be very expensive.

4.2.6 The benefits for the power supply industry

DER offers strong business opportunities not only for power utilities and energy service companies. As already discussed in Section 3, at global level there are huge global market opportunities for DER and companies that develop and sell these technologies, including all the renewable energy technologies. They can develop their business for the European and worldwide market.

Finally, to sum-up what the potential benefits of DG in the US context are, let have a look at the results of a meeting of the US stakeholders in Distributed Generation sponsored by the DOE in December 1998 in order to describe the challenges of DER. Results were summarised in the following eight hidden benefits of Distributed Generation [57], which clearly describes the American context for DER. Based on discussions in previous paragraphs, we can conclude that these benefits might be also valid for Europe up to certain extent.



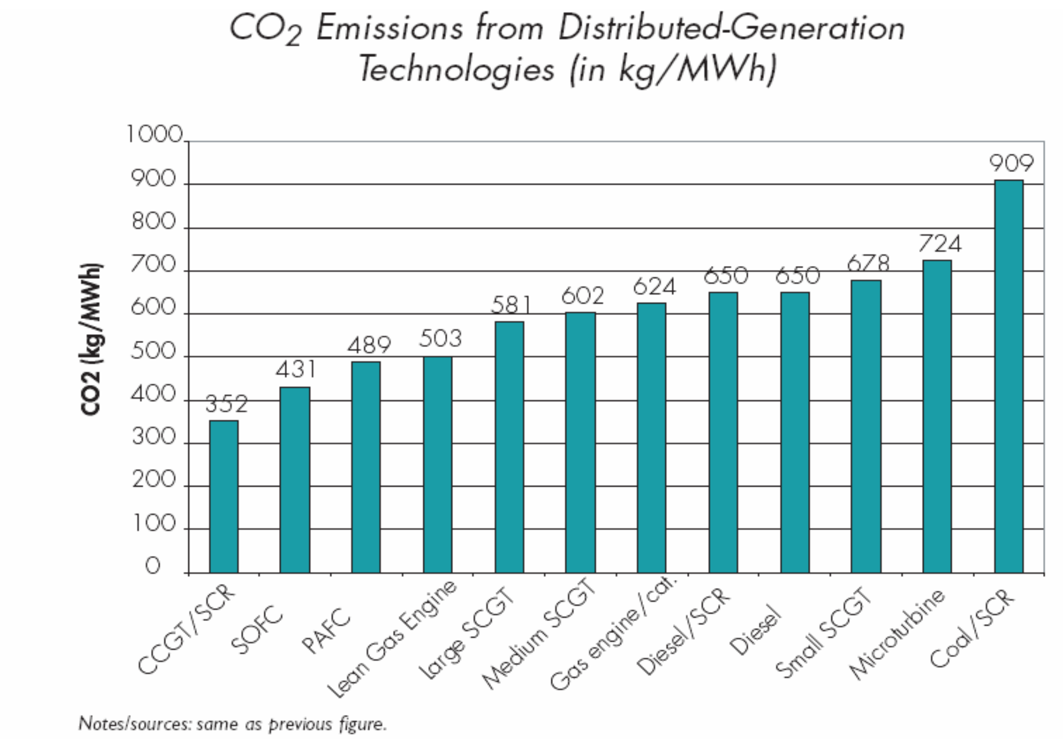


Figure 4.1. NOx and CO_2 *emissions of DG Technologies as compared to Coal Power. Source: International Energy Agency. "Distributed Generation in Liberalised Electricity Markets". OECD /IEA 2002 pages 88-91. The emissions are given per unit of electric power delivered to the user; however, total emissions figures for CHP will be further reduced if the use of heat is considered.*

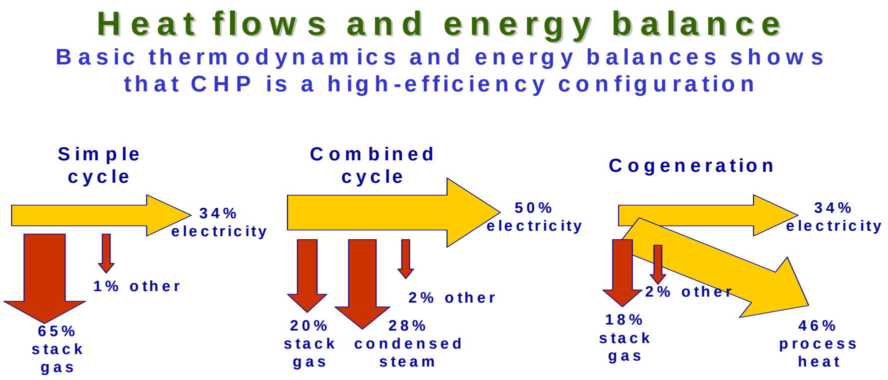


Figure 4.2. This basic schemes outline indicative energy flows of simple cycle, combined cycle and cogeneration configurations. In a simple cycle peaking configuration, only about 34% of the energy results in electricity; the rest is wasted. In a combined cycle configuration the waste heat is captured and converted to steam for additional power output. Once that steam has been through the steam-turbine though, it has to be condensed back to water, resulting in a loss of efficiency. In this configuration ,about 50% of the heat flow results in electricity. With cogeneration, the waste heat and its use in industrial process is possible; resulting in a reduced used for boilers, and the fuel that goes with those boilers, achieving a total efficiency of almost 80%, or about twice that traditional methods. If the heat can be used directly in process heat applications – e.g. furnaces- the efficiencies are even higher.

The eight hidden benefits of Distributed Generation	
Modularity	Adding or removing units can adjust DG system size to demand.
Short lead time	Small-scale power can be planned, sited and built more quickly than layer systems, regarding the risks of overshooting demand, larger construction periods, and technological obsolescence.
Fuel diversity and reduced price volatility.	DG's more diverse, renewables-based mix of energy sources lessens exposure to fossil fuel price fluctuations.
"Load-growth insurance" and load matching.	Some types of small-scale power such as co-generation and end-use efficiency, expand with growing loads; the flow of other resources, like solar and wind, can correlate closely with electricity demand.
Reliability and resilience	Small plants are unlikely to all fail simultaneously, they have shorter outages, are easier to repair, and are more geographically dispersed.
Avoided plant and grid construction and losses	Small-scale power can displace construction of new plants, reduce grid losses, and delay or avoid adding new grid capacity or connections.
Local and community choice and control	DG provides local choice control and the option of relying on local fuels and spurring community economic development.
Avoided emissions and other environmental impacts	Small-scale power generally emits lower amounts of particulates, sulphur dioxide and nitrogen oxides, heavy metals and carbon dioxide, and has lower cumulative environmental impact on land and water supply and quality.

4.3 Potential costs and present barriers of DER

DER holds great promise for improving the electrical generation, transmission and distribution systems in ways that strongly support the primary energy efficiency and renewable energy goals of the Union. However, overlaying a network with small, non-utility owned generating facilities on a grid develop around centralised generation requires innovative approaches to planning, managing and operating the utility distribution systems.

Therefore, the benefits described above are accompanied by potential costs that are not regulated today. These costs have been studied in a number of FP5-projects, such as SUSTELNET [58], DISPOWER [59] and WILMAR [60]. Table 4.5 gives a brief summary of these "existing" new integration costs, which are distributed differently to the actors of the electricity system in the different European countries. ETSO [61] and WILMAR have recently analysed the legislation and regulation practices in place in about 20 countries, including all Nordic countries, Germany, Spain and United Kingdom. According with their analysis, the following conclusions are remarkable:

- Obligations for the TSO and DSO to connect and share costs to integrate DER are in place in all European countries, but the connection is refused in one quarter of the cases due to technical or economical reasons. As an example to illustrate these costs, typical connection costs are 12% and 20% of the total investments costs for, respectively, on-shore and off-shore wind farms with 150MW and situated 20 km from the shore and further 20 km to the nearest HV-substation.
- Depending on the different national rules different parties are responsible for providing the balance power. In case the TSO has to contract it, the costs will be included into the tariff and, finally, be paid by all customers.
- Regarding the grid reinforcement, both surveys conclude that rules for sharing costs are not harmonised in Europe.

Similar analysis was reported in July 2000 for the US case [62]. The main conclusions can be summarised as follows:

- **Technical barriers** consist principally of utility requirements to ensure engineering compatibility of interconnected generators with the grid and its operation. Such requirements added $1200 or 15% to the cost of a 0.9 kW PV project, for example, plus an additional $125 per year for relay calibration.

- **Business-practice barriers** arise from contractual and procedural requirements for interconnection and, often, from the simple difficulty of finding someone within a utility who is familiar with the issues and authorised to act on the utility's behalf. This lack of utility experience in dealing with such issues may be one of the most widespread and significant barriers to Distributed Generation, particularly for small projects. Other significant business-practice barriers include procedures for approving interconnection, application and interconnection fees insurance requirements, and operational requirements. Many project proponents complained about the length of time required for getting a project approved (more than 25% of the cases had delays greater than 4 months), leadings to prohibitively costly approvals.

	Description of potential costs	
Network related	Distribution capacity cost deferral	The development of small-scale DER facilities near a load can postpone necessary investments in additional distribution and transmission capacity. DSOs can benefit from these new DG facilities. These costs differ from location to location and placing.
	Connection costs	The connection of DER to the distribution network incurs expenses regarding connection lines and grid upgrade, depending on the location of the DER facility, the voltage levels and the possibility to apply standardised equipment.
	Metering costs	Metering of DER production presents a cost that is allocated outside the network, and can be attributed to the DG operator. The costs for a management and control system that automatically collects metering data and provides control signals to the DER plants should, however, be attributed to the DSO.
	Avoiding overcapacity	Avoiding overcapacity or at least reduction of reserve margins compared to more centralised systems. In traditional power systems, increasing demand of electricity is solving by installing a new "central" power plant. In today's market environment, the over-dimensioning of power may be a risk investment. Small-scale DER plants are better equipped to respond to short-term demand changes.
	Network upgrade	Network upgrade investments should be shared proportionally to the DER operator and other network users.
	Transaction costs	Transaction costs are the costs other than the price that are incurred in trading good or services. They can split up into a large number of different costs that may occur before the actual trade can take place or even after the business transaction. For example, search and information costs, bargaining and decision costs, etc.
Energy related	Reserve capacity costs	When installing a large capacity of intermittent DER facility (e.g. wind, PV, etc) a certain backup of power needs to be available. This can be another DG, as a CHP plants, which contributes to the reserve capacity.
	Balancing costs	There might be a need for additional balancing power because of the intermittent character of some DER. Generally, the ability to balance the distribution system depends on the way that a DER generation facility is controllable and can present a burden or a benefit to the distribution system.
	Control costs	Local or other hierarchical control is needed in order to guarantee a minimum level of integration into the network.

Table 4.5. Brief description of cost created by DG to the electricity system

- **Regulatory barriers** were principally posed by the tariff structures applicable to customers who add Distributed Generation facilities, but included outright prohibition of "parallel operation" –that is, any use other than emergency backup when disconnected from the grid. The tariff issues included charges and payments by the utility and how the benefits and costs of Distributed Generation should be measured and allocated. Backup or standby charges were the most frequently cited rate-related barrier. Unless Distributed Generation customers want to disconnect completely from the grid and invest in the additional equipment needed for emergency backup and peak needs, they will be depending on the utility to augment their onsite power generation. Charges for these services varied widely -standby charges ranged from $53/kW-yr to $200/kW-yr for projects located in New York, for example.

This DOE study carried out in 2000 and one EC-sponsored survey done in March 2004 [63] with European customers, vendors, and developers of these technologies over 14 Member States showed that similar technical, business practice, and regulatory barriers are the principal obstacles for DER on both sides of the Atlantic.

Based on all the above information collected in the EU, the following findings about current barriers to the interconnection of distributed power generation projects:

- There is no national -nor European- consensus on technical standards for connecting equipment, necessary insurance, reasonable charges for activities related to connection, or agreement on appropriate charges or payments for DER.

- Many barriers in today's marketplace occur because utilities have not previously dealt with small-project or customer-generator interconnection requests.

- DER project proponents faced with technical requirements, fees, or other burdensome barriers are often able to get those barriers removed or lessened by protesting to the utility, to the utility's regulatory agency, or to the public agencies. However, this usually requires considerable time, effort, and resources.

- DER project proponents frequently felt that existing rules did not give them appropriate credit for the contributions they make to meeting power demand, reducing transmission losses, or improving environmental quality.

- Lengthy approval processes, project-specific equipment requirements, or high standard fees are particularly severe for smaller Distributed Generation projects.

- Official judicial or regulatory appeals were often seen as too costly for relatively small-scale Distributed Generation projects.

It is also evident that the above-mentioned barriers exist for all Distributed Generation technologies and in all the Member States, and that they prevent DER projects from being developed in the EU.

Industry and regulatory officials in the EU -and also in the US- are beginning to examine the nature and extent of these barriers and to debate on the appropriate responses. In Europe, the **Technology Platform for the Electricity Networks of the Future** [64] began these discussions in May 2005 with a wide range of stakeholders, including the European Commission.

4.4 Recommendations to overcame or reduce barriers

Based on the above-mentioned studies on both sides of the Atlantic, and anticipating the results of the Technology Platform in Europe, ten recommendations to reduce barriers to DER are proposed in the following sections, grouped according to the three main issues encountered above: technical, business and regulatory issues.

4.4.1 Technical barriers.

Adopt technical standards for interconnecting DER to the grid. It will be necessary to develop standards for the interconnection of DER to electrical power systems with the scope of keeping or improving –if necessary- the existing power quality and reliability of the grid. This will ensure that generation equipment and the associated interconnection devices meet the standards.

Technological improvements. Standard interfaces should suit the requirements of grid and procedures. In general, all devices should be standard and flexible –adaptable to the characteristics of the different sites and modular design. Both the improvement of DG/RES technologies and of their ancillaries –weather forecasting, tools, protections, logistics of biomass, etc.-should bring more reliable and cheaper devices.

Use of enabling technologies as Storage, HTS and ICT. A generalised use of ICT and HTS will provide the basis for active networks management (see more details in section 6.2) and for possible real time and other market issues. Storage technologies should also be adapted for widespread use as they allow improvement of power quality and provide the possibility to reduce required reserved power to balance the RES intermittent behaviour.

4.4.2 Business Practice Barriers

Involvement of grid owners and operators. It is very important that grids owners and operators contribute to the development of a grid in which DER will be more and more present. To achieve it, they must update their working methods and structures, and the concept they have of the electricity grid. They should train their operators and define procedures to select the optimum interconnection site.

Training. Training is necessary in all sectors related to DER to overcome the present lack of experience.

Reduction of bureaucracy. Establishing procedures for DER project proposals will favour the access of clients to DER, especially the smallest ones and will help to reduce bureaucracy.

No discriminatory practices from distribution companies. Companies in charge of the distribution grid should not give fewer options to external promoters in favour of promoters of the same company or group. It is also very important to clarify and agree on who should pay for the modification of the grid for an increased DER penetration.

Inform society about RES+DG benefits. Local opposition has hampered some RES and/or DG projects in the past. Agreements with social and environmental organisations should be promoted, especially for joint information and dissemination campaigns.

4.4.3 Regulatory Barriers

Promotion of RES+DG. Benefits of RES and DG technologies must be recognised and paid, according to their overall value and benefits.

Improvement in regulatory aspects. The principle of proportionality should be applied for DER. It implies that relevant law must be more simple, clear and similar in all Member States. A definition of obligations and rights of DER promoters would be very useful in order to avoid arbitrary practices from the grid owner.

5 Challenges for 2020 and beyond

The present environment is fighting to obtain maximum optimisation of existing energy resources that would lead to sustainable development. In this respect, the integration of renewable and Distributed Generation with conventional energy and centralized generation, is a step forward in the path to obtain the sustainable development to which whole society must be committed.

Javier Villalba Sánchez, Iberdrola General Manager
Final Report ENIRDG-net. December 2004

Significant amounts of DER of various technologies, particularly wind, have been installed in the EU during the last decade. Indeed, many research projects in the EU-FP4 and 5, such as MED-2010 [65] and REMAC [66] have been focusing on developing techniques to accelerate the deployment of DER, generally based on the "connecting" approach, and rightly so as this has been a necessary phase in the evolution towards a sustainable electricity system. However, levels of DER penetration in some parts of the EU are such that DER is beginning to cause operational "problems". We are now entering an era where the present approach to connecting DG is beginning to adversely impact the deployment rates of DER, increasing the costs of investment and operation and undermining the integrity and security of the system.

In order to address this problem, DER must be integrated into system operation and development, taking over the responsibilities from large conventional power plants and providing the flexibility and controllability necessary to support secure system operation. Although TSOs have historically been responsible for system security, integration of DER will require DSOs to develop "active" network management in order to participate in the provision of system security. This represents a shift from traditional central control philosophy, presently used to control typically hundreds of generators, to a new distributed control paradigm applicable for the operation of hundreds of thousands of generators and controllable loads.

The fact that many of today's networks have an ageing infrastructure cannot be managed as a one-off issue since asset replacement is a rolling activity. Considering this inertia of the present system, a reasonable time horizon for new scenarios is 2020 and beyond. In the longer term Europe has a vision of a sustainable energy system where clean hydrogen and electricity act as the two main energy forms with fuel cell technology providing the bridge between them.

5.1 The global challenge for electricity networks beyond 2020

By 2050, the World Energy Council envisions the global energy mix to be made up of at least eight different sources (coal, oil, gas, nuclear, hydro, biomass, wind and solar), none of which is expected to have more than a 30% share of the market. Only electricity can make this diverse supply portfolio possible while concurrently meeting global energy and environmental demands. Ultimately, the energy portfolio strategy is expected to result in an electricity/hydrogen energy system capable of providing globally abundant, clean and low-cost energy.

In the coming decades, electricity's share of total energy is expected to continue to grow from 24% in 1970 to 40% in 2020 (IEA estimation for OECD countries), as more efficient and intelligent processes are introduced into industry, business, homes and transportation. Moreover, the IEA predicts that about 650 GW of capacity will be needed in the EU15 over the next 30 years, of which 330 GW are needed just to replace existing capacity. Over one trillion dollars in power infrastructure is needed equally divided between generation (525 billion) and networks (transmission 120 billion and distribution 413 billion)[28]. Worldwide, these numbers are one order of magnitude higher, but the ratio between generation and investment needs for transport remain very similar.

Electricity networks are essential for the achievement of the strategic energy policy objectives of the European Union. A functioning Single Market for electricity and a secure supply of energy can only be achieved with an adequate and reliable electricity network. Furthermore, the large-scale deployment of the majority of environmentally-friendly energy efficient technologies, like renewable energies, combined heat and power, stationary fuel cells, etc and –in the long term- hydrogen, will depend on an adequate electricity infrastructure.

Many factors are converging to stretch to the limit the reliability of the electricity infrastructure: market liberalisation, increase in demands, intermittent wind energy, etc. are all challenges that today's networks -originally designed in the 50s in a context of state monopolies- are not designed to handle properly. The recent blackouts, both in Europe and in the US, are a sad reminder of these inadequacies.

There are several aspects that need to be fully understood in order to obtain maximum benefits from both DER and the power grid, mainly:

- The distribution network and DER are interacting and actively affecting each other.
- No generic conclusion can be made regarding the influence of DER on the grid, as various power sources have quite different characteristics. Instead, individual cases have to be treated separately.
- Both DER and the grid should be studied as one integrated, flexible, dynamic and complex structure. To a large extent, they do have a major impact on operation, control and stability of each other.

[28] Figures given in the OECD/IEA publications: "2003 World energy Investment Outlook" and "World Energy Outlook 2004" p.72. It should be noted that Eurelectric has reported similar figures, but a little lower than these (see section 3.1.2.2).

Among other problems to face in the near future, several experts have addressed the issue of growing DER levels in existing distribution networks [67]. They argue that if the penetration level of Distributed Generation continues to grow while the distribution grid remains unchanged, a chain of technical conflicts may develop, unless such issues as operation, control, and stability of distribution networks with DER installations are properly addressed.

The recent DENA [68] and present experiences in Western Denmark [69] study shows that many of these network constraints can be solved to a certain extent when the capacity of the distribution network is reinforced. But from an economic point of view, this is not very attractive as it concerns long-term investments; neither from a technical nor strategic point of view, network optimisation and cutting down consumption with energy-saving measures in housing should be further investigated and developed.

For the context of this paper, the following two possible scenarios can be expected for 2020:

Connecting DER Scenario. If DER are not integrated into system operation, conventional generation will continue to be necessary for the provision of system support services (e.g. load following, frequency and voltage regulation, reserves) required to maintain security, stability and integrity of the system. This implies that a large penetration of DER will not be able to displace the capacity of conventional plants. Moreover, given that a significant proportion of DER is likely to be connected to distribution networks in the coming years, maintaining the traditional passive operation of these networks and centralised control will necessitate an increase in capacities of both transmission and distribution networks.

On the other hand, the ***full integration of DER scenario*** is based on the integration of DER into network operation, i.e. covering the responsibility for delivery of system support services taking over the role of central generation. In this case DER will be able to displace not only energy produced by central generation but also its controllability, reducing the capacity of central generation. In countries with a large share of DER connected to the distribution network, such as Denmark and the Netherlands, it is already recognised that distribution networks should no longer be considered as passive appendages to the transmission network, but the whole network must be operated as a closely "integrated" unit. It's becoming more and more clear that conditions for central and local electricity production must be equalised bringing all power plants to contribute to system stability and flexibility. To achieve this, distribution networks operating practices will need to change from passive to active, shifting from the traditional central control philosophy to a new distributed control paradigm which includes significant contribution of **demand side management (DSM)** and **demand response resource (DRR[29])** techniques needed to enhance the control capability of the system.

The evolution of the total system capacity and relevant investment needed for these two scenarios could be represented as shown in Figure 5.1. In the short term, change in control

[29] DRR programs are the successors of DSM programs, which have been in the utility industry for some 20 years. A fundamental difference between DRR and DSM is the interaction with the consumer. In DRR-programs the emphasis is on consumer-action as opposed to utility control room action. An important aspect in the role of DRR is the associated information technology to settle contracts in liberalised markets. DRR can be considered to be a means of selling something you do not want to consume immediately. DRR-markets are currently in the construction phase worldwide; the largest programmes being in the US (NY: 1531 MW with 1419 customers) and South Korea. Initiatives are being initiated in Norway, Spain, Italy Australia and New Zealand and an IEA-subtask in "Demand Side Management" programme has found worldwide support.

and operating philosophy of distribution networks is likely to increase costs over the "connecting scenario" to cover research, development and deployment of new technologies and required information and communication infrastructure. However, in the medium to longer term, "full integration" of DER and DSM/DRR techniques via distributed control philosophy will deliver benefits over the "connecting scenario" as suggested in the figure[30].

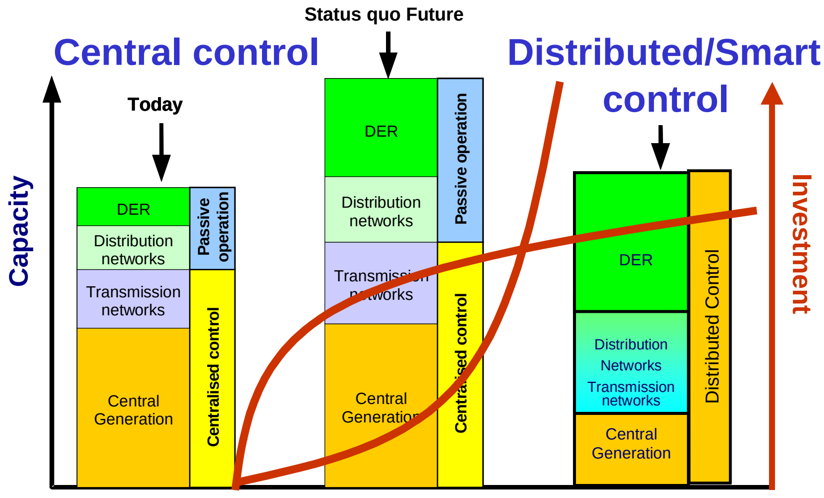


Figure 5.1. Possible trajectories of future development options of the system. The full integration scenario can reduce installed capacity and investmentin the medium to longer term.

To illustrate the present situation, in 2004 alone these small-scale, low-or no-carbon sources added nearly six times as much as net generating capacity and nearly three times as much electricity production as nuclear power did worldwide. By the end of 2004, the global installed capacity of DER totalled roughly 411 GW –12% more than nuclear plant's 366 GW, and produced about 92% as much electricity [70]. But, much as personal computers did not realise their full potential before they were linked together in the Internet, DER will provide their maximum value when they are integrated together into the future energy system.

5.2 DG and RES. Technology status and challenges.

As already described in previous chapters, the 20th century started as a coal-and steam –based economy and was transformed into oil-and electricity-based one. Recognising that oil and natural gas reserves may be depleted in some decades and the coal reserves in a few

[30] We are aware that still many analysts remain sceptical that mass-produced of small-scale generators can provide a major alternative to large central power plants. Similar doubts were observed among railroad owners confronted with the early automobiles, and among mainframe computer manufacturers facing the first personal computer.

centuries and, also recognising increased environmental concerns, not least about global warning, there is a vision to reach an electricity-and hydrogen-based economy well before the end of the 21st century.

However, in the meantime we need to make better and more efficient use of existing fossil resources –the energy endurance, which is focused on integration of distributed energy, CHP and renewables.

Several studies have been carried out during the last years to evaluate the current state-of-the-art and trends of the technologies used for DER towards 2020 and 2030.[31] This section presents an overview of the various DER technologies in the interlinked future energy system, which should have a mix of local and central production and close coupling between supply and end-use.

5.2.1 Combined Heat and Power (CHP)

CHP plants use their fuels for the production of both electric power and heat and therefore operate at high efficiency. Compared to traditional boiler plants or conventional electricity production, CHP can save around 30% on primary energy consumption. In addition this leads to a reduction in CO_2 emissions of roughly 0.5 kg per kWh of electricity produced. CHP is especially useful for consumers with a continuous and steady heat demand.

In the EU, CHP accounted for 72 GW of capacity and 11% of total electricity generated in 1998 although regional penetration was not uniform with 80% of total CHP installed in industry. Most CHP currently installed is large (>10 MW), and growth in the smaller scale applications is slow but may be set to rise, in particular for commercial applications involving reasonable cooling loads and as micro-CHP for domestic use is commercialised. Europe has a target of 18% of electricity produced by CHP units by 2010.

5.2.2 Reciprocating engines

Reciprocating engines include two technologies of generators:

- Compression ignition engines (90% of the market), using diesel fuels (30- 250 kW)
- Spark ignition engines (10% of the market), using gaseous fuels (250 kW - 1 MW).

Since reciprocating engines have the lowest installation costs among DER technologies (300-900 €/kW), this technology represents the most common current form of DG installed capacity. The OECD survey reported on orders for 16.2 GW of reciprocating engines (1 - 30 MW) between June 2000 and May 2001. COGEN Europe reported that 33500 units were installed worldwide in 2002. Assuming a payback period of 10 to 15 years and without

[31] There is a large number of documents generated during last years about RES and DG technology trends for 2010, 2020 and beyond. Three main data sources have been used in this section: the Commission White Paper entitled “An Energy Policy for the European Union”, published in December 1995; the International Energy Agency “Renewables for Power Generation; Status & Prospects”, published in October 2003; the final publishable report of EU-FP5 project ENIRDG-net, entitled “European Network for Integration of Renewables and Distributed Generation. Addressing barriers to sustainable electricity supply”. Iberdola, Bilbao 2004; available at http://www.dgnet.org

considering the benefits provided by heat recovery, the cost of the energy produced by a 150kW plant with load factors of 10, 50 and 100% respectively ranges from 0.11 to 0.15 €/kWh, from 0.06 to 0.08 €/kWh and from 0.05 to 0.07 €/kWh, which are attractive prices compared to conventional generation costs in a large number of cases.

Engines are used over a wide range of output from small units of 1 kVA to about 10 MW and are usually fuelled by diesel or natural gas. With modern emissions control technology they can achieve low environmental impact and can be run with biomass-derived fuels. Operation in a CHP mode is possible using heat recovery. Typically used for continuous or backup emergency power, they have operational characteristics including fast start-up and controllable power output.

The R&D priorities are thus to:

– increase the fuel-to-electricity conversion efficiency to a target of 50%
– improve the combustion strategy to reduce the polluting exhaust fumes
– develop engines with dual fuel capabilities

5.2.3 Small hydro

Hydroelectric is, from a global perspective, the most important RES. The global annual exploitable capacity exceeds 14000 TWh of which some 2500 TWh is utilised. Small hydro plants (10 MW or less) contribute more than 37 TWh per annum or 2.5% of the European electricity market. This technology has thus proved to be the most reliable and cost effective renewable energy source with an electricity price ranging from 0.02 to 0.19€/kWh depending on the site conditions, maintenance cost (typically low) and initial investment cost on the basis of a payback period of 10 to 15 years.

Modernisation, reconditioning and exploitation of new sites will mean that around 50% of the remaining small hydropower sites in Europe will be exploited by 2015. Hydropower has the potential to become more economically attractive via improved turbine designs and cost effective plant construction in combination with new technologies for control and operation and optimising generation as part of integrating water management systems. From an operational point of view, a hydropower station can start very fast and the power output can be controlled accurately, which is an important asset. However, to exploit such potential, many administrative barriers should be overcame during next years.

5.2.4 Micro-turbines

Gas Turbines of all sizes are widely used in the power industry. Small turbines of 1 - 20 MW are commonly used in CHP applications. Gas Turbines of less than 30 MW account for 4.3 GW of capacity ordered worldwide between June 2000 and May 2001 according to an OECD survey.

Micro-turbines operate on the same principles as conventional Gas Turbine but they work at extremely high rotational speed. Individual units are rated at 30 - 200 kW and can be readily combined into multiple units. Low combustion temperatures lead to low NO_x emissions.

The micro-turbine is a reliable, environmentally beneficial solution for power generation and can be used for peak saving standby power, UPS and other applications.

Micro-turbine technology is relatively recent, with only around 3000 units installed worldwide. Due to immaturity of this technology, the investment cost for a system using a micro-turbine is too high (1000-1200 €/kW) to compete with reciprocating engines.

The efforts in the industry aim to design, develop, test and demonstrate a new generation of cleaner, more reliable, more durable and cheaper micro-turbines. To achieve this end, the R&D goals are to:

- Increase efficiency up to 40%;
- Increase durability;
- Reduce the capital cost to below 500 €/kW;
- Develop fuel flexible systems to use natural gas, diesel, ethanol as well as landfill gas and other biomass-derived liquids and gases.

5.2.5 Stirling engines

Stirling Engines are external combustion engines. They require very little maintenance, are non-fuel specific and have high efficiencies. They are also capable of being very small but are currently very expensive. They can operate at a wide range of temperatures, from above 100 ºC to almost 800 ºC. Some interesting applications using dishes as solar concentrators have been reported during last decade [71]; but their potential economic exploitation is limited to sunny countries.

For domestic applications using any heat source, as such as solid-biomass, bio-gas, etc, Stirling engines are the subjects of increased research activity and they might reach its large potential market during next few years.

5.2.6 Wind energy

In 2004[72], the global wind power industry installed 7,976 megawatts (MW), an increase in total installed generating capacity of 20%. Global wind power capacity has grown to 47317MW. The countries with the highest total installed wind power capacity are Germany (16629 MW), Spain (8263 MW), the United States (6740 MW), Denmark (3117 MW) and India (3000 MW). A number of countries, including Italy, the Netherlands, Japan, and the UK, are above or near the 1000-MW installed.

Europe continued to dominate the global market in 2004, accounting for 72.4% of new installations (5774 MW). Asia had a 15.9% of installation share (1269 MW), followed by North America (6.4%; 512 MW) and the Pacific Region (4.1%; 325 MW). Latin America + the Caribbean (49 MW) and Africa (47 MW) had a 0.6% market share respectively. A US survey estimates a global market size of $ 49 billion by 2012.

An assessment of resources in Europe has identified a capacity of some 1000 TWh per annum. The largest current wind turbines can deliver up to 4.5 MW with typical commercial installations rated at 1.5 - 2.5 MW. The current global market for wind turbines is of some 3 billion Euros per year and growing strongly.

In 2003, the European Commission estimated that wind energy will be the main contributor to meeting the 2010 targets for renewable electricity in the European Union. The major issues of wind power integration are related to: changed approaches in operation of the power system, connection requirements for wind power plants to maintain a stable and reliable supply, extension and modification of the grid infrastructure, and influence of wind power on system adequacy and the security of supply.

In Denmark, the country in the world with the highest actual penetration of wind power, 21% of total consumption was met with wind power in 2004. In the west-Denmark transmission system, which is not connected to the eastern part of the country, some 25% of electricity demand is met by wind power in a normal wind year and, on some occasions, the wind has been able to cover 100% of instantaneous demand. Recently, experience with wind power in the areas of Spain, Denmark, and Germany that have large amounts of wind power in the system shows that the question as to whether there is an upper limit for renewable penetration into the existing grids will be an economic and regulatory rather than a technical issue. According with the EWEA [73], wind energy provides less than 3% of European power needs, but is capable of delivering 12% by 2020 and in excess of 20% by 2030 without posing any serious technical or practical problems.

Operation of a large geographical spread of wind power will reduce variability, increase predictability and decrease the occurrences of near zero or peak output. Power systems have flexible mechanisms to follow the varying load and plant outages that cannot always be accurately predicted. A European super-grid should be developed to bring large amounts of wind power to European consumers, similar to the way European gas pipelines have been constructed. As an example of the trends in this line, the European Commission has suggested that a European policy for offshore wind energy may be needed. Furthermore, in October 2005 policy makers, NGOs and industry from a number of European countries signed the Copenhagen Strategy which *"calls on the Council of Ministers to ask the European Commission to initiate a policy for offshore wind power, in the form of an Action Plan for offshore wind power deployment"*:

Regarding research, certainly there is great need to increase funding to both short-term and long-term R&D in wind energy development at national and European level, in order to further develop onshore and offshore technology, enable the integration of large-scale renewable electricity into European energy systems and maintain European companies' strong global market position in wind energy technology. Specifically on grid integration of wind energy, more research is needed in the following areas:

- Improved forecast methods;
- Methods for investigating dynamic interaction between wind farms and power system;
- Transmission network studies on transnational level;
- Uniform methods for national system studies for balancing (reserve capacities and balancing costs);
- Investigation of solutions to increase power system flexibility;

– Systematic output monitoring to validate theories on capacity credit

According with EWEA, this should be facilitated by the establishment of a Wind Energy Technology Platform under the 7th EU Framework Programme for research.

5.2.7 Biomass

Biomass is the most widely used renewable source of energy in the world. Biomass resources such as forestry and agriculture crops, biomass residues and wastes provided almost all-global energy two centuries ago; and still it provides 14% of the world primary energy supplies. The products range from a simple log, to a highly refined transport fuel. The choice of product may be affected by the quantity and cost of biomass types available, location of fuels and users, type and value of energy services required, or other co-products. It may also look at the carbon and energy balance of the process, the political support, the financial performance or the social impact. In each case a different combination of factors may be considered highest priority.

In the EU, Biomass currently contributes around 5% of energy supply; predominately in combined heat and power applications in unit sizes of 10-30 MW. Future trends for electricity generation plants are likely to be towards larger unit sizes of 50-100 MW and increased efficiency. New technologies, including biomass-integrated gasification combined cycled are increasing the efficiency of biomass generation for electricity. Efficiencies of up to 80% are possible in CHP operations. Multi-fuel operations are likely to be enhanced, in particular as the results of incorporating biomass use into CHP installations. New sustainable biomass technologies such as bio-refineries are also being developed, especially to produce biofuels for transport.

But Biomass offers opportunities for additional value to be derived from products already in the economy. The dispersed nature of most biomass resources lends itself to smaller scale operations of up to a few tens of MWs, which are within the capability of communities to feed and operate, creating and retaining wealth within the local economy. It has important direct benefits, such as economic growth through business earnings and employment, import substitution with direct and indirect effects on GDP and trade balance, security of energy supply and diversification. Other benefits include support of traditional industries, rural diversification and the economic development of rural societies. These are all important elements of sustainable development, which in many cases, the national/regional exploitation of biomass's full potential primarily depends on national/regional policy rather than on technology development.

5.2.8 Photovoltaic energy

In the last five years, global production of electricity from PV has increased by about 35%, and the total installed PV capacity is now about 3100 MW. Worldwide PV sales could reach 6 GW by 2010 with an important portion for decentralised power generation. World cell production increased by 60.5% in 2004 to reach 1194 MWp, i.e. the equivalent of 400000 systems with average capacities of 3 kWp. In 2004, and similar to the previous year, module prices of 3,5 to 4,5 $/Wp appear achievable in the majority of countries, and nearly all of the major markets, with indications that the lowest achieved prices of modules are somewhat higher than in 2003. The trade balance of PV production (on a net basis) shows some interesting regional aspects in 2004 – the US produces a significant excess of silicon feedstock material, with Europe and especially Japan showing a need for product; Australia, and Japan to some extent, rely on wafer imports; Europe shows a deficit of cell production relative to module production. One US survey estimates the market for PV equipment in 2012 to be of $ 27.5 billion.

In the EU alone, a new record with a figure of 410.5 MWp was achieved in 2004,of which approximately 363 MWp were installed in Germany. This growth has made Germany the largest photovoltaic market in the world ahead of Japan (280 MWp installed in 2004) and the USA (90 MWp). Taking these new trends into consideration, European installed capacity forecast for 2010 amounts to 4500 MWp (vs. a goal of 3000 MWp in the White Paper - COM(96)682 final). This estimate [74] is based on 20% growth in the German market in 2005 and 2006 followed by stabilisation until 2010. This growth also supposes that the photovoltaic industry will be able to ensure its silicon supplies with the manufacturers of this semiconductor. The recent German renewable energy law should make it possible to maintain the German photovoltaic market at a high level for the next two years at least. The situation continues to be very favourable in Spain as well. Even though the Spanish government must still make decisions concerning renewal of the IDAE subventions programme, the general outlook remains very positive for the next three years.

Between 1992 and 2004 the proportion of grid-connected PV capacity increased from 29 % to 83 % of the total, up from 78 % in 2003. This is mainly due to large scale, government programmes, especially in Japan, Germany and the USA, which focus on PV in the urban or suburban environment. However, in 2004 off-grid applications still accounted for the majority of the annual market in over one third of OECD countries and are certainly most significant in developing countries.

Prices for entire PV systems vary widely and depend on a variety of factors including system size, location, customer type, grid connection, technical specification and the extent to which end-user prices reflect the real costs of all the components. In 2004 system prices in the off-grid sector up to 1 kW varied from around 9 to 25 $/Wp. According with the IEA, a system price of about 13 $/Wp appears to be common in 2004. Off-grid systems greater than 1 kW tend to show similar variation and slightly lower prices.

The installed price of grid-connected systems in 2004 also varied, both within and between countries. The lower IEA reported prices were typically around 5,5 to 6,5 $/Wp. Large grid-connected installations can have lower or higher system prices, depending on the economies of scale achieved or the degree of building integration, installation difficulty and innovation.

From a cost perspective, balance of system (BOS) components account about 2-50% and 70 % of the total system costs for standard grid-connected system and for off-grid installation, respectively. Accordingly the production of BOS products has become an important sector of the overall PV industry. Particularly with the rapid expansion of the worldwide market for grid-connected PV systems, inverters are currently the focus of the interest. Manufacturers of PV inverters for grid connection faced a boom in 2004 and many companies more than doubled their output compared to 2003. In Europe the large manufacturing companies are located in Germany, Austria, Switzerland, the Netherlands and Denmark and produce almost exclusively for the German market. In total around 30 to 40 companies are currently active in this field with German SMA Technology the leading player. Also Japan, the USA and Canada reported extensive activities in this field. It is likely that more than 20 companies are producing grid-connected inverters in these countries. The leading companies are Sharp and Xantrex.

Today most of the BOS products are dedicated to the residential PV market, with typical system sizes from 2 kW up to 10 kW. However, with the increasing number of MW scale systems being installed in some countries, inverters have been developed with capacities up to 1 MW. In the field of building integrated PV (BIPV) companies specializing in façade construction and roofing are paying increasing attention. These companies are now increasingly complementing their product range by developing new and innovative systems for PV integration.

Total European and national budgets for R & D, demonstration, field trials and market stimulation measures continues to steadily increase in absolute terms during recent years. But what then are the long-term prospects for PV? Proclaimed breakthroughs in amorphous or non silicon-based PV cells including organic dye cells have turned out to be somewhat disappointing to date, and a sudden price reduction for PV systems does not appear likely in the near term. Whether or not the slower price reduction by progressive system perfection, materials reduction and mass production can continue enough to meet the financial break-even point with both the conventional energy supply systems and other competing renewable energies is yet to be confirmed. Simple grid-connected PV support schemes, implemented without a broader PV policy framework or complementary industry support measures, may do little to decrease prices, promote innovation or develop sustained market. It still remains the case that the added values of grid-connected PV, such as electricity network, architectural, environmental and socio-economic benefits are not widely appreciated by policy makers and regulators, or the more recent prospective stakeholders including the building and finance sectors.

5.2.9 Concentrated solar power

Concentrated solar power (CSP) presents several options for generating electricity in a wide range, from 10kW with decentralised dish/Stirling systems on the MWs-range based on parabolic trough and solar tower power plants. Some systems use thermal storage during cloudy periods or at night. Others can be combined with natural gas and the resulting hybrid power plants provide high-value, dispatchable power. Intensive research, component tests and system validation have been also carried out at the European test centre Plataforma Solar de Almería[32] during the last twenty-five years.

These attributes, along with world record solar-to-electric conversion efficiencies, make concentrating solar power an attractive renewable energy option in the Southwest and other sunbelt regions worldwide. Feasibility of medium to large application from half a MW to hundreds of MW range has been demonstrated during the last twenty years with total peak efficiencies of around 25%. A large number of studies carried out during the last decade

[32] The Plataforma Solar de Almería (PSA), a dependency of the Center for Energy, Environment and Technological Research (CIEMAT), is the largest center for research, development and testing of concentrating solar technologies in Europe. PSA activities form an integral part of the CIEMAT Department of Renewable Energies as one of its lines of R&D. For more information: http://www.psa.es/webesp/

have shown a significant solar energy potential for CSP in the regions with high average annual direct solar radiation [75].

Recently, as a result of the International Conference on Renewable Energies by the participants in Bonn in July 2004, the Global Market Initiative [76] for Concentrating Solar Power (GMI-CSP) has been adopted as part of the worldwide action programme. The aim of the GMI-CSP is to create appropriate conditions for the worldwide implementation of projects aiming at the solar thermal generation of energy by coordinating the efforts of all parties concerned. The elimination of existing obstacles in the electricity markets of the suitable countries situated in the sun-belt of the earth is just as part of the initiative as the provision of funds for the implementation of concrete projects. Specifically, the aim is to achieve an installed solar thermal capacity of approximately 5.000 MW by the year 2015, so as to achieve the threshold price competitiveness in the market by significantly reducing the cost of this technology.

In Europe, Spain was the first European country –in September 2002- to introduce a “feed-in tariff“ funding system for solar thermal power between 100 kW and 50 MW of capacity. The solar thermal premium was increased in 2004 to 18 € cents/kWh under Spanish Royal Decree 436, and guaranteed for 25 years, with annual adaptation to the average electricity price increase. This removed the concerns of investors, banks and industrial suppliers and launched a race of the major Spanish power market players to develop CSP projects which could be erected among the first 200 MW.

The most advanced is the 10 MW project PS10[33], which is under construction in Andalusia, the south region in Spain, which holds much of the technology developed during last years in the Plataforma Solar de Almería. Project development for two new 20 MW power tower plants has already started. Abengoa has also started to develop various 50 MW parabolic trough plants. Other projects under development in the region of Andalusia are a 15 MW solar-only power tower plant Solar Tres[34] and the two 50 MW solar trough power plants, AndaSol-1 and 2[35]

Further research at the Plataforma Solar de Almería is looking at the development of more efficient and cost effective components and plant schemes including solar-chemical applications, especially for production of hydrogen.

5.2.10 Ocean energies

The oceans contain a huge amount of power with different origins that can be exploited for generating useful energy. The energy potential for Ocean Energies along the Atlantic seaboard of Europe is of some 600 TWh per annum The most developed conversion systems concern: *tidal energy***,** which results from the gravitational fields of the moon and the sun; *thermal energy* (Ocean Thermal Energy Conversion or OTEC), resulting directly

[33] 10 MWe solar-only power tower plant project Planta Solar (PS10) at Sanlúcar near Seville (Spain), promoted by Solucar S.A., part of the Abengoa Group, together with partners, and employing saturated steam receiver technology. The PS10 project has received a €5 million grant from the European Union’s Fifth Framework Programme. Construction started in summer 2004 and will be completed during 2006. Project development of the following two 20 MW power tower plants PS20 of the same type has started. Abengoa has also started to develop various 50 MW parabolic trough plants.

[34] The project Solar Tres is promoted by the Spanish company SENER using US molten-salt technologies for receiver and energy storage. More information at http://www.solarpaces.org/SOLARTRES.HTM

[35] These two projects are being promoted by the German group Solar Millenium. http://www.solarpaces.org/ANDASOL.HTM

from solar radiation; *marine currents***,** caused by thermal and salinity differences in addition to tidal effects, and *ocean waves*, generated by the action of the winds blowing over the ocean surface.

According with the IEA [77], the development of ocean energy systems is gaining momentum. A number of devices have launched full-scale prototypes recently, new policies have been announced, and investors and the media are increasingly interested.

Tidal energy can be considered to have attained maturity since a 240 MW power plant is under successful operation for more than 30 years. However, the high cost of the construction has deterred further investments.

Although using standard components, the OTEC prototypes that have been tested since the 1930s have posed technical problems. This and economic factors did not encouraged relevant activity in this area since the mid-1980s [78].

Recently, a 300 kW prototype for the exploitation of tidal currents has been successfully tested and operated in 2004 under the 5-years EU project *SeaFlow*[36]. A dedicated company has been set up by the partners, Marine Current Turbines Ltd to take forward the development of the technology under a the new project *SeaGen*[37], the 1 MW *SeaGen* tidal energy turbine in Northern Ireland, which will be installed and connected to the National Grid during 2006. The SeaGen project will assess the environmental impact of this technology; it will be the showcase the commercial potential of tidal stream energy.

Due to the complex characteristics of ocean waves and its energy extraction hydrodynamics, the development of the technology to harness this resource requires research work to a larger extent than the others sources do. The EU research project *Wave Dragon*[38] is the world's first offshore wave energy converter producing power for the grid in Denmark. Long term testing is carried out to determine system performance; i.e. availability and power production optimisation in different sea states. These tests will lead to a multi-MW project deployment in 2007. In comparison with traditional hydroelectric power stations, this new technology is competitive.

5.2.11 Fuel Cells

Fuel cells are a very promising technology that could respond to environmental concerns and offer an alternative to the current petroleum based energy industry. It has the potential

[36] SeaFlow (http://europa.eu.int/comm/research/energy/pdf/seaflow_en.pdf) has been a 5-year project to develop and test a commercially-sized marine current turbine. The turbine was installed in the summer of 2003 off Foreland Point, near Lynmouth on the North Devon coast of England, and has been successfully operated and tested since then. The turbine is a 300 kW, horizontal-axis machine that resembles a 2-bladed wind turbine, but with the rotor underwater. The turbine is mounted on a steel pile fixed into a socket in the seabed, and the power train – the rotor, gearbox and generator - can be slid up and down the pile and out of the water for servicing. SeaFlow lays the foundations for the development of a new industry, exploiting what is could be a sizeable renewable energy resource.

[37] SeaGen Project, which has received a £4.27m at the end of 2005 a grant from the DTI's technology programme, will have two rotors, each generating at least 500 kW output. The twin-rotor concept means that more power can be achieved from a single pile installation – reducing costs, and it also keeps the rotors away from the pile wake for regular bi-directional operation. http://www.marineturbines.com/home.htm

[38] The Wave Dragon concept combines existing, mature offshore and hydro turbine technology in a novel way: the water is initially stored in a reservoir and then passed through turbines which produce electricity. This prototype is a quarter the quarter of the size of the full system. Wave Dragon is the only wave energy converter technology under development that can be freely up-scaled. Due to its size service, maintenance and even major repair works can be carried out at sea leading to low O&M cost relatively to other concepts. Plans to build and deploy power production units elsewhere in the EU are already underway. http://www.wavedragon.net/

to replace a very large proportion of the current energy system in all applications from mobile phones through vehicles to DG. However, fuel cell technology is currently in its infancy as shown by the high cost of the electricity produced in demonstration plants.

There are several types of FC that are classified according to the nature of their electrolyte, which also determines at what temperature they operate and the range of hydrogen-containing fuels. The investment costs for PEMFC[39], PAFC[40], MCFC[41] and SOFC[42] are respectively 6000-20.000€/kW, 2.400-5.000€/kW, 10.000€/kW and 30.000€/kW. These costs are particularly prohibitive because the life expectancy of fuel cells only ranges from 9000 hours (MCFC) to 40.000 hours (PEMFC). It is expected that the industrialisation of fuel cell components will bring about a significant cost reduction.

Fuel Cells suitable for DG operate between 80 and 1000 ºC and in CHP mode can deliver efficiencies of over 80%. Small (1-10 kW) FCs could be developed for residential power generation - the ultimate DG. In the long term FCs are a key part of a large RES-based energy supply, where hydrogen and electricity are the principal energy vectors. FCs are therefore a crucial strategic technology with a huge potential global market set to emerge over the next 10-20 years. Market forecasts predict very large (40 - 60%) average annual market growth. The market for all FC applications could be around $ 12.5 billion by 2012.

Research and development tends to decrease the investment costs and improve the life expectancy by focusing on:

- Basic material research;
- Improvement of fuel cells, stacks, and fuel processors components;
- Development of balance of plant simplification and optimisation;
- System integration.

5.3 Enabling Technologies. Status and challenges.

5.3.1 Information and communication technologies (ICT).

In today’s electricity networks, communication is, and will be to an even greater extent, a key tool for the operation of the electricity networks, for both technical and administrative purposes. Observing the developments curve of ICT, we could expect that increasing the communication capacity of the networks is not only required because of the integration of large amounts of DER into the distribution networks, but also due to the establishment of additional electricity markets in a near future (market for the wholesale, balancing, new services, etc).

ICT have seen a revolution since the current model of electricity networks was instituted. The classical ways of communication through narrow-band solutions (range of 100bit/s)

[39] PEMFC: Proton Excahnge Membrane Fuel Cell
[40] PAFC: Phosphoric Acid Fuel Cell
[41] MCFC: Molten Carbonate Fuel Cell
[42] SOFC: Solid Oxide Fuel Cell

have been replaced by broadband communication highways (range of 100 Mbit/s) in many cases, at the introduction of fibre optics solutions. It is only with the development of modern communication methods that systems like SCADA[43] and PANDA[44] have become feasible. DISPOWER has successfully integrated a software package with AREVA's SCADA to allow operators to monitor and forecast the power production of wind farms in order to manage them economically and reliably from a grid perspective. Generic real-time interfaces between SCADA systems and wind-forecasting packages have been designed, based on the open and platform-independent standard. These interfaces are used to provide SCADA real-time data for the prediction packages, and to make forecast and generation schedules available for display and implementation through the SCADA user interface. This design has been tested and validated in FP5 project DISPOWER.

Among others, the new generation internet protocol IPv6 [79] opens great possibilities for serving the needs of the projected human population, enabling a whole new range of remote home management applications, including network controllers, DER, etc. It will provide secure networking and interconnection of a myriad of devices, users and applications of the future with a permanent connectivity that is not feasible with present IPv4 addresses.

The expected developments[45] of peer-to-peer communications, the use of novel forms of interactive multimedia services over the broadband access infrastructure, the take-up of machine-to–machine communications, all point to the urgent need for a rapid evolution towards IPv6. It allows real-time pricing schemes of consuming/producing power by DER as well as the on-line settlement of contract between DER owners and third parties. Implementing IPv6 in mobile networks will also allow for wireless machine-to-machine interconnection, thereby considerably boosting the third generation mobile communications system (3G-application) range.

To conclude, the grid will be interactive for both power sources and loads, which means a standardised and virtually unlimited access for power and linformation at all power and voltage levels. In 2020, energy service companies will enable everyone to have access to the provision of electricity supply services such as the demand management capabilities described before. Enabled by smart metering, electronic technologies, modern communications and the increased awareness of customers, local electricity supply management will play a key part in establishing new services that will create value for the parties involved. In this context, metering services will represent the gateway for the access to the active network and will be a critical link to power demand evolution. For that reason, electronic meters, automated meter management systems and telecommunications, among other power line communications that use electricity supply networks as the physical mean for delivering the new service, will be enabling technologies. For this goal, service oriented ICT and business process integration will be valuable components in the management of the value chain across suppliers, active networks, meters, customers and corporate systems in real time.

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[43] SCADA –the Supervisory Control and Data Acquisition System- is concerned with providing the system operator with remote information and the control of remote facilities in order to operate in the most reliable, efficient and economical manner. The advantage of this scheme is that the operator is acting upon data, which represent the actual operation condition throughout the whole system at any given instant.

[44] PANDA –the plan and Data Acquisition System- is concerned with providing the market operator with schedules, measurements and the ability to make settlements.

[45] A large number of IPv6 projects totalling some €55Mio of EC support were funding in EU-FP5. The transition to all-IPv6 networks will require several years of efforts in Europe.

5.3.2 Power Electronics Converters

The introduction of power electronic systems into the traditionally passive distribution networks has initiated a set of concerns regarding quality of supply[46] and network operation. Interconnection requirements as expressed in standards or grid codes in different European countries are quite heterogeneous, which represents a major barrier to the integration of DER. Indeed, present requirements are based on the fact that DG penetration is small, and they basically consider distributed generators as “passive” elements. For example, generators are usually not allowed to actively support the voltage (by controlling the reactive power for example).

This approach is however changing now[47] and DER are starting to be considered as more active elements of the system, which means that generators, and by extension the Power Electronic Systems integrated in their architecture, have to present some particular behavioural features.

Within the envisaged networks of the future, power electronic converters will be needed to perform many different conversion functions (AC-AC conversion, AC-DC conversion, unidirectional power flow, bi-directional power flow, reactive power injection, FACTS[48], etc) connected at various points in the network.[49] Such converters will provide, for example: interface for connection of renewables, integration of energy storage, optimised utilisation of transmission/distribution infrastructure, enhanced network stability, power quality (active filtering), power flow control, voltage support and unbalance compensation.

To be acceptable in the marketplace, power converters must have low energy losses, very high reliability, small size, high performance and low economic costs[50]. Innovative approaches to converter topology and control are required which encompass the latest and predicted developments in semi-conductor devices, magnetic materials and insulation materials.

Up to now, relatively few FACTS have been installed in Europe for various reasons. One of these reasons is the lack of experience with these technologies, but it is expected that applying FACTS technology will enable the integration of larger shares of RES and/or DER in the medium to long-term, while guaranteeing an economically enhanced operation.

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[46] The term Quality of Supply is defined in the International Electro-technical Vocabulary as: “an estimate of the deviations with respect to specified explicit or implicit values of the electrical energy supply, or of the aggregate supply criteria ensured by an electrical system. IEV 604-1-5

[47] The document “EEG-Erzeugungsanlagen am Hoch- und Höchstspannungsnetz”, issued by the VDN (German Association of network operators) in August 2004 fixes requirements regarding the reactive power supply, the active power feed-in and the behaviour in case of grid disturbances

[48] Flexible Alternate Current Transmission Systems

[49] The DGFACTS project “Improvement of the Quality of Supply in Distributed Generation Networks through the integrated application of power electronic techniques”, European Commission contract ref. ENK5-CT-2002-00658. The project aims at investigating solutions (devices based on the FACTS concept for connection to Distribution networks) in order to improve the Quality of Supply. As result of the project, several so-called DGFACTS prototypes (integrated and standalone) have been produced. The prototypes that are being built within this project have powers between 5 kVA and 50 kVA and are intended to connection to LV networks.

[50] Power electronics are still expensive and complex devices that are engineered and manufactured for specific tasks. Obviously, if such an expensive conversion system is only able to fulfil one task, the investment costs are considered much too high. The main drawback of high-power converters today is that they are optimised for single applications and must be engineered for each new application.

5.3.3 Storage Technologies

Electricity networks are never in a steady state condition, but rather in a perpetual dynamic state. The random nature of the loads in electricity networks and the limited capacity to store electricity in significant quantities are clear examples of some of the challenges involved in today's management of networks. The availability of cost-effective energy storage technology will contribute to the integration of DER into networks, as well as for other energy applications.

A wide variety of technologies are being studied[51] for various applications of different storage capacity and duration. The technologies include batteries of various types (conventional lead acid, Gel and AGM lead, NiMH and lithium-ion and lithium polymer), super capacitors, reversible fuel cells and redox batteries, super conducting magnetic energy systems (SMES), flywheels, thermal storage and compressed air storage.

A brief overview of the different storage options suitable for network operation is given in the following paragraphs.

5.3.3.1 Pumped storage

It consists on an upper and a lower water reservoir and hydroturbine-generators that can be used as motor-pumps. The upper reservoir has sufficient storage capacity usually for 4-6 h of full-load generation with a reserve of 1-2 h. The sequence of operation is as follows: during times of peak load on the network the turbines are driven by water from the upper reservoir in the normal way. During low load periods, the generators then change to synchronous motor action and, being supplied from the general power network, drive the turbine that is now acting as a pump. During the night the electricity is cheaper, and it is the moment to reload the water from the lower to the upper large storage reservoir capacity.

5.3.3.2 Compressed air

Air is pumped into large receptacles during night and used to drive gas turbines for peak day loads. The compressed air allows fuel to be burnt in the gas turbines at twice the normal efficiency. One of the disadvantages is that much of the input energy to the compressed air manifests itself as heat and is wasted. The EU FP5 project AA-CAES[52] is studying the economic feasibility to store also the heat from the compressed air and re-use it in a heat exchanger when the air is drive to the gas turbine.

5.3.3.3 Super conducting magnetic energy stores (SMES)

Continuing development of the High-Temperature Superconductor, where the transition temperature can be of around 60-80 K has led to the possibility of storing energy in the magnetic field produced by circulating a large current (over 100 kA) in an inductance. For a

[51] INVESTIRE project "Investigation of Storage Technologies for intermittent renewable energies. Evaluation and recommended R&D Strategies" European Commission contract ref. ENK5-CT-2000-20336. Further information is available in the Cluster IRED web site: www.ired-cluster.org: a summary of research needs for the development of these technologies is included in the ENIRDGnet report no. D23 "Report on Recommendations for further R&D needs". There are also specific publications for each technology issued during the project INVESTIRE.

[52] Compressed Adiabatic Air Energy Storage. EU Contract ref. ENK6-CT-2002-00611. Information on this project is available in CORDIS.

coil of inductance L in air, the stored energy is given 0.5 LI^2, which can provide 100 MW for several seconds with a coil diameter of around 20m. Initially it is expected that commercial units will be used to provide energy for sensitive loads to guard against voltage sags or to provide continuity whilst emergency generators are started. Another use in transmission networks would be to provide fast response for enhanced transient stability and improved power quality

5.3.3.4 Flywheels

A flywheel, in essence, is a mechanical battery - simply a mass rotating about an axis. Flywheels store energy mechanically in the form of kinetic energy. They take an electrical input to accelerate the rotor up to speed by using the built-in motor, and return the electrical energy by using this same motor as a generator. The use of flywheels in micro-grids has a large potential of success.

5.3.3.5 Super capacitors

The interface between an anode and cathode in an electrolyte has a very high permeability; this property can be exploited in a capacitor to produce a 25 V with a capacitance of 0.1 F. Many units in series and parallel would have the capability of storing many MWh of energy, which can be quickly released for transient control.

5.3.3.6 Batteries plants:

One example is the Regenesys system that has been developed in the United States and in Great Britain. The operation principle is the reload of the batteries between the night (cheaper energy) and the generation of energy during the peak hours (higher demand of energy, more expensive energy price). The interest of this installation is essentially economic but it can help to control and supply the peaks of energy. So this power plant could be used as a backup plant that it would be ready to produce when it would be necessary.

Table 5.1 shows some basic data of these technologies in a comparable manner. A detailed benchmarking study for these technologies was carried out in the project INVESTIRE under three different aspects: purely technical adequation of the technologies with the requirements, economic effectiveness and environmental impact. The aggregation of this data shows that from a purely technical point of view, the best matching storage technology within the main four application categories defined below can be summarised as follows, the technology in bold being the most economical one when taking into account the additional cost for electricity:

⇒ Small stand alone applications — Lithium-ion, **lead acid**

⇒ Solar Home Systems and hybrid systems — Lithium-ion, redox flow and **lead acid**

⇒ Load levelling — Super capacitor and **compressed air**

⇒ Power quality — **Flywheel**, super capacitor

Some storage technologies are characterised by wide spans in performance parameters, which means that different products exists, for example, for different applications and each technology has its own particularities that make it suitable for certain niche markets. In these cases, a careful selection of the storage product is necessary.

Energy	Storage system	Efficiency	Storage density (kWh/m^3)	Download time
Gravitational	Reservoir	0.75	1000·Q· H	Every day, week or season
Thermal	Heat storage	0.65 to 0.85	20 to 150	Every day
Pressure	Air compression	0.7	2 to 5	Every day/week
Chemical	Batteries	0.7 to 0.9	5 to 150	Some days to some minutes
Kinetic	Flywheel	0.7 to 0.9	10 to 100	Some minutes
Electromagnetic	Superconductor coil	0.9 to 0.95	0.1 to 5	Some milliseconds
Electrostatic	Super capacitor	0.9 to 0.95	1 to 10	Some seconds

Table 5.1.Comparison between different storage elements

Storage technologies continue to be developed and improved to reach a cost level that would allow better commercialisation of these systems. The main efforts of R&D concern:

- The improvement of the systems (efficiency, lifetime, lower cost);
- The ability to recycle the systems and to use of non-toxic products;
- The integration with other DER equipments (engines, micro-turbines, fuel cells) to combine the technology benefits.

In the long term vision hydrogen systems potentially offer storage and long-distance delivering advantages, e.g. isolated places equiped with reversible fuel cells. An initial analysis in the 1990's showed that hydrogen systems could be competitive with electricity as an energy carrier for thermal end-users, particularly over longer distances [80]. Development of cheaper bulk electric storage technologies, e.g. superconducting magnetic energy storage, could erode this advantage. Hydrogen energy systems do not appear to be competitive when the end user is electric so far, but the economics of hydrogen as an energy carrier would significantly improve in electric end-use applications if cogeneration value is considered, specially if fuel cell and other efficient applications are improved beyond expected limits. Sensitivity studies for transportation distance, electric transmission costs, capacity factor, storage time, cogeneration, time-dependent end-use value, hydrogen system requirements and costs, etc. would be valuable areas for further investigation.

6 Smart Electricity Networks

DER is a new model for the power system. It is based on the integration into electricity networks of small and medium size generators based on new and renewable energy technologies. It may create a new era, where thousands or millions of users will own their generators, becoming both producers and consumers of electricity. All these generators will be interconnected through a fully interactive intelligent electricity network.

This revolution will require sophisticated control and communications technologies to ensure smooth operation of electricity networks, the establishment of new models for power distribution, as well as the development of advanced energy storage technology, power electronics and super conducting devices.

Philippe Busquin, European Commissioner for Research
"New ERA for electricity in Europe" ref. EU20901. Brussels 2003

The watchword of the electricity network of the future will be uncertainty. It is virtually impossible to predict how large the share of Distributed Generation will be, or when these new types of generator will become economically competitive. Today it is wind power and gas fired Combined Heat and Power. Tomorrow, perhaps, micro-turbines, fuel cells and photovoltaics. There will be uncertainty on the future primary energy mix, uncertainty in the electricity flows created by the free market, uncertainty on the instantaneous power output of many new generators.

To cope with this uncertainly, we need to develop a new electricity system model which is flexible and robust in the face of all these uncertainties. A system that will not only remove all barriers to the deployment of new technologies, but a system capable of exploiting and optimising the multiple benefits of all the new generation alternatives.

The availability of reliable and inexpensive Internet and communication technologies allows us to think about innovative solutions that were unimaginable just a few years ago. The large-scale use of real-time sensors and data communication technologies will transform today's electricity grid into a future, smart, electricity web. New energy services will appear, such as the remote control of loads and home appliances, monitoring the environmental condition of elderly peoples' accommodation, automatic energy audits, and many others.

Research efforts should be intensified and coordinated in the coming years to reach 2020 with validated technologies, find win-win solutions among the stakeholders and break the inertia of the electrical infrastructure and the energy sector in general.

6.1 Future electricity networks: smart, distributed and interactive.

Today most users are passive receivers of electricity without further participation in the operational management of the grid. Each user node is simply a sink for electricity. As in other technologies and markets, future electricity grids in Europe should allow the users to play an active role in the supply chain : the Smart Electricity Networks.

With the emergence of DER in a liberalised energy market a new model is emerging where centralised and decentralised generation will coexist. A large number of small and medium size generators based on new and renewable energy technologies should be integrated into the network. Thousands or millions of users will own their generators, becoming both producers and consumers of electricity. The large-scale use of real-time sensors and data communication technologies, concepts like plug-and-play and self-healing will transform today's electricity grid into a future smart electricity web.

Therefore, not only will existing aspects of the network be touched, but new features and energy services will be introduced; for example, monitoring and control will be possible at a finer scale than ever before, which will allow automatic energy audits, new ancillary services, etc; intelligence will be distributed throughout the network making real-time pricing schemes, on-line settlement of contracts and other local decision making the norm; information and communication services will not only be available and transmitted, but assigned value and traded alongside the power.

The implication of this is a huge increase in data and information traffic to meet the requirements for the functioning of future networks, for which the most obvious communication link would be the Internet. The flow of information around the World Wide Web uses the concept of distributed control where each node, web host computer, e-mail server or router, acts autonomously under a global protocol. In the analogous electricity system every supply point, consumer and switching facility corresponds to a node.

In this model, DER provide a significant proportion of power generation. Power can even flow from DER into the distribution network and from distribution to transmission networks. The intelligent FACTS at the nodes between producers and consumers would 'route' power between the nodes in the same way as e-mail is routed from node to node in the Internet.

The integration of ICT into the centralised grid transforms it into a fully interactive intelligent network. Sensors and intelligent agents embedded in the grid provide instantaneous information on energy conditions throughout the system, allowing current to flow exactly where and when it is needed and at the cheapest cost. An agreed protocol for exchange of information about power demand and supply could make it possible to distribute control of the electricity distribution system to a much smaller scale. Each node would 'listen' to the rest of the network, adjusting its power production or consumption in relation to the global state of the electricity network. This information and control layer would extend into the home, where systems already exist that can adjust domestic consumption to 'shed load' at times of network 'stress'.

The Internet model allows the easy addition of new sub grids as the level of control is at the level of the nodes themselves. The 'power' protocol would provide standard components and interfaces giving ‘plug-and-play’ capability for any new entrant to the network as long as they manage their operations in a manner compatible to the protocol.

As the market is liberalized, monopoly control of the system will change with multiple TSOs and DSOs operating the system transparently to enable the market, and without discrimination under the governance of a regulator. To operate it successfully, all players in the European system must have a common set of guidelines. It will also require a more active role for DSOs in controlling network stability, optimising central and distributed power inputs, interconnection and, of course, metering and billing.

Bulk electricity transport and power balance will be performed in a unified and strong trans-European grid. This grid will have the potential to exploit fully the use of both large, transmission connected generators and smaller distributed power sources throughout Europe. The aim of Smart metworks is sustainable development and a trans-European transmission system. It will facilitate the combination of areas with different renewable supply structures that complement each other (such as wind power and hydropower) and allow large resources of renewable energy to be used because a large group of consumers will be connected. Besides making the full integration of separate systems today existing in Ireland and in parts of Scandinavia possible, this grid will provide means for an effective electricity exchange with neighbouring systems in the East and towards Africa.

In summary, grids are being transformed into millions of interconnected bilateral nodes at all levels of transmission and distribution integrated across Europe. Bulk transmission and distributed generation will coexist on interconnected grids where the distinct difference between traditional transmission and distribution becomes increasingly blurred. This unified European electricity grid will provide Europe’s industry and European citizens with a highly secure electricity supply on a most cost-effective basis with minimum damage to the environment, in line with European related policies.

6.1.1 Benefits

Smart Electricity Networks is a new concept of electricity networks that will respond to the rising challenges and opportunities, bringing benefits to all network users, all other stakeholders and those network companies that perform efficiently and effectively. As markets across Europe will become more liberalised and dynamic, an increasing number of stakeholders will participate in shaping Smart Electricity Networks. These are:

Customers: Customers’ needs include quality of service and value for money. In the next years, customers’ expectations will grow rapidly and involve value added services, energy “on demand” and total connectivity. They will be asking for services on demand, in-house generation, real time tariffs and freedom to choose their suppliers.

Electricity network companies: Network owners and operators are requested to fulfil customers’ expectations in an efficient and cost effective way. They are requested to perform necessary investments, improving the actual level of power quality and system’s security, assuring remuneration for their shareholders. Changes in generation availability and demand management, which enable customers to adapt their consumption in response to price signals, will require fundamental investment decisions that have long term impact.

Investment remuneration and stable regulatory frameworks will be necessary for a “level playing field” competition in a liberalised market.

Energy service companies: Customer needs will become even more important. Some will seek tailor-made solutions, most will seek simple ‘turnkey’ products. Savings will need to be made visible, in monetary terms, an increase in comfort and a reduction of fuss (like the maintenance and operation of the system). In general, a trend will be observed from the present “infrastructure-driven” to the progressive “service-driven” paradigms in the European electricity supply industry.

Technology providers: A period of significant technology and business change lies ahead and equipment manufacturers will be key players in developing innovative solutions and in achieving their effective deployment in grid companies. As with electric power companies, technology providers will have important investment decisions to make and a shared Vision will be critical to ensuring sound strategic developments that provide open access, long term value and integration with existing infrastructure.

Researchers: The research community has a critical role to play, as without research there is no innovation, and without innovation there is no development. The cooperation among universities and research centres, the industry, regulators and legislators must be fostered, not only for the successful development of new technologies, but also to overcome non-technical barriers.

Traders: Free trade throughout Europe will be facilitated by open markets, harmonised rules and transparent trading procedures. Congestion management will be resolved on a fully integrated European market. Customers will benefit from the opportunity to choose the best energy supplier.

Regulators: The European market for energy and related services should be supported by a stable and clear regulatory context, with well-established and harmonised rules across Europe. Regulatory frameworks should secure a grid with increasingly open access, a clear investment remuneration system and transmission and distribution costs as low as possible.

Governmental agencies: Governments and law-makers will have to prepare new legislation to take into account apparently contradictory goals. Increasing competition should keep a downward pressure on energy prices, but a more environmentally friendly energy mix may bring cost challenges. Legislation will be affected by the evolution of grid organisations, by the requirement for greater flexibility and cross-border trading and, of course, to ensure economic development, greater competitiveness and job creation in the EU.

New businesses: New businesses will be provided with the choice between own (on-site) generation, including sales of surplus to the grid, and purchase of electricity from supplier companies. They will have the opportunity to offer demand side response products and services to the grid. In the case of electricity-intensive industries, their decisions will be influenced by market price changes. Thus business will be seeking a wider range of solutions than currently.

6.1.2 Opportunities

The opportunities presented by these Smart Electricity Networks are multiple. Some examples are the following:

- The increased penetration of DER for power generation and heat/cool use, together with higher energy efficiency will help security of supply by reducing energy imports and building a diverse energy portfolio.

- The new technologies developed and the experience of implementing new energy management models will provide invaluable expertise and knowledge with immense export potential to developed countries, but also to the developing world and the possibility to use local resources.

- Wide scale use of DER will reduce fossil fuel consumption and green-house gas emissions as well as noxious emissions such as oxides of sulphur and nitrogen (SO_x / NO_x) therefore benefiting the environment.

- Increased opportunities for smaller scale generators will revolutionise production for the benefit of consumers and the distribution system itself, whilst the integration of DER will create new markets and business opportunities - in particular for SMEs specialising in ICT and electricity marketing issues.

6.1.3 European added value

The implementation of this new model will bring the following expected European added value:

- The evolution of the electricity network is a necessary prerequisite for the success of several EU policies, in the areas of Sustainable Development, Internal Market and Competitiveness. The large-scale use of energy efficient and/or renewable technologies, like cogeneration plants and fuel cells, or reaching the objectives of the RES-E Directives, cannot be achieved without removing the barriers that present-day networks are posing to their deployment. Only new electricity network based on distributed intelligence will allow the full environmental and economic exploitation of these new technologies.

- As highlighted in section 5.1, the worldwide market for electricity transmission and distribution is of the order of 5 trillion dollars in the next 30 years. Industries that will be in a position to be the first to offer innovative solutions for electricity networks will have the opportunity to secure a large share of this huge market, with consequent positive benefits for job creation and the overall European economy.

- As mentioned in section 3.2.1.4, the liberalisation process is having some very negative side-effects on the research effort in the area. Large-scale European projects and initiatives in the area are a good way to reverse the trend toward disinvestments and loss of know-how, and to enable the research establishments to survive the transition period toward a fully liberalised internal market and to reorganise their activities for the new conditions.

6.2 Possible network architectures

The architecture of smart electricity systems recognises the fundamental change that with increased levels of DER penetration the distribution network can no longer be considered as a passive appendage to the transmission network. The entire system has to be designed and operated as a robust integrated unit. In addition this increased complex operation must be undertaken by a flexible system under multiple management.

The increased amount of control required also leads to a vastly increased information traffic derived from status and ancillary data. In this way, and in the ability to re-route power, the active network represents a step towards the internet-like model. The evolution towards Smart Network is summarised in Figure 6.1 and can be described as follows:

- First Stage: Extension of DG and RES monitoring and remote control to facilitate greater connection activity. Some circuits will rely on bilateral contracts with distributed generators for ancillary services. Rules will have to be defined to outline physical and geographical boundaries of contracting.
- Second Stage: A management regime capable of accommodating significant amounts of DG and RES has to be defined: local and global services and trading issues, adaptability without information overload, control issues.
- Final Stage: Full active power management. A distribution network management regime using real-time communication and remote control to meet the majority of the network services requirement. The transmission and distribution networks are both active, with harmonised and real-time interacting control functions and efficient power flow.

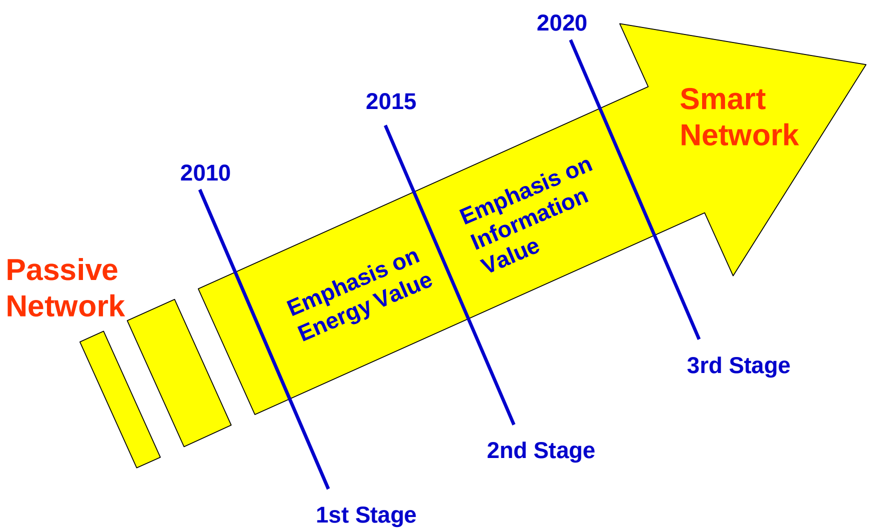

Figure 6.1. Possible evolution towards the Smart Electricity Networks

When the final stage is achieved, the users of the Smart Network will expect a responsive system. They will anticipate connection according to simple and defined standards. They will also expect accurate billing - to pay for what they use and to be paid for what they supply. Plug and play with real-time trading and accounting will be a consequence.

In managing the transition to the internet-like model it may be useful to consider concepts under development in a number of projects under the European Commission’s Framework Programmes. In Europe, three conceptual models have been envisaged: Active Networks supported by ICT, Microgrids and ‘Virtual Power Plants’ or the ‘Internet’ model - all of which could have applications depending on geographical constraints and market evolution.

6.2.1 Active Networks

The current system essentially provides an *infinite* system in that the network itself remains virtually unaffected whatever is happening on the customer side. The “*Active Networks*” model employs two novel concepts. The first is that the primary role of the network is to provide connectivity, i.e. the network is a highway system that provides multiple links between points of power supply and demand. The second is that the network must interact with the consumer. The function of the active distribution network is to efficiently link power sources with consumer demands, allowing both to decide how best to operate in real time.

Active networks are envisaged as a possible evolution of the current passive distribution networks and may be technically and economically the best way to initially facilitate DER in a re-regulated market. Active networks have been specifically conjectured as facilitators for increased penetration of DG and are based on the recognition that new ICT technology and strategies can be used to actively manage the network.

The level of control required to achieve this is much greater than in current distribution systems. Power flow assessment, voltage control and protection require cost-competitive technologies and new communication systems with more sensors and actuators than presently in the distribution system.

Possible structures of this model are shown in Figures 6.2 and 6.3. Active Network Vision is based on increased interconnection –“aggregators”- as opposed to the current mostly linear / radial connections; relatively small local control areas; and the charging of system services based on connectivity. The active network has some analogies to telephone networks, i.e.: there is always more than one path; active management of “congestion” -unlike conventional passive systems that rely on Kirchhoff’s laws to determine power routing; and prevent propagation of an overload by “isolating the sick” part of the network.

With increased distribution of power input nodes due to DER, bi-directional energy flow is possible. New power electronics systems offer ways to control the routing of electricity and also provide flexible interfaces to the network, i.e. switch from thinking one-directional to bi-directional. FACTS and Custom Power Devices at lower voltages offer the potential to manage routing of power supply in an active manner.

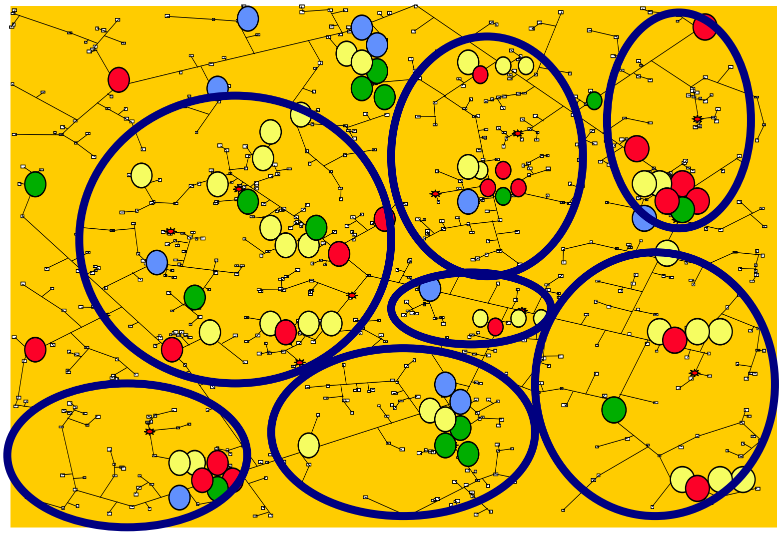

Figure 6.2. The Active Network Vision is based on the following concepts: interconnection, local control areas –or "cells"- and specific system services to individual customer. The most revolutionary change is the introduction of "Medium –Voltage Cells", which are in fact "local control areas"

Electricity transmission in this system is not dependent on a single route so failure due to a single component problem is reduced. However an inherent risk of interconnected networks is a domino effect - that is a system failure in one part of the network can quickly spread. Therefore the active network needs appropriate design standards, fast acting protection mechanisms –not too different from what is being used today already- and also automatic reconfiguration equipment to address potentially higher fault levels.

The greatest change in the active network model is at the local control area level –or cell- where each defined area has its own power control system managing the flow of power across its boundaries. The cell concept does not have a large impact on the topology of the power network, the difference is mainly in control hierarchy. The system would be ICT-based with management enabled by remote actuators controlling the system. The central area control computer would 'negotiate' with neighbouring areas on the exchange of power. If an area were isolated, then the system would react by disconnecting enough load or generation to maintain the correct power balance. This could lead to considerable improvements in the reliability of the supply system as a whole.

ELTRA, in Denmark, has pursued the Active Networks vision since 2002; its experiences at Western Denmark during 2002-2003, where already about 50% of the production capacity was connected at lower voltage levels –60 kV and below-, show that this model requires relatively little further investment in infrastructure; however, strong international connection to balance the system and investment in automated switch gear were necessary [67]. Inspired by the Active Networks vision, actions are being taken to enhance the system to handle even larger amounts of DG. Experiences will be very important to see the needs of investments, R&D needs, and regulation to operate an Active Network nation-wide [81].

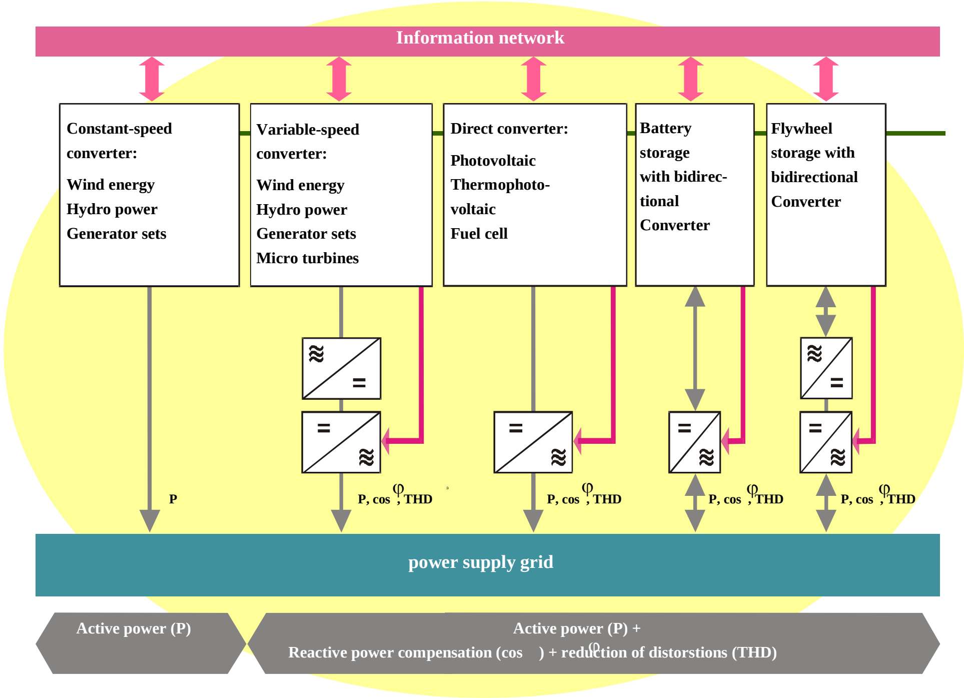

Figure 6.3. Management of information and power supply in Active Networks. Each node is "aware" of the status of the grid in real time and can contribute to grid stability, balance and reliability by delivering ancillary services, reestablishment after disturbances, black-starts, etc. Accurate information on the state of the network and coordination between local control centres is essential using state of the art ICT. Reference: DISPOWER.

A more recent experience is being tested under the FP5 project DISPOWER at a pilot installation of the Settlement "Am Steinweg" in Stutensee, near Karlsruhe (Germany) since beginning of 2005. The objectives of these tests are to validate the DISPOWER approach for integrating Distributed Generation with a large share of renewable energies into low-voltage electricity grids. This settlement represents a typical residential area with approximately 400 people living in 101 apartments. Electrical power consumption mainly comes from residential loads for cooking, TV etc. (see Figure 6.4).

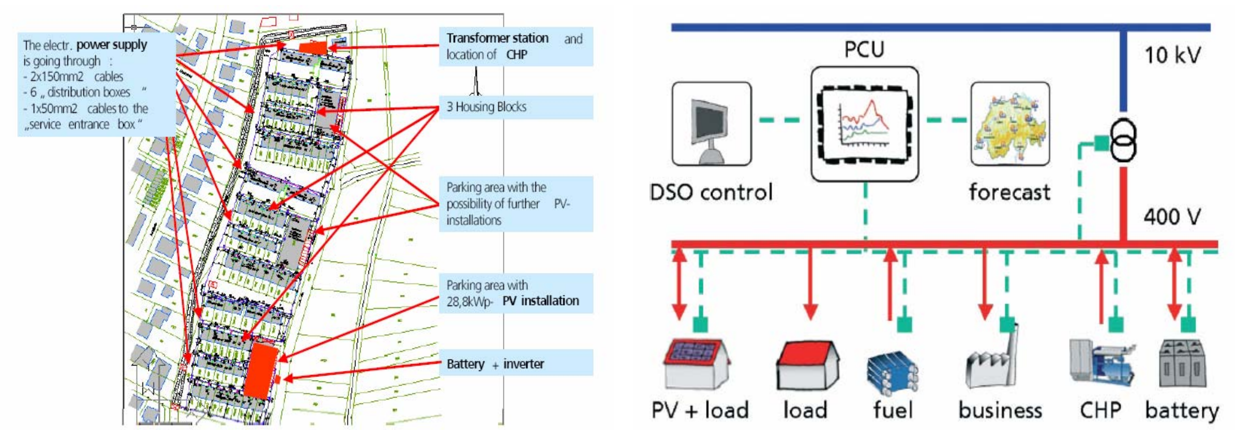

Figure 6.4. Project DISPOWER. Map of Settlement "Am Steinweg", Stutensee, Germany (left). Web interface for monitoring and management the distributed components at the pilot installation (right). Source:DISPOWER – Project highlights: Highlight No. 17: A Power Quality Management Algorithm for Low Voltage Grids with Distributed Resources

The grid is connected to one transformer and is operated in closed configuration. The energy storage installation also provides energy control options that can be used by “PoMS”, the power management system. PoMS is a new Power and Power Quality management system specially designed for operation in low voltage grids. This PoMS system has been designed in such a way that a central control unit (“PCU”) elaborates time schedules for the operation of the decentralised components on the basis of technical and economic considerations. These time schedules are sent to decentralised units in the grid, called PoMS interface boxes (PIB), which communicate directly with the decentralised energy generators, storage systems and (if applicable) loads and measuring.

In addition to technical aspects, the DISPOWER team has successfully addressed socio-economic issues under real market conditions in this settlement, such as:

- different contract relations and tariffs for diverse distributed generators (privately owned and utility owned);
- economic evaluation of operation modes; and
- social integration of inhabitants of the settlement into the DISPOWER project.

In The Netherlands, tests under FP5 project CRISP [82] have started by clustering some DER plants in a single field test for industrial and domestic settings (Figure 6.5). The experiments are currently under implementation.

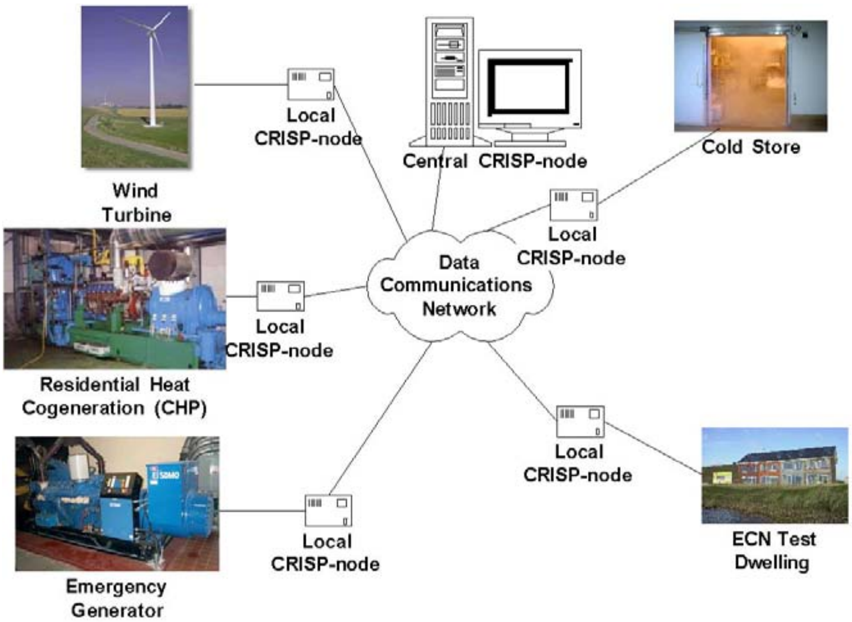

Figure 6.5. FP-5 project CRISP. Experiment setting during 2005-2006

Tests are particularly focused on the scenarios and strategies concerning local market-oriented demand-supply matching and associated highly distributed architectures. The ICT tools developed in the CRISP project will be used for monitoring and dispatching purposes, in order to create an efficient balance between generation and demand without causing local overload of the electricity distribution infrastructure. Particular attention will be given to the fact that customers must perceive this as a service and not as an intrusion into their private lives. Off-the-shelf computing and communication hardware will be used to interconnect and interface a cluster of power generation and consumption installations in a network using secure Internet technology in an isolated branch of the public Internet, a virtual private network. On these computers, tools will be installed for data-collection, database storage and safe execution of novel control algorithms.

Application and governance of information and communication technology, in use in other sectors of industry for decades now, is still in its infancy in the power sector today. The field test aims to prove that power flow fluctuations from the embedding of intermittent power production from renewable energy resources can be compensated for in near real-time by other suppliers and consumers of electricity in a commercially viable way when using the network communication facilities and processing capabilities of modern ICT.

6.2.2 Microgrids

Microgrids comprise Low Voltage distribution systems (below 1kV) with distributed energy sources, storage devices and controllable loads (e.g. water heaters, air conditioning) with a total installed capacity in the range of few hundred kWs to a couple of MWs [83]. A key motivation of Microgrids is the desire to move control of power reliability and quality closer to the point of end-use so that these properties can be optimised for the specific loads served.

Microgrids are typically characterised by multipurpose electrical power services to communities with populations of up to 500 households with overall energy demands reaching several thousand kWh per day and are interconnected via low voltage networks. Microgrids can operate connected to the main power network or islanded, in a controlled, coordinated way.

From the customer point of view, Microgrids provide both thermal and electricity needs, and in addition enhance local reliability, reduce emissions, improve power quality by supporting voltage and reducing voltage dips, and potentially lower costs of energy supply. From the Utility point of view, the application of distributed energy sources can potentially reduce the demand for distribution and transmission facilities.

Microgrids operate mostly connected to the Medium Voltage Distribution network, but they can also be operated isolated from the main grid, in case of faults in the upstream network (see Figure 6.6). The flexibility of microgrids comprises important benefits, but also very challenging problems.

In order to enjoy the full benefits resulting from the operation of Microgrids, it is important that the integration of the distributed resources into the LV grids, and their relation with the MV network upstream, contribute to optimise the general operation of the system. To achieve this goal, a hierarchical system control architecture comprising three critical control levels, as shown in Figure 6.6, has been envisaged for this network architecture:

- The *Microgenerator Controller* (MC) takes advantage of the power electronic interface of the micro source and can be enhanced with various degrees of intelligence. It uses local information to control the voltage and the frequency of the Microgrid in transient conditions. MCs have to be adapted to each type of micro source (PV, fuel cell, micro turbine, etc.). Local *Load Controllers (*LC) are also installed at the controllable loads to provide load control capabilities.

- The *Microgrid Central Controller* (MGCC) functions can range from monitoring the actual active and reactive power of the distributed resources to assuming full responsibility of optimising the Microgrid operation by sending control signal settings to the distributed resources and controllable loads.
- The *Distribution Management Systems* (DMS) controller provides the control interface of the Microgrid with the rest of the distribution network.

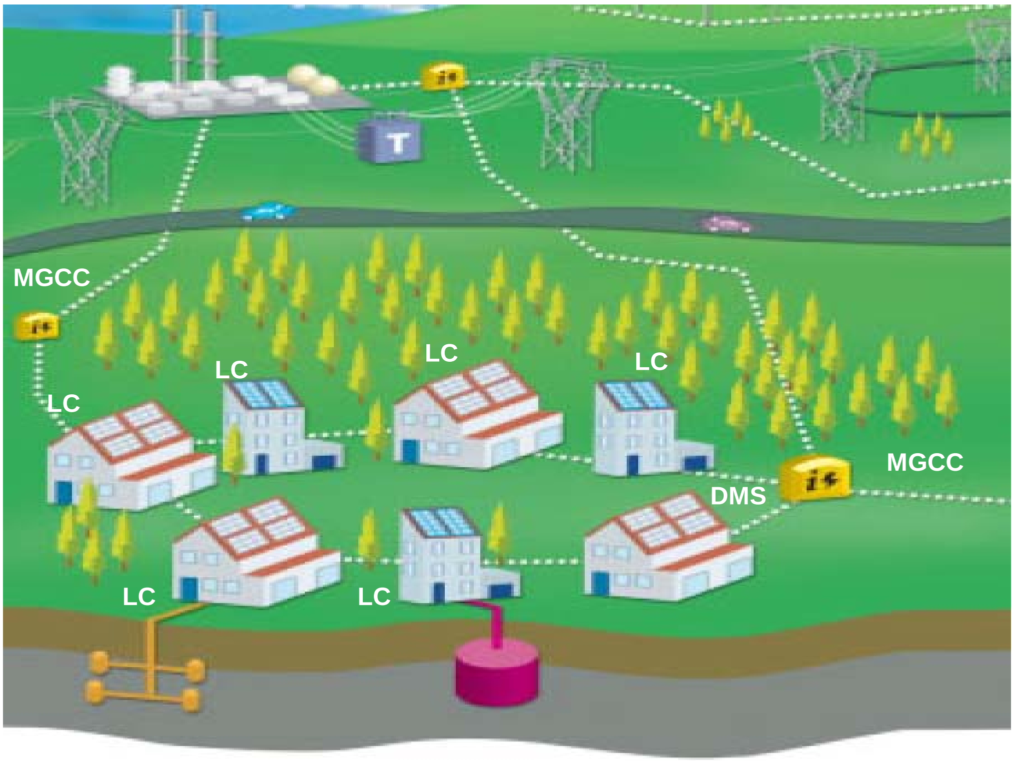

Figure 6.6. Microgrid Control architecture: Local Microgenerator Controllers (MC) and Load Controllers (LC); MicroGrid System Central Controller (MGCC), and Distribution Management System (DMS).

Research within the EU-FP5 Project MICROGRIDS (ENK5-CT-2002-00610), which focused on the operation of a single Microgrid, has successfully investigated appropriate control techniques since 2003 and demonstrated the feasibility of Microgrids operation through laboratory experiments.

The EU-FP6 Project MORE-MICROGRIDS (SES-CT-2005-019864) includes the first European set of experimental validation under real conditions of various Microgrid architectures in interconnected and islanded mode and transition. The project started in January 2006 and results will be available over the next four years.

6.2.3 The Virtual Utility

The Internet enables many new opportunities. A conventional power station generates electricity in one location using one type of generating technology and owned by one legal entity. A Virtual Utility (VU) model consists of a an aggregation[53] of a large number of multi-fuel, multi-location and multi-owned power stations as well as responsive loads and storage devices which, when integrated, have a flexibility and controllability similar to large conventional power plants.

In a Virtual Utility, the structure of the Internet Model and its information and trading capability is adopted, rather than any hardware. Power is purchased and routed to agreed point(s) but its source, whether conventional generator, RES or from energy storage is determined by the seller, the system being enabled by information technology. New sources have the potential to gradually substitute the existing ones. To achieve this, distributed control system architecture needs to be designed and an appropriate communication and information infrastructures will need to be developed to enable distributed control to be implemented. Furthermore an appropriate market and commercial structure will need to be developed to support the exchange of services among all actors including TSOs, DSOs and VUs.

The first experiments in Europe are being prepared under the EU-FP6 Project FENIX[54] , Contract SES-CT-2005-518277, which includes the proof of the VU concept and its demonstration through both simulation and field trial test (see Figure 6.7). The core aspects of FENIX include the three main interrelated pieces of research whose outcome will form the basis for the operation of future highly decentralised electricity supply systems. These include the development of:

- Distributed system control architecture
- Information and communication architecture
- Supporting market and commercial structure

For a grid operator or energy trader, purchasing energy or ancillary services from a virtual power station is equivalent to purchasing from a conventional station. The concept of a virtual power station is not itself a new technology but a method of organising decentralised generation and storage in a way that maximises the value of the generated electricity to the utility. Virtual power stations using DG, RES and energy storage have the potential to replace conventional power stations step by step until a sustainable energy mix has been developed. Extending this concept to a virtual utility merely extends the services available.

[53] An aggregation here is not a simple collection of DER, but it takes into account the actual location of individual consumer/generator in the network. Hence network effects impact is a key feature of a Virtual Utility.

[54] The overall aim of FENIX is to conceptualise, design and demonstrate a technical architecture and commercial framework that would enable DER based systems (LSVPPs) to become the solution for the future cost efficient, secure and sustainable EU electricity supply.

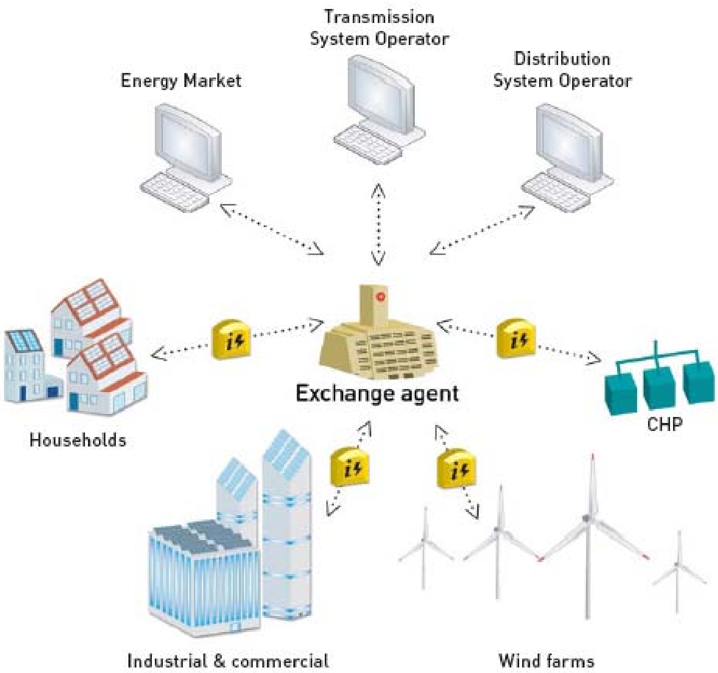

Figure 6.7. The Virtual Utility model. Ref. Project FENIX

The project FENIX started at the end of 2005 and results should be available over the next four years.

6.3 Top S&T priorities for Smart Electricity Networks in European and National Research Programmes

Many recommendations to cover pending scientific and technological issues for *Smart Electricity Networks* have been reported in previous papers, especially within the EU-FP5 Cluster IRED. A brief summary of top scientific and technological priorities can be the following:

- **Intelligent electricity networks.** RTD should cover the development of new concepts, system architectures and regulatory framework for control, supervision and operation of electricity transmission and distribution networks, so as to transform the grid into an interactive (customers/operators) service network, while maximising reliability, power-quality, efficiency and security. These systems should be based on applications of distributed intelligent, plug & play, e trading, power line communications, etc.
- **Efficient Distributed energy generation technologies**. RTD programmes should reinforce and balance efforts on Distributed Generation technologies including fuel cells, micro-turbines, photovoltaic systems, reciprocating engines, hybrid power systems, thermally activated technologies, etc.
- **Demand-Side Management and Demand Response Resource techniques.** These systems allow customers to shift their power consumption towards off-peak periods

and to reduce their total or peak demand. RTD should cover the development of customer-side energy management systems capable of managing local power consumption and re-dispatching local loads, so as to take full advantage of the real-time energy price and network status information.

- **New energy services**. RTD is needed for the development of new energy services, such as remote metering, remote control of appliances, the real-time monitoring of homes to enable better care for the elderly and other vulnerable groups, building stock performance rating and so on.
- **Improving the efficiency of power transmission and distribution.** To minimise these losses (around 7% in OCDE countries), RTD is needed in areas like HVDC, advanced high temperature superconductivity, high efficiency transformers, etc.
- **Enabling technologies**. To build the new type of grid structure it is essential to bring to the market low-cost technologies, which can bridge between local networks and create a modern pan-European network with the capability of integrating significant DER. Key enabling technologies will facilitate this development. RTD should focus on High Temperature Super conducting Systems and Devices, Power Electronics Converters, Power Line Communication Technologies, etc.
- **Stationary Energy Storage.** Energy Storage has a very important strategic value in future electricity networks. Energy Storage is essential for the full exploitation of the energy produced by intermittent energy sources. Energy Storage can allow the reduction of spinning reserves to meet peak power demands, by storing electricity, heat and cold, which is produced at times of low demand and low generation, and releasing it when energy is most needed and expensive. RTD should focus on energy storage technologies including advanced batteries, flywheels, super conducting magnetic energy storage, compressed air energy storage, and super capacitors.

7 Recommendations for a Paradigm shift: further efforts and support needs

Future work and support to development of Smart Energy Network should aim at increasing the efficiency, safety and reliability of the European electricity transmission and distribution system by transforming the current electricity grids into an interactive (customers-operators) service network and to removing obstacles to the large-scale deployment and effective integration of distributed and renewable energy sources.

European Commission. COM(2005)353final
Proposal for the 7FP. Brussels 6 April 2005

This chapter presents the main messages from previous chapters, which could be synthesised into the following four messages:

i. *To pave the way to sustainable electricity networks, there is a clear need to prepare the European energy system for the large-scale integration of DER. Considering the pending research and validation activities, plans for 2020 should start now.*

ii. *Fully integrated DER will have the potential of delivering the following benefits for Europe:*
   - *reduced central generation capacity as well as transmission and distribution losses,*
   - *enhanced transmission and distribution network capacity,*
   - *improved system security,*
   - *reduced overall costs and CO_2 emissions, and*
   - *shaping Europe's competitiveness worldwide*

iii. *In order to address this integration, a change in the emphasis from "connecting" to "integrating DER" into the overall system operation -and its development- is absolutely required. This represents a shift from the traditional, central-control culture to a new, more distributed control paradigm.*

iv. *But major technological changes, i.e.: operation, protection, control, etc, and regulatory changes will be needed to accommodate this new open and unified electricity service market approach during the next decades in Europe.*

The following paragraphs give a summary of the main recommendations for a paradigm shift, complementing to certain extent those already given in the previous chapters. The purpose is not to set out the path to achieve the new paradigm, but to consolidate a set of recommendations for further efforts and remark on the different sources of support needed, i.e. what is needed and, based on that, what is still missing.

7.1 Recommendations for further efforts

7.1.1 Distributed Energy Technologies

Distributed and renewable energy technologies have, in the long term, the potential to make a large contribution to the European –and global- energy supply, achieving security of energy supply and environmental sustainability.

Generation technologies vary widely in their technological and market status. However, all renewable energy technologies require further R&D and demonstration to further reduce costs, optimise performance and improve their competitiveness. Projected target costs of electricity production with wind, biomass, geothermal, ocean and concentrated solar energy should be below 0.05 €/kWh by the year 2020. Renewable energy technologies typically have relatively high capital costs and can have low running costs. The potential for future capital cost reduction varies between technologies. Niche markets can be entered with 1500 €/kW, but to penetrate the wholesale electricity market on a broad basis, a further cost reduction down to 500 €/kW should be achieved.

Forecasting accuracy for renewable generation should be increased. Better forecasting systems, energy management and improved market mechanisms will help to reduce the balancing services required from conventional power plants.

Mature DER technologies also require further RTD to be integrated into the network system and to overcome market barriers such as lack of awareness of commercially available technologies, lack of investor support, low conventional energy prices, lack of appropriate regulations, standards and codes, and lack of policy harmonisation. Widespread demonstration of decentralised energy management systems in the coming years is required to overcome these issues before 2015. This includes operational functions and strategies, distributed real-time monitoring and control of distributed generators, storage management and demand-side management, real-time energy exchange and ancillary services trading, constrained optimal dispatch of generation, etc. Overcoming these barriers with successful demonstration projects will help the technology to penetrate new markets by 2020 with substantially lower subsidies than currently required, and will later help to bring these technologies into developing countries.

7.1.2 Key enabling technologies

Advanced power electronic devices are designed to optimise power transmission capabilities, improve power quality and reliability, minimise losses and cost, integrate storage devices, etc. Research and validation of these advanced power electronic applications should continue to develop new concepts and new materials that can dramatically lower their costs.

High temperature superconductor devices such as generators, transformers and current limiters for electricity networks improve the performance and stability of electricity networks, which allows to conduct up to three times as much as electricity within the existing conduit at half of the current costs. RTD efforts should be devoted to develop reliable and cheaper new applications in this area.

Energy storage technologies such as new batteries, reversible fuel cells, redox flow batteries, flywheels, capacitors, etc are valuable for reducing pricing volatility, protecting against power quality problems, and supporting intermittent RES on the grid. Future research efforts should be focused on applications (hardware and software), which contribute to the integration of DER into the new network architectures foreseen for the future.

Last, but not least, information, automation and communication technologies will play a key role in future energy supply monitoring, operating and controlling the networks and the generation units. RTD on new control systems and control concepts are becoming more and more necessary. Further work on harmonisation of interfaces and communication protocols and components is urgently required for interoperability and to provide stable solutions to security concerns. Real-time energy trading and billing systems for DER are key topics of future markets.

7.1.3 Testing and certification infrastructures at EU level

Standardisation is a voluntary process based on consensus amongst different economic actors (industry, SMEs, consumers, workers, environmental NGOs, public authorities, etc). It is carried out by independent standards bodies[55], acting at national, European[56] and international level. The electricity market might use standards to make sure that competition is fair. The public would benefit from a standard, which improves the quality and safety of the power supply or other services and reduces the cost. European standards are also developed to help people comply with European legislation on policies such as the single market.

Several testing laboratories were created in the second part of the last century to support the development of electric network components by manufacturers and the integration into national electric systems by utilities/companies. Examples are CESI in Italy, KEMA in The Netherlands, TÜV in Germany, RISOE in Denmark, ARSENAL in Austria, Labein in Spain, etc. The testing and research approach followed by such labs were traditionally “component” oriented (transformers, switchgears, isolators, etc); however, the development and testing of power electronic based devices in the last years (FACTS, AC/DC converters, etc) has transformed their research and testing activities to more “system” oriented.

Many of these labs have participated in the project ENIRDGnet. The outcome of this collaboration has been summarised in a number of recommended practices for testing and certification as well as recommendations for further research on new standards[57]. The

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[55] The European Standards Organisations are CEN, CENELEC and ETSI, of which CENELEC (European Committee for Electrotechnical Standardisation) deals with standards in the eletrotechnical field. http://www.cenelec.org/Cenelec/Homepage.htm and http://www.setsi.mityc.es/normali/normaliz/cen_cene.htm

[56] The European Union has, since the mid-1980s, made an increasing use of standards in support of its policies and legislation in the areas of competitiveness, ICT, public procurement, interoperability, environment, transport, energy, consumer protection, etc.

[57] For further information, see the ENIRDGnet report “D18: Recommended Practices for Standardisation & Testing and Certification” at www.dgnet.org from which a number of common themes can be extracted, as follows:

- Some issues are adequately covered by existing standards and requirements (e.g. grounding, EMI Protection) and no further action was proposed. Similar conclusions may be applied to others issues (e.g. harmonics, flicker) which have a high impact with high penetration of DER.
- Some issues should be considered in the future, but do not present barriers now (e.g. black start, dispatching). Issues were identified that may become significant with high DER penetration, or in specific circumstances.

further transformation of these labs into a real European research infrastructure is the next step to guarantee the appropriate testing and certification infrastructures in fields such as information and communication technologies for electricity networks, control/automation systems and new management procedures. It shall also enable the generation and development of the necessary knowledge and training, and the sharing of this know-how among all the European operators of electric systems. Such transformation is being launched presently within the Network of Excellence DER-Lab[58].

New specific infrastructures and networks might also be needed for the future, such as interconnected European wind measurement network, European electricity network simulation system for power flow, etc.

7.1.4 Operation of Transmission and Distribution networks

Transforming the conventional electricity transmission and distribution grid into a sustainable, unified and interactive energy service network with a large share of DER requires further RTD efforts on control and supervision of an integrated European network. DER must interact more positively to the DSO's grid problems and vice versa. Ancillary service markets will arise at transmission and distribution levels so that system operators can optimise the use of the grid, using support from both the generation and the demand side. Advanced planning and simulation methods are urgently required to address the increasing complexity and new challenges involved, such as securing energy services to the end-users, determining technical constraints of the network, testing operational strategies, on-line decision support during network operation, training operators to cope with complex features, etc.

If the distribution network is gradually transformed into a power exchange grid with increasing DER penetration in the future, development of real-time risk management will become necessary to manage intermittent renewable generation and appropriately reconfigure the grid. Additional effort will be required in protection, security of supply and ancillary service provision to enable network management. Dynamic grid operation (i.e. dynamic setting of protection relays, real-time monitoring of bottlenecks or dynamic re-dispatch on real-time markets) would allow for a better capitalizing of existing assets and avoid or delay grid expansion to meet load growth.

- DER should contribute actively to the stability of the network in terms of voltage and frequency regulation and should be compensated for that added value. In scenarios with high DG+RES penetration, DG+RES should be allowed to play a more active role enabling a flexible operation of the network.
- Further development of the communications network is a major issue. This conclusion has been identified in several areas (e.g. monitoring and control, synchronisation, voltage regulation, provision of ancillary services). The complexity of the infrastructure must be developed according with the level of penetration of DER.
- Islanding, both intentional and unintentional, requires particular attention in terms of protection, re-closing procedures, safety, etc.
- The case of weak grids (e.g. microgrids) is particularly important since the effects produced by DER are more significant. Thus, particular requirements for weak grids are highly recommended.
- The role of DER after black-outs in terms of fast and significant contribution to the recovery of the power system (black start) should be further discussed.

[58] DER-Lab "Network of DER Laboratories and Pre-Standardisation". European Commission Contract Ref. SES6-CT-2005-518299 started in November 2005 and has a duration of 6 years. The Network brings together a group of 11 organisations for the development of certification procedures for DER components for electricity grids. A major objective is to establish a durable European DER-Lab Network that will be a world player in this field. http://www.der-lab.net/.

7.1.5 Socio-economic research

Harmonised tools should be developed to tackle the complex social, economic and cultural issues of new energy technologies, such as the medium- and long-term competitiveness with conventional technologies, environmental safety, implementation and acceptance of emerging technologies, and future energy networks.

Different strategies for energy governance should also be considered to achieve sustainable development objectives. Socio-economic studies including the development of common strategic roadmaps for energy service networks should be undertaken to harmonise regulations, safety, testing, certification, education and training. Strategically important areas of research are: estimating the external costs of energy, developing quantitative and qualitative modelling and forecasting energy/electricity methods, and assessing the role that DER can play in Demand-Side Management.

The technical and socio-economic R&D in social, regulatory and economic aspects of large-scale integration of DER will certainly support the future development and implementation of optimal energy policies. This includes fields such as:

- Developing new regulations (e.g. for optimal operation and connection of distributed electricity generation technologies) for promoting high DER integration;
- Improving the security of energy supplies and reliability to customers by DER technologies in future energy markets;
- Further development and use of support schemes (e.g. feed-in laws, green certificate schemes, energy taxation);
- Planning guidance and design of new DER operating systems with lower cost of electricity and heat by testing and analysing new concepts;
- Regulatory improvements for the creation of pro-active network management and operation enabling the use of all benefits and capabilities of DER for supply of electricity and heat.

7.1.6 Training and Education issues.

One of the challenges to integrating DER is to properly analyse the electric transients and to find adequate solutions to stabilise the bus voltage during load insertions and disconnections.

To cover these needs at operational level, an interactive operator training facility for power systems with dispersed generation has been developed in the project DISPOWER. It complements an existing training simulator with various models of distributed generation sources, as well as the appertaining control structures; it also aims to establish the model for an appropriate training programme for both smaller dispersed generation-based systems as well as large transmission systems under the influence of strong wind generation.

At University level, however, it is more and more clear that the engineering discipline in Europe does not provide today a sufficient number of well-trained engineers in DER fields.

To develop, operate and maintain future networks, cross-functional educational strategies – matching power engineering and ICT- must be adopted mainly at University level for a new generation of scientists and engineers. Some successful initiatives have already started in the field of renewable energy: The European Master Degree on Renewable Energy of EUREC Agency[59], the European Academy of Wind Energy[60] or the International Institute for Renewable Energy[61] are good examples of such initiatives. These networks can be seen as a sound basis for a wider and more systematic information exchange and educational activities on a global scheme.

7.2 Type of Support needed

As described in section 3.1.1.4, the liberalisation of the energy markets in the Nineties has had the effect of lowering electricity RTD outlays. This creates the need for a public RTD approach that is not only supply-pushed, as in the early days of the nuclear industry or the aerospace industry, but which should also involve commitments from all parties concerned - i.e. producers, government and consumers- along the three types of support initiatives required: financial, policy-oriented and international.

7.2.1 Financial Support

Many aspects are still far from real market applications and, as explained in previous section, the ultimate results are of public interest. One cannot expect this kind of RTD to be funded purely from private actors. Public financial support is also required both as a clear policy signal on the necessity of this type of research and as a leverage for additional private investment in the field.

The full environmental, social and economic potential of the *electricity web* can be exploited only if common solutions are identified, leading to EU wide standards. But common solution cannot be achieved without a collaboration of all relevant actors in

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[59] European Renewable Energy Centres Agency. www.eurec.be. The European Renewable Energy Centres Agency was established as a European Economic Interest Grouping in 1991 to strengthen and rationalise the European research, demonstration and development efforts in all renewable energy technologies. As an independent member-based association, it incorporates 48 prominent research groups from all over Europe. EUREC disseminates knowledge, fosters contacts and cooperation between the renewable energy scientific community and the industry as well as policy makers. EUREC develops strategies for R&D, manages projects and promotes professionalisation of education and training.

[60] Euroepan Academy of Wind Energy. The EAWE is a co-operation on wind energy R&D of research institutes and universities in four countries: Germany , Denmark , Greece and the Netherlands. The Academy is founded to formulate and execute joint R&D projects and to coordinate high quality scientific research and education on wind energy on a European level. The initiating partners are: Denmark, RISØ, DHI, universities of Copenhagen (DTU) and Aalborg (AAU). Germany, ISET, university of Kassel. Greece, CRES, universities of Athens (NTUA) and Patras. The Netherlands, ECN, Delft University of Technology (DUWind). http://www.eawe.org/

[61] International Institute for Renewable Energy. http://www.nu.ac.th/english/research/location/i_iire.htm. In recognition of the need to develop human resources globally, thus enhancing management skills, and to provide a source of knowledge and information on renewable energy for bridging the information gap, eight international universities have joined together to establish an International Institute for Renewal Energy (IIRE). The eight founder member universities (in alphabetical order of their host countries) are: Curtin University of Technology (Australia), University of New Brunswick (Canada), Yunnan Normal University (China), Claude Bernard Lyon University (France), Kassel University (Germany), Tokyo University of Agriculture (Japan), Tribhuvan University/Institute of Engineering (Nepal), and Naresuan University (Thailand).

Europe. Furthermore, the scale of resources required to meet the ambitious objective needs a mobilisation of resources that can be assembled only through EU-wide collaboration.

7.2.2 Policy oriented Initiatives

One of the essential conditions for a reliable operation of the electricity system is that TSOs and DSOs maintain an overall technical understanding and supervision of the system. In the unbundling process, they have been separated by the research centres of the utilities, with a consequent loss of know-how.

Today TSOs and DSOs are facing common problems, and not being in competition with each-other, they would welcome common solutions in the medium to long-term. It should therefore be relatively easy to organise collaboration between TSOs and DSOs in R&D, with obvious benefits both for them and for the European networks of the future.

A present issue is the source of finance for this RTD effort. Rationally, the electricity market actors should find within it the resources to finance its RTD needs, and the main source of finance should come from the TSOs and DSOs themselves. However, in the current economic environment, they are put under pressure by the regulators to reduce costs in any possible way. Most regulators do not differentiate between economic gains (which are in the interest of the TSOs and DSOs shareholders) and investments in long-term RTD projects (which in this case are mostly in the public interest).

Therefore, a closer RTD collaboration between TSOs and DSOs should be promoted at European level [62] to identify suitable self-financing mechanisms for this collaborative effort, acceptable by the regulators, and compatible with the subsidiary principle. One possibility would be to use a small fraction of the electricity transport tariffs for this mechanism, but other means should be investigated as well[63].

7.2.3 International relations.

The integration of DER into electricity networks requires the development of significant RTD cooperation actions. In addition to the running dialogue and collaborative works promoted under international associations like CIGRE, IEEE, IEA, etc. the European Cluster IRED has initiated intensive discussions with researcher groups and other actors in developed economies- specially in Canada, Japan and the US- for potential collaboration and shared efforts on major technological and regulatory issues of the electricity supply system in the medium- to long-term.

Two good examples of these activities are the joint organisation of the 1st International Conference for Integration of DER held in Brussels last December 2004 and the

62 In this line, during 2005 the Commission has set-up and supported the first steps towards the establishment of the "European Technology Platform for the Electricity Networks of the Future" with wide representation of all stakeholders involved .

63 The FP6 Coordinating Action RELIANCE (Contract Ref. SES6-CT-2005-20088) is focused on this objective.

consolidation during 2004-2005 of the new International Journal for DER as the vehicle to a periodic exchange of information of a scientific and technical nature.

Although the cooperation achieved so far during almost two years has been limited to the exchange of information, there is a clear tendency to intensify more and more the international role of the European Cluster IRED under which a few collaborations with Canadian and North Americans groups are emerging.

International collaboration in this area is becoming one of the topics of the political agenda of Presidents of State of developed countries, as recognised during the last G8 meeting in July 2005 in Gleneagles. The final join declaration says [84]:

"Electricity Grids…we will work with the IEA to:

a) Draw together research into the challenges of integrating renewable energy sources into networks and optimising the efficiency of grids, and produce a report; and

b) Identify and link "centres of Excellence" to promote research and development in the developed and developing world; and

c) Promote workshops during 2006/07 aimed at evaluating and promoting means to overcome technical, regulatory and commercial barriers."

Clearly, European stakeholders can and have to actively contribute to such collaboration at international level. This will contribute to a common understanding at the early stages of potential benefits and standardisation requirements for distributed resources at international level. In addition, international collaboration helps to avoid duplication of research efforts; it complements present research and running approaches; and it contributes to develop joint research activities of mutual interest in the future.

Experiences during last years show that European co-operation at international level is very effective when the European actors are acting at European level. In the area of electricity research such "acting at EU level" might not have been possible a few years ago since the field is relatively new in the Framework Programmes. However, after the creation and consolidation of specialised RTD groups in Europe during FP5&6 -e.g. the cluster IRED or the Network of Excellence of Laboratories DER-Lab as well as the new working groups under the European Technology Platform- the European contribution on this area is very promising and can play a key role at international scale.

8 EPILOGUE

The development and operation of smart electricity networks is a key element to achieve sustainable electricity economies based on large integration of DER in the medium- to long-term. It will shift the responsibility of the electricity production to a much large number of actors who generate on a much more smaller scale; it will mean that the responsibility for the control and transmission of electricity is also shifted to a smaller scale.

Another aspect of the smart electricity networks towards a sustainable and competitive way is to use more and more intelligent control and less hardware such as lines and generators to provide the required level of reliability for power supply and to improve the overall cost/benefit ratio.

The vision presented here shows a distributed network managed by distributed control where every node in these smart electricity networks will be awake, responsive, adaptive, price-smart, eco-sensitive, real-time, flexible, humming and interconnected with everything else.

A single leap from the current network to this vision is not credible, but taking the period beyond the lifetime of the current generation of equipment –say beyond 2020- enables trials and development of the concept described here.

This would lead to a coherent approach across the three domains involved, namely: i) technical issues; ii) regulation, standards and political issues; and iii) organisation, management and markets.

From a technical point of view, the idea is still rather speculative, but the biggest investment needed to achieve it is certainly research and engineering effort to establish what kind of communication technology and control solutions could support this vision. Key projects have been initiated in Europe during last few years, but a lot of work remains to be done over the next decade for the design, validation and implementation of the appropriate architecture and control strategies.

Regulatory barriers can be overcome provided that representatives from regulatory bodies take their responsibilities in facilitating innovative solutions for the tariffs and system service changes described in this thesis, which is expected to happen in the near future.

The major risk is the organisation of the designing of the network structure, as the process would have to involve a large number of stakeholders at European level. As in a few other issues at this level, if this smart network vision fails to be implemented during the next decade in the EU, it will not be because we lack technology, vision or motivation, it will be because we cannot set a direction and march collectively into the future.

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ANNEX 1: EU Legislation and policies affecting DER

European legislation and policies are playing an increasingly important role in defining the framework conditions for the current use of DER in Europe and in shaping its future markets. This section, based on several Commission briefing documents, aims to provide a clearer picture by summarising the most important pieces of European legislation and by outlining how they affect DER.

There are two websites on EU law, which are recommended for further consultation on the information provided in this Annex:

i. *EUR-Lex is the portal to European Union law. It provides all legislative documents in the different official languages (http://europa.eu.int/eur-lex/lex).*

ii. *PreLex follows the decision-making process on the different pieces of EU legislation under preparation (http://europa.eu.int/prelex).*

EU LEGISLATION, NON-BINDING MEASURES AND POLICY DOCUMENTS

Regulations are directly applicable and binding in all EU Member States without the need for any national implementing legislation.

Directives stipulate the objectives to be achieved within a certain time limit, but leave the national authorities the choice of form and means to be used. Directives have to be implemented in national legislation in accordance with the procedures of the individual Member States.

Decisions do not require national implementing legislation and they are binding in all their aspects for those to whom they are addressed. A decision may be addressed to any or all Member States, to enterprises or to individuals.

Communications usually set out a Commission action plan, which may include proposals for legislation

Recommendations and opinions are not binding.

With Green Papers, the Commission presents initial policy considerations and ideas, opening the debate to interested parties who may wish to comment.

In White Papers, the Commission communicates a decided policy or approach on a particular issue. While some discussion still may occur, they are primarily intended to prepare the development of concrete measures.

EU LEGISLATION AND POLICIES IN FORCE

RENEWABLE ENERGY SOURCES and COGENERATION

Electricity from Renewable Energy Sources ("Renewables Directive")

Full Title	Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market
Brief Outline	The main objective of the Directive is a doubling of renewable energy from 6 per cent to 12 per cent by 2010. The Directive defines renewable energy as all non-fossil sources, including biogases, biomass, geothermal, hydropower, landfill gas, sewage treatment plant gas, solar and wind. Electricity is classified as being produced from RES if it is obtained from plants using solely renewable energy sources, as well as the proportion of electricity produced in hybrid plants that use conventional energy sources. The Directive defines national indicative targets for the share of electricity to be produced from renewable sources by 2010. It is up to the Member States to take appropriate measures to promote renewable energy production and consumption in order to reach these targets, and they must issue regular reports assessing the progress made. The Directive introduces a system of 'guarantee of origin' to ensure that electricity really is produced from a renewable source. Certificates to this effect are to be issued by the Member States and they should be recognised EU-wide. Member States have to ensure that the operators guarantee access of the renewable electricity to the grid. They may also provide for priority access to the grid system of renewable electricity. Connection charges have to reflect the economic cost and benefits associated with the connection. This is to avoid unfairly high costs for small producers.
Comments	The Directive is important for all types of renewables, including bio-fuelled cogeneration. It has led to simplified planning procedures for renewable projects and guaranteed grid access for green power. It has also created more transparent terms for grid access and use.
Procedure	A Commission report on the share of renewable energy in the EU from 26 May 2004 shows that Member States are not on track for meeting their national indicative targets. Under current circumstances, a share of only 18 or 19 per cent would be achieved, not 22 as foreseen in the Directive. At the end of 2005, the Commission is to present a report on the experience gained from the application and coexistence of various support schemes in the Member States. This report can be accompanied by a proposal for a EU-wide framework for RES support schemes.
Websites	http://europa.eu.int/comm/energy/res/legislation/electricity_en.htm

	CHP Directive
Full Title	Directive 2004/8/EC on the promotion of cogeneration based on a useful heat demand in the internal energy market
Brief Outline	The aims are to create a framework for the promotion and development of high-efficiency cogeneration in the internal energy market. The Directive covers all existing and "future" cogeneration technologies. It introduces methods to calculate "electricity from cogeneration" and to determine the efficiency of installations. The use of alternative calculation methods is accepted until end 2010, subject to certain conditions. To qualify as "high-efficiency", cogeneration installations need to achieve primary energy savings of at least 10% (or less in the case of units of up to 1 MW electrical capacity) compared to separate production of heat and electricity. Electricity generated from high-efficiency cogeneration is eligible for a "guarantee of origin". Support schemes for cogeneration should be based on useful heat demand and primary energy consumption. Member States must apply the provisions of the Electricity Directive and the Renewables Directive concerning connection to, and use of, the electrical network by cogeneration installations. Member States have to evaluate their national potentials for high-efficiency cogeneration and to report on their progress in realising it. They also have to revise administrative procedures in order to facilitate cogeneration projects.
Comments	The Directive sets out the methods to determine high-efficiency cogeneration and it issues hard measures on electrical network issues and administrative procedures related to cogeneration installations. Yet, instead of setting binding targets for the development of cogeneration, the Directive requires Member States only to identify their cogeneration potentials. The Directive does not prescribe whether or how Member States have to support cogeneration, but it specifically provides the framework for support including state aid. It demands that any form of support given is compatible with EU competition law.
Procedure	The Directive has to be transposed by 21 February 2006. It left three regulatory areas unresolved: (a) specifications for determining what is a cogeneration plant and what are the cogeneration products, (b) the reference cases for comparing cogeneration with separate production, and (c) guidelines on how to undertake a potential study. A Regulatory Committee composed of Member State representatives was created in January 2004 to determine these issues. It is planned to complete this process by end 2005. In parallel, the Commission has commissioned a study to prepare analyses and guidelines in order to provide technical input and make recommendations to the three regulatory issues. An international consortium has been selected to undertake this study.
Websites	http://europa.eu.int/comm/energy/demand/legislation/heat_power_en.htm

SPECIFIC SUPPORT POLICIES AND PROGRAMMES

	Environmental Technologies Action Plan (ETAP)
Full Title	Communication from the Commission "Stimulating Technologies for Sustainable Development: An Environmental Technologies Action Plan for the European Union" (COM/2004/38 final)
Brief Outline	Joint initiative from DG Environment and DG Research to improve the development and wider use of environmental technologies within the EU, combine environment and competitiveness, and contribute to the Lisbon targets. Key actions include the launch of technology platforms with stakeholders (i.e. hydrogen and fuel cells, near zero emission power plants, etc); establishing environmental performance targets for products and services; and making the most of funding schemes and public and private procurement policies. ETAP aims to break down the existing barriers to environmental technologies (economic barriers, unclear or too detailed regulations and standards, insufficient research efforts, inadequate availability of risk capital and lack of market demand) through a concerted effort to help maximise the potential of environmental technologies.
Comments	Although DER is not specifically mentioned under environmental technologies, ETAP indirectly contributes to its further promotion through: funds and research to further improve the cleaner electricity generation and distribution; improving the market conditions in a liberalised energy market; addressing and dealing with barriers; promoting cogeneration as an example of good practice; and increased regional co-operation by transfer of technology to new Member States and enhanced co-operation with them..
Procedure	At the Spring European Council in March 2004 the Heads of States and Governments gave the political impetus to its implementation. The Commission will review the implementation of ETAP and report on it in 2006. It will also set up a European Panel on Environmental Technologies, where all relevant actors will exchange information, create synergies and help the Commission on ETAP.
Websites	http://europa.eu.int/comm/environment/etap/index.htm

	Intelligent Energy for Europe
Full Title	Decision No 1230/2003/EC adopting a multiannual programme for action in the field of energy: "Intelligent Energy - Europe" (2003 - 2006)
Brief Outline	Intelligent Energy - Europe (EIE) was adopted on 26 June 2003 and entered into force on 4 August 2003. It is the EU support programme for non-technological actions in the field of energy efficiency and renewable energy sources. The programme is structured in four fields: – SAVE: Improvement of energy efficiency and rational use of energy; – ALTENER: Promotion of new and renewable energy sources for centralised and decentralised production of electricity and heat and their integration into the local environment and the energy systems; – STEER: Support for initiatives relating to all energy aspects of transport, the diversification of fuels and the promotion of renewable fuels (bio fuels) and energy efficiency in transport; and – COOPENER: Support for cooperation initiatives in the developing countries.
Comments	Three parts of the programme can provide financial support for international projects on DER.
Procedure	The current Global Work Programme 2003-2006 outlines the programme's priorities, administrative and financial arrangements, the evaluation procedure and the indicative planning of calls for the programme throughout the programme duration. For each programme year there is an annual work programme establishing a limited number of priorities.
Websites	http://europa.eu.int/comm/energy/intelligent/work_programme/index_en.htm

	State Aid for Environmental Protection ("State Aid Guidelines")
Full Title	Community guidelines on State aid for environmental protection (2001/C37/03)
Brief Outline	The guidelines came into force in 2001 and will be applicable until 31 December 2007. They explain the criteria used to decide when state aid measures for environmental protection (like tax reductions, exemptions, or new forms of operating aid in the energy sector) are justified, and whether they are compatible with the rules of the Common Market. Stranded costs and state aid in the agriculture sector are not covered by the guidelines. Generally, the internalisation of external environmental costs and the application of the polluter pays principle would make state aid not necessary. Yet, state aid is justified if full costs internalisation is not achieved, or to stimulate further improvements in firms. But state aid only to meet investment needs arising from new EU technical standards is considered unjustified. Energy-saving measures and the use of renewables are explicitly understood as actions to protect the environment, although renewables are only recognised if used by installations of less than 10 MW capacity. State aid for DER is generally seen as acceptable subject to the conditions established in the guidelines. A distinction is made between investment and operating aid: – Investment aid for investment into CHP is acceptable when CHP is highly efficient, less environmentally damaging, or reducing energy consumption. The general maximum support rate of 40 % of eligible costs can even be higher if renewable energy sources are used, in assisted regions, or if the investors are SMEs. Eligible costs are defined as "extra investment costs necessary to meet the environmental objectives". – Operating aid must be limited to compensating for extra production costs compared to market prices, and it has to be temporary: Degressive operating aid may cover 100% of extra costs initially, but it must decrease in a linear fashion to zero within a maximum period of 5 years. If operating aid is non-degressive, it must not cover more than 50% of eligible extra costs, and its duration is limited to 5 years. In addition to these provisions, the Guidelines make detailed statements on the use of operating aid in form of tax reductions and exemptions.
Comments	The guidelines look favourably upon aid for cogeneration and renewable energy sources.
Procedure	Member States can choose between several options for granting such aid up to certain thresholds, and many governments have used this opportunity so far.
Websites	Websites http://europa.eu.int/comm/competition/environment/#state_aid.

AIR, CLIMATE CHANGE AND EMISSIONS TRADING

	Greenhouse Gas Emissions Trading ("Emissions Trading Directive")
Full Title	Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community
Brief Outline	The Directive establishes a scheme for greenhouse gas emission allowance trading within the Community. It applies to a range of large emitters defined in Annex I (installations with combustion installations exceeding 20MW thermal input, plus large mineral oil refineries, ferrous metals production or processing installations, mineral industries, and pulp, paper and board industries), and thus many existing or potential CHP installations. During the first trading period, 2005-07, only CO_2 emissions will be covered. During the second trading period, 2008-12, additional greenhouse gases, installations and activities may be opted into the scheme. Installation operators will have to hold a greenhouse gas emission permit. Member States have to develop National Allocation Plans describing how operators will obtain an initial allocation of emissions allowances, whereby 1 allowance allows emitting 1 tonne of CO_2 eq. Annex III of the Directive defines criteria for allocation methods. At least 95% of the allowances must be allocated for free (90% during the 2008-12 period). From 2006, operators will have to submit each year sufficient allowances to cover their emissions during the preceding year. Excess allowances can be sold to operators who are short. A system of national registries and a European Central Administrator and transaction log will facilitate the international trade of allowances. Failure to submit sufficient allowances will carry a €40 fine (€100 in 2008-12) per each emitted tonne of CO_2 eq. for which no allowances are submitted.
Comments	Emissions Trading is expected to increase the marginal cost of fossil-fuelled power generation, to increase the price of electricity, to change dispatch orders, and to create new opportunity costs in the power sector arising from the price of carbon. These factors are likely to push towards more investment in low-carbon and high-efficiency generation, such as DER. But allocation will also be important. A number of National Allocation Plans foresee favourable allocation rules for CHP, albeit using different approaches.
Procedure	On 07/01/04, the Commission issued a guidance document on National Allocation Plans (COM/2003/830), and on 29/01/04 guidelines for the monitoring and reporting of emissions (C/2004/130). The deadline for transposition was 31/12/03. Member States submitted their draft National Allocation Plans on 31/12/03 (old Member States) or 01/05/04 (new Member States). The Directive entered in force on 1 January 2005 with an initial trading price of € 7 per ton of CO_2 eq.. During the first six months prices have increased more than initially expected to about € 25 per tonne of CO_2, and it is expected to rise up to € 40 during 2006.

Websites	http://europa.eu.int/comm/environment/climat/emission.htm

	Joint Implementation and Clean Development Mechanism ("Linking Directive")
Full Title	Directive 2004/101/EC amending Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community, in respect of the Kyoto Protocol's project mechanisms
Brief Outline	The Directive will allow operators covered by the EU's Emissions Trading Scheme to use credits from the Kyoto Protocol project mechanisms to meet their targets in place of emission cuts within the EU. Firms will be able to use CDM credits (called CERs) from January 2005 and JI credits (ERUs) from 2008. JI projects can be undertaken in countries that have quantitative emissions reductions targets under the Kyoto Protocol (mainly Russia), while CDM projects may be hosted by developing countries, which have no such quantitative targets. The final version of the Directive sets no limitations on the quantity of credits that can be imported from into the EU Emissions Trading Scheme, although Governments are bound to consider the issue of supplementarity - doing more than half of the emissions reductions domestically – in their twice-yearly monitoring and of emissions. Authorities must thus set national limits, in the form of a percentage of the number of allowances allocated centrally by governments. The Directive excludes credits from nuclear projects and from sinks. Large hydro projects must be subjected to international rules "including" those drawn up by the World Commission on Dams.
Comments	Combined with Russia's decision to ratify the protocol, the Directive alters the market landscape by increasing the diversity of low-cost compliance options and by improving market liquidity.
Procedure	Member States must transpose the Directive by 13 November 2005. The Commission may later propose a harmonised limit if it thinks too many external credits are being sucked into the market and preventing efforts to abate emissions inside the EU.
Websites	http://europa.eu.int/comm/environment/climat/emission/linking_en.htm

	Emissions from Large Combustion Plants ("Large Combustion Plants Directive", "LCP Directive")
Full Title	Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plants
Brief Outline	This Directive replaces the first Large Combustion Plants Directive from 1988. It applies to combustion plants with a rated thermal input of greater than 50 MW. It aims to reduce acidification, ground level ozone and particles throughout Europe by controlling emissions of SO2, NOx and dust from large combustion plants. These include plants in power stations, petroleum refineries, steelworks and other industrial processes running on solid, liquid or gaseous fuel. If the waste gases from separate plants could be "discharged through a common stack", they are considered as one unit. The scope includes gas turbines – not covered in the old Directive, but it excludes gas engines and plants fuelled by diesel and petrol. The Directive sets new, stricter limit values for SO2, NOx and dust. Member States are allowed to adopt even stricter values if they wish. There are specific emission limit values for the use of biomass as fuel. "New" plants (licensed on or after 01/07/87) have to comply with emission limit values fixed in the Directive by 1 January 2008. "Existing Plants" (licensed before 01/07/87) have now also to comply with emission limits set in the Directive. Alternatively, operators can run them less than 20000 hours between 2008-2015, nominate them as peaking plant - in which case they can run up to 2000 hours a year – or the Member State can develop a National Emission Reduction Plan (NERP). With the NERP, a Member State could define a fixed annual tonnage of SO2, NOx and dust that can be emitted by all existing installations as of 1 January 2008. This tonnage must not exceed the amount of emissions, which would be obtained by applying the emission limits set in the Directive to each plant individually. For all newly built plants, and for plant extensions by at least 50 MW, Member States have to ensure "that the technical and economic feasibility of providing for the combined generation of heat and power is examined. Where this feasibility is confirmed, bearing in mind the market and the distribution situation, installations shall be developed accordingly."
Comments	How governments and operators will react to the Directive's requirements is often still unclear, but some degree of plant closures and changes in dispatch orders are to be expected. This should stimulate the market and provide some opportunities for new projects. Countries with large coal and oil fuelled power generation capacities are most affected, i.e. Germany, Greece, Spain, Italy, the UK, Czech Republic and Poland.
Procedure	On 15/01/2003, the Commission issued a guidance document on national emission reduction plans (2003/47/EC). The Directive is currently under review.
Websites	http://europa.eu.int/comm/environment/air/future_stationary.htm

OTHER ENVIRONMENTAL ISSUES

	Waste Electrical and Electronic Equipment ("WEEE Directive")
Full Title	Directive 2002/96/EC on waste electrical and electronic equipment
Brief Outline	The WEEE Directive entered into force on 13 February 2003. It tackles the fast increasing waste stream of electrical and electronic equipment (EEE) and complements EU measures on landfill and incineration of waste. Increased recycling of EEE limits the total amount of waste, makes producers responsible for taking back and recycling and provides incentives to eco-efficient design. National governments have deadlines for organising separate collection (31 August 2005) and achieve recovery targets (31 December 2006). By 31 December 2008 new EU targets for recovery, recycling and reuse will be set. Member States are to draw up a register of producers and keep information on the quantities and categories of EEE placed on the market, collected, recycled and recovered in their territory. By middle of August 2005, producers must provide the financing of the collection, treatment and recovery of WEEE. For products placed on the market later than 13 August 2005, each producer is responsible for providing financing in respect of his own products.
Comments	The scope of this Directive applies i.e. to large and small household appliances. If micro-generators become more standard in households, it is important to adequately address the waste phase of these appliances. Issues like design of some RES and micro CHP plants, separate collection systems, recovery and recycling techniques, collection targets and producer responsibility (financing, information to consumers) will fall under the WEEE Directive.
Procedure	The deadline date for implementation of the Directive by Member States was 13 August 2004. In February 2004, the Commission presented proposal COM (04) 81 for a Council Decision to grant the Czech Republic, Hungary, Slovenia, Slovakia, and the three Baltic States temporary derogations from the Directive was adopted by the Council
Websites	http://europa.eu.int/comm/environment/waste/weee_index.htm

	Hazardous Substances in Electrical and Electronic Equipment ("RHS Directive")
Full Title	Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment
Brief Outline	The RHS Directive entered into force on 13 February 2003. Alongside the WEEE Directive, it tackles the fast increasing waste stream of electrical and electronic equipment (EEE). In order to prevent the generation of hazardous waste, the RHS Directive particularly focuses on the harmful content of EEE and requires the substitution of various heavy metals, brominated flame retardants and or polybrominated diphenyl ethers. From 1 July 2006, lead, mercury, cadmium, hexavalent chromium, PBBs and PBDEs in EEE must be replaced by other substances.
Comments	The RHS covers the same scope as the WEEE Directive, i.e. large and small household appliances. If RES and micro CHP heating systems become more standard in European households in the near future, it is important to adequately address their potentially harmful content. Issues like prevention and adaptation to scientific and technical progress will fall under the RHS Directive.
Procedure	During the first half of 2005, the Commission reviewed the provisions of the RHS Directive, in particular as regards the feasibility of widening its scope and adapting the list of substances it covers so as to take account of new scientific facts.
Websites	http://europa.eu.int/comm/environment/waste/weee_index.htm

Environment Action Programme (EAP)	
Full Title	Decision No 1600/2002/EC laying down the Sixth Community Environment Action Programme
Brief Outline	This Decision establishes the sixth Environment Action Programme (Commission Communication "Environment 2010: Our future, our choice" of 24 January 2001). The EAP, covering 1 January 2001 to 31 December 2010, defines the priorities, objectives and implementation measures of EU environmental policy up to 2010 and beyond. It proposes five priority avenues of strategic action (i.e. improving the implementation of existing legislation, integrating environmental concerns into other policies) and four priority areas for urgent action (climate change; biodiversity; environment and health; and sustainable management of resources and wastes).
Comments	As a highly environmentally friendly energy production process, DER can play a role in the priority area of climate change in helping to reduce greenhouse gases. More specifically, it can contribute to the following EAP challenges: the integration of climate change objectives into energy policy; the reduction of greenhouse gases by means of specific measures to improve energy efficiency, to make increased use of renewable energy sources, to promote agreements with industry and to make energy savings; the establishment of an EU-wide emissions trading scheme; and a review of energy subsidies and their compatibility with climate change objectives.
Procedure	No more than four years after the adoption of the Decision, initiatives must be taken in each area of action. During the fourth year of operation of the Programme and upon its completion, the Commission is to submit assessment reports to the European Parliament and the Council.
Websites	http://europa.eu.int/comm/environment/newprg/index.htm

	Noise Emissions of Outdoor Equipment
Full Title	Directive 2000/14/EC on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors
Brief Outline	This Directive entered into force on 3 July 2000. It simplifies the legislation about many noisy types of equipment and harmonise the requirements for their noise emissions. The Directive lies down provisions for equipment subject to permissible sound power levels (22 types) and equipment that is subject to noise marking only (41 types). Annex I defines the relevant equipment (i.e. compressors, combustion engines) and therefore these types of equipments are subject to rules that regulate to noise emissions to the environment. Next to noise limits, it also gives provisions on information of the public on the noise emitted by the equipment, conformity assessment procedures, manufacturer responsibilities, etc. However, the scope of the Directive only applies to equipment being placed in the European market or put into service in Europe for the first time after 3 January 2002.
Comments	The Directive covers a variety of combustion-engine cogeneration equipment, compressors (less than 350 kW) and power generators (less than 400 kW).
Procedure	After its entry into force, a list of notified bodies designated by the EU Member States and the EFTA Countries (EEA Members), under the new approach Directives, was drawn up.
Websites	http://europa.eu.int/comm/environment/noise/home.htm#3

	Integrated Pollution Prevention and Control ("IPPC Directive")
Full Title	Council Directive 96/61/EC concerning integrated pollution prevention and control
Brief Outline	The Directive establishes a set of EU-wide common rules on permitting for industrial installations. All installations covered by Annex I of the Directive are required to obtain an authorisation (permit) from the authorities in the EU countries. Unless they have a permit, they are not allowed to operate. The permits must be "integrated", i.e. they must take into account the whole environmental performance of the plant, including air emissions, water, land use, waste, use of raw materials, energy efficiency, noise, prevention of accidents, risk management, etc. Permits must be based on the concept of Best Available Techniques (BAT). The concept of BAT is defined in Article 2 of the Directive, whilst Annex IV provides considerations to be taken into account when determining BAT. In order to prevent disruptive changes and plant closures, the Directive grants to existing installations a transition period until 2007 (with extensions granted to Poland, Slovenia, Slovakia, Latvia and possibly Bulgaria and Romania). To all new installations and significant modifications of existing installations, it applies since October 1999. The Directive also provides for the setting up of a European Pollutant Emission Register (also known as EPER). EPER, but also permit applications, permits, and monitoring reports have to be accessible to the public.
Comments	Work on BREFs (BAT reference document) is under way in some 30 sectors. The end of 2005 will complete all BREFs. The draft BREF on Large Combustion Plants from March 2003 discusses CHP extensively. Because of its high conversion efficiency, CHP is generally considered the Best Available Technology for the combustion of gaseous and liquid fuels, biomass and peat in such plants. It is thus recommended to use CHP whenever a suitable heat demand is available.
Procedure	The final deadline for existing installations to apply the best available techniques and meet all other requirements is October 2007. The Commission organises an information exchange on BAT, which is coordinated by the European IPPC Bureau. In order to promote effective implementation of the Directive, the Commission reports on progress made in the Member States.
Websites	http://europa.eu.int/comm/environment/ippc/index.htm http://eippcb.jrc.es http://www.eper.cec.eu.int/eper/default.asp

BUILDINGS

	Energy Performance of Buildings ("Buildings Directive")
Full Title	Directive 2002/91/EC on the energy performance of buildings
Brief Outline	Lays down a general framework to devise a methodology to calculate the integrated energy performance of buildings, for which Member States have to define minimum requirements. This performance describes the amount of energy, which the standard use of the building consumes. The calculation process has to take into account the “positive influence of electricity produced by CHP” and of “district or block heating and cooling systems”. For new buildings with a useful floor area of more than 1000 m2, Member States have to ensure that the feasibility of alternative systems, including “CHP” and “district or block heating or cooling” systems is considered. The Directive also sets the basis for creating an energy performance certification system of buildings. This certificate must be visibly displayed in larger public buildings. Member States will also have to make sure that regular inspections of old boilers, air conditioning systems and heating installations are being carried out, and that the owners of the buildings are advised on improvements, alternatives, or replacements.
Comments	Four mechanisms could support DER: (a) requirement to integrate its benefits into the calculation of the energy performance of buildings (b) mandatory feasibility studies for CHP for larger new buildings (c) the inspection duties for old heating installations (d) the energy performance certificate of buildings. But buildings smaller than 1000m2 are not properly covered. The effect on the market penetration of micro systems for single apartments or individual dwellings may therefore be limited.
Procedure	The deadline for transposition into national legislation is January 2006. Supported by most Member States, the Commission aims to harmonise the application of the Buildings Directive. It therefore has requested CEN, CENELEC and ETSI to develop European Norms to standardise energy efficiency calculation methods, energy performance standards and inspection duties established in the Directive. The standardisation timetable foresees the development of pre-standards (prENs) by 2005. Member States have been asked to keep a regulatory "stand-still" until the ENs become binding. A proposal to amend the Directive to cover buildings smaller than 1000m2 is expected by the 2nd half of 2006, with final adoption possibly in 2008.
Websites	http://europa.eu.int/comm/energy/demand/legislation/buildings_en.htm

INTERNAL MARKET FOR ENERGY

	Internal Market for Electricity ("Electricity Directive")
Full Title	Directive 2003/54/EC concerning common rules for the internal market in electricity
Brief Outline	Defines common rules for the generation, transmission, distribution and supply of electricity. The electricity market has to be opened at the latest to all non-household customers from 1 July 2004 and to all customers on 1 July 2007. Authorisation procedures for new generators can include requirements related to environmental protection, energy efficiency or specific primary energy sources. They also should reflect the limited size and potential impact of small and/or distributed generators. Distribution system operators have to consider energy efficiency, demand side management and/or Distributed Generation when they plan the network. Member States can require transmission and distribution system operators to give priority dispatch to generators using renewables, waste or CHP. Electricity suppliers have to specify in their bills and promotional materials for final customers the fuel mix of their electricity during the last 12 months. They also have to inform customers where to find information on the CO_2 emissions and the radioactive waste, which this fuel mix generates. Transmission and distribution system operators, which form part of an integrated electricity company, need to have at least a legal form, organisation and decision-making, which are independent from other activities of the company. Integrated electricity companies have to keep separate accounts for their transmission, distribution and other activities. Revenue from ownership of electricity networks has to be specified. The connection of new generators to the transmission and distribution networks has to be based on objective, transparent and non-discriminatory criteria, and all costs and benefits from connecting generators using renewables, CHP and/or Distributed Generation have to be taken into account. Network tariffs have to be approved and published before being applied. Member States have to designate a national regulatory authority, which is "wholly independent of interests of the electricity industry" and which disposes of a minimum set of regulatory and supervisory powers vis-à-vis electricity undertakings. They have to be able to monitor the functioning of the market and of competition, control grid connection and grid use conditions and tariffs, and settle disputes between market participants.
Comments	The Directive gives national governments a wide margin to establish regulatory mechanisms and economic incentives to promote energy efficiency, Distributed Generation and cogeneration. Yet, whether Member States make use of these opportunities or not depends to a large extent on their policy objectives and determination. In its latest benchmarking report, the Commission expressed disappointment about slow progress in developing the internal electricity market in most Member States. The risk of new pan-European oligopolies is a genuine possibility.
Procedure	The deadline for transposing the Directive into national law was 1 July 2004. Until 2010, Member States have to submit by 31 of each year a

	report to the European Commission, which informs on market dominance, and predatory or anti-competitive behaviour of market participants.
Websites	http://europa.eu.int/comm/energy/electricity/legislation/index_en.htm

	Internal Market for Natural Gas ("Gas Directive")
Full Title	Directive 2003/55/EC concerning common Rules for the Internal Market in Natural Gas
Brief Outline	Establishes common rules on the storage, transmission, supply and distribution of natural gas. Lays down detailed rules on the organisation and functioning of the natural gas sector, including liquefied natural gas (LNG), biogas and gas from biomass and other types of gas. The gas market should be opened for all non-household customers by July 2004 and for all customers by July 2007. Legal unbundling of network activities from supply is required like in the Electricity Directive. Member States have to establish a regulator, require published network tariffs, reinforce public service obligations and monitor security of supply. Member States can chose between negotiated or regulated access to the gas network system. Gas undertakings may refuse access only if they can give substantial reasons. The Commission has to benchmark progress on the Gas Directive annually.
Comments	According to the latest benchmarking report from 2004 of the European Commission, competition in the natural gas market has developed well in only 4 out of 25 Member States, whilst the majority of countries haves only taken initial steps towards market opening. There are still too many barriers to reach the objective to "…[to create] a fully operational internal gas market, in which fair competition prevails…" seems therefore still remote. Despite indications that gas prices particularly for large customers may be becoming more competitive, the evidence in published statistics is still unclear. The risk that national monopolies will be replaced by a pan-European oligopoly is a genuine possibility. Recent trends point towards this development.
Procedure	The deadline for transposing the Directive into national law was 1 July 2004.
Websites	http://europa.eu.int/comm/energy/gas/legislation/index_en.htm

	Taxation of Energy Products and Electricity ("Energy Taxation Directive")
Full Title	Directive 2003/96/EC restructuring the Community framework for the taxation of energy products and electricity
Brief Outline	This Directive widens the scope of the EU's minimum rate system for energy products, previously limited to mineral oils, to all energy products including coal, natural gas and electricity. It aims to reduce distortions caused by different tax rates on energy products between Member States, and between mineral oils and the other energy products. It also provides for national incentives to encourage energy efficiency and emissions reduction. Energy products are taxed only when used as fuel or for heating, and not when used as raw materials, or in chemical reductions or in electrolytic or metallurgical processes. Furthermore, energy products used in particular in stationary engines and for agricultural purposes will normally be taxed at lower levels than the levels applicable to fuel used in motorcars. Member States will be able to tax business use of energy products at a lower rate than non-business use, and to exempt renewable energy sources -including bio fuels- and electricity from high-efficiency CHP. The Directive includes various transitional periods and derogations for certain Member States of the old EU15.
Comments	The Directive gives Member States the possibility to support the development of renewables and high-efficiency cogeneration through preferential tax regimes. But this outcome depends (a) on national governments and (b) on whether installations qualify as high-efficiency cogeneration under the European Cogeneration Directive.
Procedure	The Directive came into force on 1 January 2004. The Commission has proposed a Directive to amend the Energy Tax Directive by detailed transitional arrangements for the 10 new Member States (COM/2004/0042)
Websites	http://europa.eu.int/eur-lex/lex/JOHtml.do?uri=OJ:L:2003:283:SOM:EN:HTML

RESEARCH AND DEVELOPMENT

	Research and Development ("FP6")
Full Title	Decision No 1513/2002/EC concerning the sixth framework programme of the EC for research, technological development and demonstration activities, contributing to the creation of the European research area and to innovation (2002-2006)
Brief Outline	European Communities Framework Programme 6 aims to contribute to the creation of a true "European Research Area" (ERA). It fosters scientific excellence, competitiveness and innovation through the promotion of better co-operation and co-ordination between relevant actors at all levels. Objectives of the 6the Framework Programme are: integration and strengthening the European research area, structuring the European research area and activities of the Joint Research Centre
Comments	The 6th Framework Programme has specific provisions for electricity networks of the future, integration of DER and development of RES and fuel cells. RTD priorities for the long-term development of projects selected in these areas have shown a coherent strategy with integration of DER into future active networks as well as matching with other EU policy objectives of sustainable development, energy savings, competitiveness of the European Union and environmental protection, especially climate change mitigation.
Procedure	Call for proposals
Websites	http://europa.eu.int/comm/research/fp6/index_en.html

EU LEGISLATION AND POLICIES UNDER DEVELOPMENT

DEMAND SIDE MANAGEMENT AND ENERGY SERVICES

	Energy end-use efficiency and energy services ("Energy Services Directive")
Full Title	Proposed Directive on energy end-use efficiency and energy services (COM/2003/739)
Brief Outline	The proposed Directive aims to boost the cost effective and efficient end-use of energy in the Union by establishing a framework for the creation of a competitive European market for energy services. It is addressed mainly at final consumers (affecting non-energy intensive industries and transport), energy distribution and retail energy sales companies, and Member States. "Energy end-use services" would be defined as including both energy and energy using equipment or technology. The proposal would set a national mandatory target for cumulative annual energy savings of 1% (1.5% in the public sector) in the area of energy supplied to final consumers. Actions taken by energy producers to comply with EU Emissions Trading requirements would count towards meeting these targets. Energy distributors would be required to integrate energy services into their distribution and sales activities and to cover at least a 5% share of their consumers. Member States would have to makes sure that energy services and energy efficiency measures are offered to all eligible customers. Governments would also to ensure that energy distributors and retailers promote actively energy services, and refrain from activities that impede their delivery. Regulations impeding the use of financial instruments and contracts for energy savings would have to be removed. The Directive would request qualification and certification schemes for players delivering energy services, promote the use of financial instruments and contracts for energy services, establish funds to support energy efficiency programmes, and ensure availability of independent energy audit schemes. There are also various requirements for metering and informative billing of energy consumption proposed.
Comments	The proposed Directive could potentially help to remove market barriers and create new business opportunities for DER. The cost-efficiency of DER and its competitiveness in the new market for energy services would become important criteria for success.
Procedure	Procedure reference: COD/2003/0300. The co-decision procedure applies. The Council has issued a first revised version of the draft Directive on 23 September 2004. The Committee on Industry, External Trade, Research and Energy (ITRE) of the European Parliament finalised its first reading in summer 2005. The Directive may be approved towards 2006, but this is uncertain.
Websites	http://europa.eu.int/comm/energy/demand/legislation/end_use_en.htm http://europa.eu.int/prelex/detail_dossier_real.cfm?CL=en&DosId=187530 http://wwwdb.europarl.eu.int/oeil/oeil_ViewDNL.ProcedureView?lang=2&procid=2898

INTERNAL MARKET FOR ENERGY

	Access to Gas Transmission Networks
Full Title	Proposed Regulation on conditions for access to the gas transmission networks (COM/2003/741)
Brief Outline	The proposal is based on voluntary guidelines adopted by the European Gas Regulatory Forum ('Madrid Forum') and aims to make these guidelines binding. The proposal provides for the adoption of binding guidelines on Third Party Access services to be offered by the system operators, capacity allocation & congestion management, transparency requirements and tariff structures.
Procedure	Procedure reference: COD/2003/0302. The co-decision procedure applies. The European Parliament Committee responsible is ITRE (Industry, External Trade, Research and Energy). Parliament is currently working on its second reading.
Websites	http://europa.eu.int/prelex/detail_dossier_real.cfm?CL=en&DosId=187550 http://wwwdb.europarl.eu.int/oeil/oeil_ViewDNL.ProcedureView?lang=2&procid=2899

ENERGY INFRASTRUCTURES

	Energy Infrastructure Investment and Security of Supply ("Infrastructure Directive")
Full Title	Proposed Directive concerning measures to safeguard security of electricity supply and infrastructure investment (COM/2003/740)
Brief Outline	The proposed Directive aims to promote investment in the European energy sector by both strengthening competition and helping to prevent the reoccurrence of the blackouts that took place during summer 2003. In particular, it highlights the major importance of a clear demand management, through the development of a more oriented energy efficiency policy. It also emphasises the need of a clear EU legislative framework for the proper functioning of a competitive internal market for electricity, by safeguarding security of electricity supply and ensuring an adequate level of interconnection between Member States, through general, transparent and non-discriminatory policies. Moreover, the Commission makes further proposals for the Energy Transeuropean networks in electricity and gas, in order to make it more efficient, to link decisively the future new Member States to the Energy Single Market, and to develop a similar approach with neighbouring countries. It also proposes a regulation on cross-border exchanges in gas that will incorporate in the EU legislation the guidelines agreed by the sector and empower the national regulators to ensure their implementation.
Comments	Under the Directive, Member States would have to develop policies on how to satisfy electricity demand and define standards to ensure secure transmission and distribution. Transmission system operators and national energy regulators would play a bigger role than now in producing and monitoring investment strategies.
Procedure	The procedure reference is COD/2003/0301. The draft Directive has been issued by the European Commission in December 2003. The co-decision procedure applies.
Websites	http://europa.eu.int/comm/energy/electricity/infrastructure/com_proposal_2003_en.htm http://europa.eu.int/prelex/detail_dossier_real.cfm?CL=en&DosId=187573 http://wwwdb.europarl.eu.int/oeil/oeil_ViewDNL.ProcedureView?lang=2&procid=2900

	Trans-European Energy Networks (TENs)
Full Title	Proposed Decision laying down a series of guidelines for Trans-European energy networks (COM/2003/742)
Brief Outline	It aims to support the development of cross-border electricity and gas networks, particularly to link up with new Member States and neighbouring regions; it would identify projects of common interest, including those with priority, access to Community financial aid from the budget for TENs, Structural and Cohesion Funds, and the European Investment Bank; it would introduce the Declaration of European Interest and nominate a European co-ordinator for some cross-border projects; it would oblige Member States to set out streamlined timetables for these projects and grant planning permits for their accelerated development; Commission would have to report annually on overall level of interconnection, the projects, and its financial contribution to them.
Comments	The construction only of the priority projects foreseen for the 2007-13 period would require a total investment in the order of €28 billion. The EU financial support foreseen will lead towards a more centralised electricity system in the EU. An investment of a similar size in the development of a more decentralised electricity system would probably result in better security of supply, higher efficiency, primary energy savings, reduced CO_2 emissions, lower specific investment costs, and more jobs.
Procedure	The procedure reference is COD/2003/0297. The co-decision procedure applies.
Websites	http://europa.eu.int/prelex/detail_dossier_real.cfm?CL=en&DosId=188750 http://wwwdb.europarl.eu.int/oeil/oeil_ViewDNL.ProcedureView?lang=2&procid=2954

RENEWABLE ENERGY SOURCES

	Heat from Renewable Energy Sources (RES-H)
Full Title	Expected measure on Heat from Renewable Energy Sources
Brief Outline	As suggested during the first phase of the European Climate Change Programme, this initiative would complement other measures set in the White Paper on “Energy for the future: Renewable sources of Energy”. It would address targets, support schemes and certification procedures for RES-H. The Commission has published a study that analyses the need for such a Directive. It suggests two possible ways of moving forward on this issue. First, a Directive on RES-H, aiming at setting specific targets and co-ordinating with the legislation in this area. Or second, a Communication on RES-H, aiming at setting out a strategy for promoting RES-H through legislation, list indicative legislative and non-legislative measures relating to RES-H and a timetable for their adoption. In this case, the Commission would review the strategy at the end of 2005, at which time it would decide whether a separate Directive on RES-H is needed.
Comments	It is to date unclear whether the proposed initiative will take the form of a Directive or of a Communication on a strategy. Whatever the outcome, this initiative could become an instrument to promote heat generation by means of bio-fuelled cogeneration and solar heating installations.

ENVIRONMENT AND CLIMATE CHANGE

Air Quality	**Clean Air for Europe Programme (CAFE)**
Full Title	Commission Communication "The Clean Air for Europe (CAFE) Programme: Towards a Thematic Strategy for Air Quality" COM (2001) 245
Brief Outline	CAFE was launched in March 2001 and is a programme of technical analysis and policy development, which will lead to the adoption of a thematic strategy on air pollution under the Sixth Environmental Action Programme. Its aim is to develop a long-term, strategic and integrated policy advice to protect against significant negative effects of air pollution on human health and the environment.
Comments	Under CAFE research is currently undertaken concerning the costs and environmental effectiveness of reducing air pollution for large and small-scale combustion installations. More specifically, the programme looks at the amounts of heavy metals emitted, the cost-effectiveness and costs and advantages of further emission reductions, the technical and economic feasibility, an inventory of existing measures and an inventory of new and emerging technologies.
Procedure	Research into the small and large combustion plants were carried out during 2004. The integrated policy advice from the CAFE programme was ready at the beginning of 2005. The European Commission presented its “Thematic Strategy on Air Pollution” during the first half year of 2005, outlining the environmental objectives for air quality and measures to be taken to achieve the meet these objectives.
Websites	http://europa.eu.int/comm/environment/air/cafe/index.htm