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# Europe's Vulnerability to Energy Crises

World Energy Council 2008

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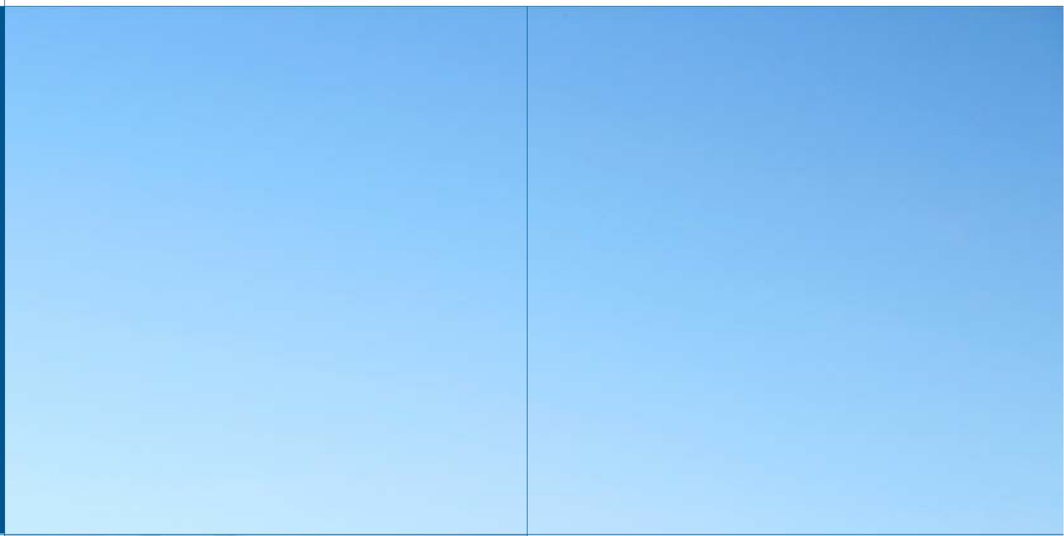

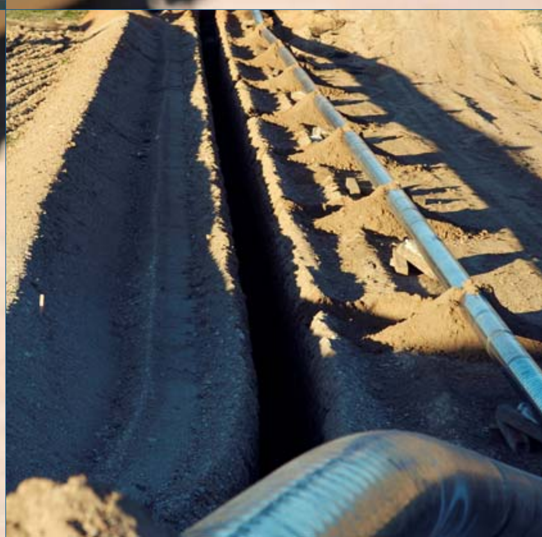

# Europe's Vulnerability to Energy Crises

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World Energy Council 2008



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# Foreword and Acknowledgements

## Background

The growing dependency of Europe as a whole on energy imports and anticipated further increases in energy prices reinforce the concerns about meeting the energy demand in the future. It is well recognised that ensuring secure and reliable energy supplies at affordable, stable prices is vital to economic and social development and should constitute an integral part of a sound and consistent energy policy. This is particularly valid in the current process of market liberalisation and competition: conditions where the impact on security of supply is insufficiently confirmed.

Aware of these uncertainties, the WEC-European Member Committees have supported the proposal made by Mr. Pierre Gadonneix, the vice-chair, WEC-Europe, at its regional meeting (Brussels, 10 March 2005) to undertake a regional study entitled "*Vulnerability of Europe and its economy to energy crises".* The development of this study has been approved by the WEC-Study and Programme Committees.

## Objective

The objective of the Study is to identify the threats leading to potential energy crises and suggest solutions for facing, in an appropriate way, the related key challenges. In addition, the Study intends to develop a number of indicators effective enough to assess the level of different types of vulnerability, as well the overall vulnerability of a country or region, including threats to physical disruption, higher energy prices etc. The use of vulnerability indicators is highly recommended for all WEC-European countries, as well as to policy makers and market players.

## Organisation

A study group was in place by May 2005. It was composed of some 28 participants from 19 countries. I served as Chair; Mr. Kelvin Beer (United Kingdom) as secretary during the first year; and Mr. Slav Slavov as WEC Liaison. Along with the chapter co-ordinators, we developed a study approach and agreed on the structure, assignments and timetable. We held a number of meetings in Zagreb, Bucharest, Milan, Prague, Neptun (Romania) and Lisbon where we agreed on the final draft of the Study.

## Message

The message of how to mitigate the growing current and future vulnerability of the European energy markets is reflected in the overall conclusions and recommendations.

The Study has identified the major challenges and suggested a number of recommendations upon which all stakeholders involved in the energy sector should act. The WEC-European Group fully support the EC-position for setting up a common EU-energy policy which may enhance the energy co-operation and trade and thus to reduce the European energy vulnerability. Europe should speak with one voice when maintaining a policy dialogue with strategic external suppliers. Substantive investment in the European energy market is required. The current legal framework does not attract investors. The climate change issue presents a new dimension; a stronger energy efficiency approach is needed, while the energy mix must be more tolerant to new alternative sources, including nuclear energy.

## Acknowledgements

It is my privilege and pleasure to express my sincere thanks to all the members of the Study Group who contributed to the different chapters and final conclusions/recommendations. I am particularly grateful to the chapter co-ordinators, namely:

**Chapter 2**

- Prof. Denis Babusiaux, French Institute on Oil

**Chapter 4**

- Jorg Schupan, Vatten-Fall Europe

**Chapter 5**

- Nils Andersson and Leif Halvorsen, Vattenfall-Sweden

**Chapter 6**

- Herve Nicolle, Gas de France

Thanks to Slav Slavov, we have drafted the final conclusions and recommendations. A special thanks to Kieran O`Brien, Chairman of Irish WEC-MC, for his efforts in harmonising the different chapters.

At the conclusion of this two-year effort, I would like to:

First, express my hope that this study may contribute to policy makers, energy market players and civil society in Europe, and provide more constructive forms of co-operation when facing the major energy challenges (national, regional and global) whose solutions nowadays are differently sought.

Second, thank all WEC-European MCs who nominated experts to the Study Group and to those who kindly hosted a Study Group meeting.

Third, give my gratitude to the WEC-London Office for providing full support in terms of substance and logistics. This appreciation is particularly directed to the Director of WEC-Programmes, Ms. Elena Nekhaev and her staff, for editing, formatting and publishing the Study.

Lastly, request the Study participants and the WEC-MCs to promote the Study recommendations and vulnerability indicators as widely as possible, for the benefit of all WEC-European countries.

**Anca Popescu**
*Study Chair*
*Bucharest, May 2007*

# Part One
# Introduction

The rapid change of the economic environment requires the energy sector to develop new concepts and policies to respond better to the security requirements of energy supply.

A discussion about security of supply requires a common understanding of the definition of this concept.

Energy security is defined as an uninterruptible supply of energy, in terms of quantities required to meet demand at affordable prices.

As a principal issue, the subject of energy security initially arose from concerns about the physical security of energy supplies. However, recent concerns have been focused on the economic conditions affecting those supplies. Physical risk will remain as long as energy supply has to rely on transportation and related infrastructure. Diversification of energy resources reduces the chance of serious disruption to energy access.

There are several risks that could endanger the security of energy supply, e.g. exporting countries might use the threat of disruption to apply political pressure. Another risk is an energy price shock, followed by sustained higher prices and a negative impact on the economy. This situation could create a long-term supply/demand imbalance, with the probability of serious tensions in national and international markets. In addition, these threats can have environmental implications at local, regional and international levels.

## Energy Security Means…

- Reduced vulnerability to transient or long-term physical disruptions to import supplies
- Availability of local and imported resources to meet the growing demand for energy over a period of time and at affordable prices

The European Commission (EC) emphasised that "Energy supply security must be geared to ensuring the proper functioning of the economy, the uninterrupted physical availability at a price which is affordable, while respecting environment concerns. Security of supply does not seek to maximise energy self-sufficiency or to minimise dependence, but aims to reduce the risks linked to such dependence".

The EC promotes long-term security in Europe because it is associated with long-term adequacy of supply, availability and infrastructure for delivering this supply to markets and a framework to create strategic security against major risks.

Ensuring a reliable supply of energy to Europe and elsewhere has traditionally been considered primarily the responsibility of governments. Therefore, governments intervened to manage risks to supply interruption and did so with little regard to cost. Measures ranged from subsidies to producers and consumers of domestic energy resources (e.g. coal and nuclear), stocking imported fuel, to awarding government contracts and even military interventions. Many of these approaches are no longer feasible in a free market and it is therefore important to establish how security of supply can be achieved under conditions of energy market liberalisation and deregulation. Energy security needs must be investigated and taken into consideration both at regional and global levels.

In general, liberalisation enhances the security of supply by increasing the number of market participants and improving the flexibility of energy systems. However, liberalisation may also pose new risks, as the markets make the cost of security of supply more transparent. However, the main effect of liberalisation is that it has shifted the prime responsibility from governments to market participants.

In this Study, the key issue relating to energy security is that of vulnerability. This can be defined either as "something that is not protected against attack, therefore exposed to damage" or "a critical turning point in time of supply, creating a sense of danger or anxiety about the future", both definitions are applicable to energy security vulnerability.

The vulnerability of an energy system can be measured by its ability to cope with adverse events. This is defined in the context of the increasing energy imported to Europe and the increase in energy prices over recent years. Reasons include, among other things, an unstable political climate in the countries of the major suppliers and/or the substantial energy demand growth in the emerging economies. This can be coupled with the uncertainty of market liberalisation and competition relating to the security of supply and grid reliability.

The ultimate objective of the Study is to assess how the European economies could respond to a possible energy crisis initiated by events such as physical disruption of supplies, higher energy prices or lack of reserves capacity. The Study also attempts to develop a set of vulnerability indicators. These can be used to evaluate the level of vulnerability, both at the national and regional level. These indicators may help to pinpoint areas where policy makers and market players need to act in order to mitigate the impact of a possible energy crisis.

The Study tries to enhance the understanding of the conceptual viewpoint of vulnerability that the European energy markets might face in an unpredictable future, characterised by uncertainty, difficulties, danger or anxiety.

# Part Two Vulnerability Indicators

## Introduction

The introduction of indicators helps to simplify the complex and diverse relations that characterise energy economics in the wider context of Europe. They help us to focus on those elements of energy economics that either increase, or reduce the vulnerability.

Energy vulnerability is now of more concern to Europeans than it has ever been before and Europe seems determined to take action to reduce both the likelihood of supply interruptions and the economic impacts they may have on its economy and welfare.

Currently the EU is debating a number of energy issues: nuclear renaissance, strategic gas stocks, the potential contribution to vulnerability reduction by enhanced demand side management, a renewed push for liberalisation and the acceptance of major energy market distortions for strategic reasons.

There is clearly no suitable methodology to assess and quantify energy vulnerability in a way that is factual, objective, unbiased and above all transparent and accessible. This Study can be best understood in terms of metrics: that is, the application of set parameters and indicators to the wide range of factors, which influence energy vulnerability

Vulnerability is multi-dimensional, and several indicators are needed. A distinction is generally made between physical disruptions and of socio-economic and environmental risks.

Using aggregate and simple indicators, the next section discusses vulnerability at the macroeconomic level, addressing economic risk at a national level. The microeconomic level is covered in section 2.3, from the point of view of the consumer, then those of energy suppliers in section 2.4. Finally, the main events causing energy vulnerability are discussed. This divided approach enables accounting for the various risks mentioned above.

## A Global and Macroeconomic Approach

It is important to distinguish energy vulnerability from energy dependency, as it is possible to be dependent without being vulnerable. A country that imports the majority of its energy at a sustainable cost and ensures the security of its supply by means of well-diversified sources will be dependent but not vulnerable. A country which produces the majority of its energy at a prohibitive cost or using obsolete technologies will be vulnerable, even if independent of external suppliers.

A country may be considered vulnerable when energy policy decisions are dictated by economic factors beyond its control. It can be vulnerable when an energy spot price increases, as the import energy bill is too costly in macroeconomic terms. These impacts are considered in Chapter 3. Here the focus will be on factors that underlie vulnerability: price volatility and exchange rate fluctuations.

Vulnerability is also possible when the energy spot price is decreasing. Net energy exports by a country may represent a significant portion of its national budget or a low rate of return on related energy investments to this drop in price.

**Table 2-1** Rate of Energy Independence

| Country | Year | Rate of energy independence in % for Solid mineral fuels | Oil | Gas |
|---|---|---|---|---|
| France | 2005 | 1.8 | 1.5 | 2.0 |
| | 1995 | 36.6 | 2.8 | 10.8 |
| UK | 2005 | 31.9 | 120.1 | 93.7 |
| | 1995 | 66.9 | 189.3 | 102.3 |
| Italy | 2005 | 0.0 | 7.1 | 15.2 |
| | 1995 | 0.8 | 5.4 | 40.8 |
| Spain | 2004 | 32.9 | 0.4 | 1.3 |
| | 1995 | 51.8 | 1.2 | 7.2 |
| Germany | 2005 | 65.0 | 3.0 | 18.0 |
| | 1995 | 82.0 | 2.0 | 22.0 |

Source: Comité Professionnel du Pétrole

Policy decisions on energy may impact a country's dependency rate, energy efficiency and supply diversification. Relatively straightforward indicators can measure the corresponding results. Policies aimed at diminishing price volatility are more difficult to quantify and are discussed in the next chapter.

## Energy Interdependence

Vulnerability may be linked to a strong dependency on energy imports. The rate of dependency is measured by the ratio of net energy imports to total (primary) energy consumption. The energy dependency rate (ED) is naturally the complement of the rate of energy independence. The latter, often mentioned in various statistics, is the ratio of domestic production to total primary energy consumption.

For example, the energy independence rate in 2005 for certain countries is as follows:

- **50 percent** for France, relatively stable since 1990, due to nuclear power, against **24 percent** in 1973 and **62 percent** in 1960
- **92 percent** for the United Kingdom against **129 percent** in 1999[1]
- **14 percent** for Italy against **20 percent** in 1995
- **35 percent** for Germany against **40 percent** in 1995

It is important to calculate a separate rate of dependency for each type of energy (for example the ratio of net oil imports to consumption). Each energy source has to some extent a captive market (oil in the transport sector for instance) and uses different logistic systems for delivery. Oil has the highest energy vulnerability in Europe because the European Union (EU) relies significantly on imports and a substantial volume of imports comes from those regions considered to have a high geopolitical risk.

Oil price volatility is greater than that of other energy sources, particularly coal. Other energy systems depend to a certain extent on transport and therefore on oil. As an example Table 2-1 lists the rate of independence per energy resource for five countries. These indicators are further discussed in chapter 4 and rates are given for all countries involved in this study.

It is possible to calculate the dependency or independence rate for electricity. Thus, the independence rate was 104.4% in 2005 for France and 96.4% for the United Kingdom. It must be noted that this rate does not have the same significance for the other energy resources. The vulnerability of the electricity sector is more closely linked to the primary energy resource used to generate electricity than to the rate of coverage of demand by domestic production. Since electricity cannot be stored, it is important to consider not only an average dependency rate but also variable rates, which may differ according to the season or to the time of day.

[1] Ratio of energy domestic production to energy consumption: this ratio exceeds 1 in case of net export.

It is also possible to define dependency or independence indicators relative to the geopolitical area (dependency on the Middle East, for example, is considered to be a high-risk area).

**Import Concentration**

Dependency on external supplies corresponds to a greater vulnerability at a given dependency rate if procurements are concentrated on a small number of sources. It is then possible to calculate an import concentration index. This index [HHI] (Hirschmann-Herfindahl Index) is the sum of the squared market shares held by the various suppliers; namely:

- (0.1) $HHI = \sum_i s_i^2$

Where $s_i$ represents the market share of, for instance, Saudi Arabia, Kuwait, Venezuela or Norway (etc.) in the oil supply of the relevant country.

An HHI between 8,000 and 10,000 usually indicates a high supplier concentration leading to increased vulnerability. On the other hand, a HHI smaller than approximately 1,600 indicates diversified supply sources, which should reduce vulnerability. For example, the French HHI in 2004 amounted to 2,538 for oil imports and 2,469 for natural gas imports.

An alternative way to characterise the diversification of supply is to use the Shannon-Wiener Index. It is formulated as follows:

- (0.2) $SWI = -\sum_i p_i \ln(p_i)$

Where $p_i$ represents the proportion of the total energy supplied by source i.

The value of this index is naturally higher with a greater number of suppliers. With a fixed number of suppliers, it is all the greater for market shares of suppliers closer to one another. Like the HHI, this index can be used to measure the diversification of the energy mix of a given sector. Thus, a power generator or the electricity production of a country could be considered as less vulnerable if different primary energies: coal, nuclear, gas, renewable energies, etc., are used in balanced proportions. Massive reliance on combined cycle gas fired power plants, considered to be the cheapest in recent years, could ultimately be a factor of vulnerability if natural gas prices rise steeply.

**Energy Intensity**

The energy intensity of GDP is the ratio of primary energy consumption expressed in tonnes-of-oil-equivalent (toe) to GDP (expressed in euros). Since the first oil shock, industrialised countries have witnessed a significant drop in energy intensity resulting from energy conservation, technical progress and changes in economic activities (larger share of tertiary activities in GDP).

The reinforcement of voluntary energy efficiency measures can contribute to reducing the European economy's sensitivity to fluctuating energy prices. Further decreases could result from structural changes in the economics of transition countries like Poland, the Slovak Republic, Hungary, Romania and Bulgaria where energy intensity is still high compared to most other EU member states.

**Net Energy Import Bill**

Vulnerability is not only linked to dependency on imports expressed in quantities, but also to the value of these imports.[2] It is possible to calculate the ratio of this "net energy import to the balance of trade or, more frequently, to GDP. A certain number of elements are included in the energy bill showing that it depends on several indicators and consequently may be analysed in many different ways.

The energy bill: cost of net energy imports expressed as a fraction EB of GDP, may be written in the following ways:

- (0.3) $EB = \frac{EVEB}{GDP}$
- (0.4) EB = ED x INT x ASC x EXC
- (0.5) $ED = \frac{NEI}{TPES}$ ;
- (0.6) $INT = \frac{TPES}{GDP}$ ;
- (0.7) $ASC = \frac{DVEB}{NEI}$ ;
- (0.8) $EXC = \frac{€}{\$}$

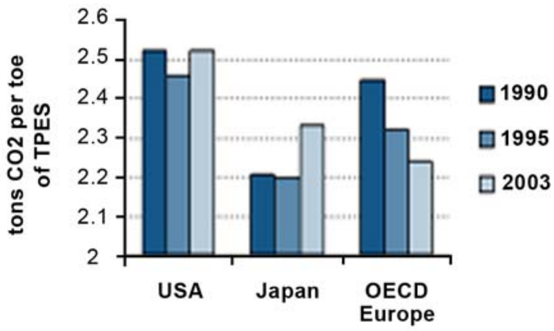
[2]Several parts of this section are extracts of Jacques Percebois paper (2006) with the author's permission (see References).

Thus, it can be noted that the "vulnerability value" of energy imports may be linked to dependency on imports, as well as to a high average cost of an imported tonne, or to a euro to dollar exchange rate unfavourable to the euro. If the energy intensity of GDP is higher, the energy bill will be more substantial. Note however that the most important factor explaining the differences in energy bills between the European countries is the dependency rate (ED). In fact, for the five countries listed previously in table 2-1, the energy intensity only varies between 0.13 and 0.17 toe per thousand euros of GDP, while the dependency rate, which was negative for the United Kingdom until 2004, rose to 95.5% in Italy in 2005. As an example, the French energy bill amounted to 5.2% of GDP in 1981, at the height of the second oil crisis and of the "dollar crisis", against 1.8% in 1986, 1.4% in 2003 and 2.3% in 2005.

**Terms**

- EVEB is the value of net energy imports, expressed in euros (€)
- DVEB is the value of net energy imports, expressed in dollars ($)
- ED is the rate of energy dependency analysed above, i.e. the ratio of net energy imports to total primary energy supply TPES (expressed in toe)

**Figure 2-1** Ratio of $CO_2$ Emissions to Total Primary Energy Supply




Source: IEA

The pursuit of energy independence may thus increase the vulnerability of the rest of industry, weakened through lack of investment.

- INT is the energy intensity of GDP, i.e. the ratio of total primary energy supply expressed in toe to GDP (expressed in euros).

These latter two ratios are the indicators mentioned in the previous sections. Energy policies can have an impact more easily on these than on the next two.

- ASC is the average supply cost, i.e. the weighted average cost of net energy imports expressed in $ (ratio of the energy balance value, expressed in $, to net energy imports (NEI), expressed in toe). It is, therefore, the weighted average cost in dollars of a unit of imported toe

- EXC is the euro to dollar average exchange rate, i.e. amount of € required to buy 1$.

### Carbon Content of Primary Energy Supply

Rising concerns about global climate change will make greenhouse gases, and particularly $CO_2$, emissions become more and more costly in Europe and probably worldwide. The $CO_2$ content of the total primary energy supply (TPES) depends mostly on energy substitution. Countries such as Australia, Greece and Poland with a significant market share of coal have a high carbon content of their primary energy supply. From 1990 to 2003, the ratio of $CO_2$ emissions to TPES decreased by 2.8% in the OECD as a whole while this pattern varies from one country to the other. As Figure 2-1 shows, the ratio was stable in USA, increased in Japan and decreased by 8.3% in OECD-Europe.

The performance of OECD-Europe was mainly due to the substitution of coal and oil by natural gas and nuclear. From 1973 to 2003, the share of coal and oil in OECD-Europe decreased from 84.5% to 55.6% while natural gas and nuclear energy accounted for 11% in 1973 and 41.3% in 2003.

### Price Volatility

Energy vulnerability may be linked to the volatility of energy prices. When an oil crisis occurs, investing heavily in alternate high-cost sources may be imprudent, especially if there is a subsequent oil price collapse. As there is a high capital intensity in the energy sector, certain investments are only profitable in the long term. This volatility demonstrates the cost of irreversibility (sunk costs) and explains why many investors will choose technologies with low risk and a short payback period. Encouraging customers to choose natural gas when the price of hydrocarbons is low may be questionable if the oil price increases sharply. Hence, there is a need to consider mechanisms for stabilising prices in order to protect certain areas of the industrial sector from extreme price fluctuations.

As an example, during reconstruction after the Second World War, France developed electricity generation from coal (as well as from hydropower sources). The choice of coal was perfectly justified at the time but became questionable at the beginning of the sixties, a period of low international oil price. French industry became vulnerable due to the high cost of national energy supplies, while having to face strong international competition (creation of the Common Market). The main policy response was to substitute expensive national coal with cheap imported oil, a measure that justified the "coalmine decline" process.

This choice proved to be a source of vulnerability at the time of the first oil crisis (1973-1974), as the rate of energy dependency rose from under 50% in 1960 to nearly 75% in 1973. Priority was given to nuclear power at national level as a means of reducing the energy vulnerability of the French economy. However, the large investment required for nuclear development may have negative effects, such as cancelling investments in other resources that then become vulnerable. In this case, we could speak of a "crowding out effect" of certain technologies, by nuclear technology or others.

The pursuit of energy independence may thus increase the vulnerability of the rest of industry, weakened through lack of investment. When energy prices rise sharply, the revenues of an oil exporting country are suddenly increased, which may impact negatively on the rest of the economy and the competitiveness of the industrial or small-scale sectors. This is the "Dutch Disease" syndrome that bedevils oil-producing economies. These "windfall profits" could cause a certain vulnerability, in the long run.

Germany's choice to phase out nuclear power and to give priority to renewable energy sources (notably wind energy) may lead to a certain vulnerability if the technology employed is not competitive in the long term or if the development of wind farms on a large scale is not accepted. In such circumstances, it is often preferable to opt for a diversity of alternative or complementary solutions with the aim of reducing the risk of vulnerability; "flexible systems" being theoretically less vulnerable than "rigid systems" in view of the uncertainty related to energy price in the medium and long term.

The issue of flexible versus rigid systems raises an interesting debate as to whether market mechanisms or central planning deliver the optimum portfolio of energy investments in terms of vulnerability.

Experience gained in many countries shows that well balanced regulation and market mechanisms are required to manage the risks of energy insecurity.

**Exchange Rates**

Energy vulnerability can be linked to fluctuation in currency exchange rates. A sharply stronger dollar can make oil imports more expensive, even if the oil price remains constant in dollars. Europeans talked about a "dollar shock" after the second oil shock of 1979-80. The steep rise in the US currency from mid-1980 added to the increase in the oil price, exacerbating the initial shock for most European countries.

**Technology**

Energy vulnerability may be a consequence of the inability of a country to control advanced energy technologies and thereby making individual energy choices (this includes nuclear technology, hydrocarbon exploration-production technologies,

**Table 2-2** Number of patents per sector

| | Oil | Gas | Biomass | Solar |
|---|---|---|---|---|
| Germany | 293 | 19 | 131 | 42 |
| France | 255 | 12 | 34 | 4 |
| GB | 299 | 17 | 37 | 9 |
| Italy | 51 | 1 | 16 | 3 |

Source: IFP

and those related to renewable resources, such as fuel cells). The efforts expended in research and development and the number of patents registered by national operators may be considered good indicators. Paradoxically, the strong dependency on oil, at the time of oil crises, gave Japan the opportunity to gain a comparative advantage in the field of advanced technologies due to great efforts in research and development at that time. In this case, vulnerability has quite beneficial effects.

The Table 2-2 lists the number of patents filed in some European countries in various sectors between 1995 and 2006.

Inadequate communication and information technologies and poor governance arrangements can be a factor of vulnerability for an energy system, particularly power systems. Information management came to light during the Italian blackout of September 2003.

### Other Factors

The variety of vulnerability factors categorised can be quantified, and summarised using one or more indicators, others are harder to quantify. Operators' strategies, aimed at limiting vulnerability, may face obstacles associated with the acceptability of their projects. The attitude of the population regarding the siting of new power plants or high voltage lines is important.

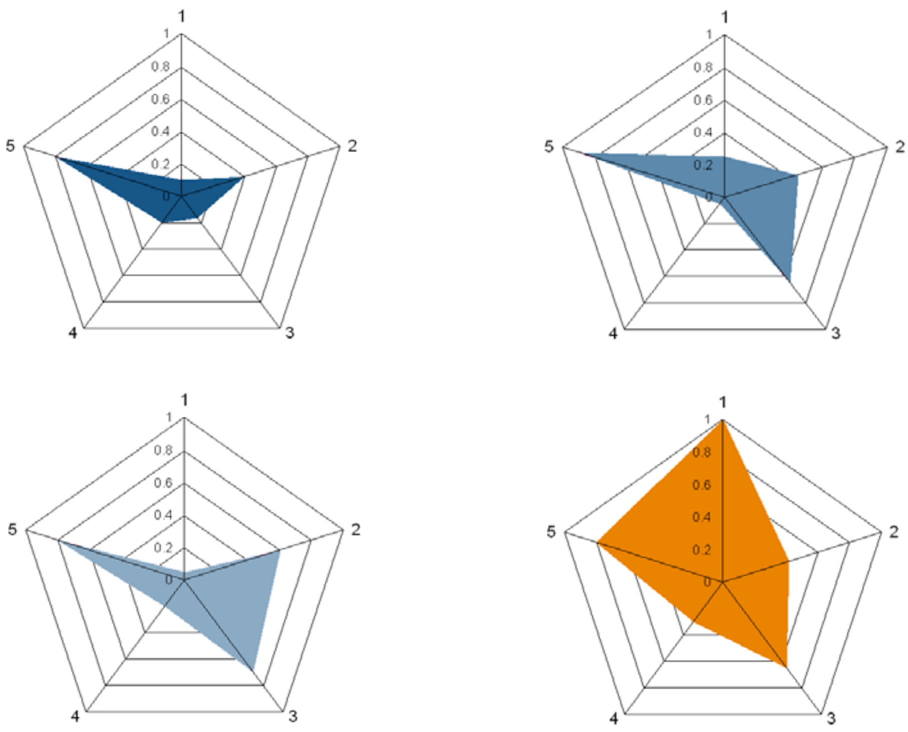
International relations naturally figure among the varying factors in the energy sector. Political events increase the risks of vulnerability, as illustrated by the tensions between Russia and its neighbouring countries in the gas sector over the past few years.

Lastly, industrial aspects may also explain energy vulnerability. It is a matter of controversy. Some politicians and industrial leaders think that, faced with floating assets on the energy market (therefore a possible target for hostile take-over bids), or assets controlled by foreign decision-making bodies (pension funds, banks or foreign operators), the vulnerability of the national energy system might be higher than if national actors control the foreign hydrocarbon reservoirs and operate on domestic territory. Some also think that there might be less vulnerability with public operators (at least partially) than with private operators. We must keep in mind that governments have at their disposal sovereign prerogatives to which private operators are also held and that vulnerability will finally depend on the institutional system implemented in this strategic sector. In France, the Law of the 31 December 1992 suppressed the government monopoly on oil imports but maintained strategic stocks corresponding to 95 days of consumption in continental France. Another example in the field of maritime transport is the persistence of a certain obligation to show the national flag.

### Towards a Synthesis

It is difficult to quantify the influence of a single vulnerability factor using indicators, and there are cases where the enhancement of a given indicator can have negative effects. It is even more difficult to attempt to synthesise different factors. In order to present several indicators simultaneously and

**Figure 2-2** Energy Vulnerabilities of (clockwise from top left) Sweden, Croatia, Bulgaria, and Germany



Source: E. Gnansounou

facilitate comparisons or aggregations, it may be better for these to be expressed in the same units. To do this, the various indicators can therefore be normalised to values between 0 and 1. For some, the energy intensity, carbon content of energy supply, rate of dependency of electricity supplies, such an index can be defined by means of formula (0.9):

$$(0.9)\quad I_j = \frac{X_j - \min\limits_k (X_k)}{\max\limits_k (X_k) - \min\limits_k (X_k)} \qquad k = 1, 2, ...., n$$

where $X_k$ is the indicator considered of a country k among n countries.

## Vulnerability indicators

- Energy intensity, of which the index is calculated using formula (0.9)
- An indicator of dependency on oil and gas imports which is the smaller of two values, the first being the actual dependency rate and the second an indicator of the geopolitical risk of supply disruption.
- The index representing the carbon content of primary energy supply (formula 0.9)
- A vulnerability indicator of the electrical system involving the index of dependency on imports (0.9), via a quadratic mean, a public acceptability indicator and an index of non-diversity for electric power generation of Shannon-Wiener type, the first index having twice the weight of the next two
- An indicator of non-diversity of fuels used for transport of the Shannon Wiener type
- Vulnerability can be calculated as a quadratic mean of these five indices, represented graphically below as constructed by E. Gnansounou.

At the microeconomic level, vulnerability can initially be analysed from the consumer viewpoint. The fossil energy supply is addressed first and then vulnerability indicators of electricity supply are considered followed by those of social risks.

**Table 2-3** Stocks

| Energy | Type of Consumer | Day(s) to be considered a crisis |
|---|---|---|
| Gas | Domestic | 1-3 days |
| Gas | Industry | 1 week |
| Gasoline, diesel oil | Domestic | 1-3 days |
| Fuel oil/diesel oil | Industry | One week |
| Coal | Industry | 8 weeks |

## The Microeconomic Level: Consumer Vulnerability

### Vulnerability of Fossil Fuel Supply

For the consumer, vulnerability is characterised by the risk of supply disruption and associated price increases. A recent example of a physical supply disruption happened in the summer of 2005 in the United States caused by the hurricanes Rita and Katrina, which not only destroyed the oil and gas production rigs in the Gulf of Mexico, but also damaged several refineries. The corrosion on pipelines transporting crude oil from Prudhoe Bay, Alaska, during the summer of 2006, caused a 400 000 b/d drop in production, provoking fears of a disruption of supply to refineries on the US Pacific coast. However, a distinction should be drawn between a contained supply disruption and those, which threaten to disrupt supply completely.

Prevention naturally implies stockpiling. The consequences of hurricanes Rita and Katrina were contained by reliance on the strategic stocks of the IEA (International Energy Agency), which released 2 Mb/d for 30 days. In the summer of 2006, the American administration authorised access to the Strategic Petroleum Reserve to contend with the problem of lower output from Alaska. Thus, the level of stocks is a meaningful indicator. The best measurement should be expressed as the number of consumption days. An attempt can be made to estimate the political acceptance of the number of days without supply. This level is suggested in Table 2-3.

In the case of oil, the EU rules impose strategic stock levels of 90 days of consumption of the main petroleum products, while the IEA rules stipulate 90 days of net imports of crude oil and petroleum products. The question of strategic stocks and particularly natural gas stocks is developed further in chapter 6.

Substitution of energy sources is important in order to alleviate consumer vulnerability. Some companies can change energy sources mainly for producing heat depending on relative price variations. This is often the case for power companies, particularly in the United States. In Europe in 2003, the production of power plant burning alternative fuels was: 38.5 TWh in Germany, 4.8 TWh in Spain, 27.0 TWh in UK, 98.2 TWh in Italy, 2.5 TWh in Lithuania, 7 TWh in Romania. These figures give an order of magnitude of the possible substitutions.

Interruptibility, especially for gas, may be contractually agreed between contractors. Many medium and large gas customers choose to buy their gas on an interruptible basis. The gas supplier and the customer can jointly decide the commercial terms and the conditions under which either party can interrupt supplies. With an interruptible contract, the customer can switch to alternative supplies in order to optimise economics in certain market situations. This facility, in addition to the lower price paid for an interruptible supply of gas, should compensate for the extra cost incurred by the customer for securing alternative operational solutions in case of imposed interruption, such as investment in dual firing back-up facilities.

## About 60% of gas consumed within the European Union crosses at least one border.

### Vulnerability of Electricity Supply

There are several recent examples of electricity disruption. Severe damage was caused by the storm that occurred in France in December 1999. Major blackouts were experienced by the United States and Ontario in August 2003, and Italy in September 2003. Regarding oil products and natural gas, the risk of supply disruption for consumers is reduced due to storage possibilities. In contrast, it is not possible to store electricity; consequently it is necessary to have production or import capacities instantly available in order to meet any unexpected increase in demand or plant failure. Electricity vulnerability thus depends on the following three main factors:

The first factor is the "margin of surplus capacity" in relation to the peak power demand. In a public monopoly system, this margin is often comfortable, since one of the priorities of the monopoly is to prevent energy failure. It is certainly a costly strategy as reserve capacities are not used and it is the consumer who bears the cost. In an open market system, it is not necessarily in the companies' interest to have an over capacity. Risks of energy failure are more likely, unless the regulator imposes a public service obligation either on the incumbent or on all the operators. The concept of cost failure was defined by Electricity de France (EDF) precisely in order to estimate the macroeconomic cost of the non-supplied kWh due to production failure. This cost is a parabolic function of f, the "depth of failure", defined as the ratio of non-supplied electricity to electricity demand.

This function takes the form of:

- (0.10) $\gamma = af^2 + bf + c$

Where $\gamma$ is the failure cost (non-supplied marginal kWh) while a, b, and c are parameters to be estimated.

An optimal probability of failure can be defined (for instance about 4 to 5% in France). In some tense situations, when the high price observed on the spot market is representative of this marginal failure cost, operators are prepared to charge high prices (1,000 - 10,000 euros/MWh) for the marginal kWh to prevent failure. In 1995, the EDF estimated this marginal kWh at 60 FF, which is the equivalent of more than 10 euros today.

The second factor is the "interconnection rate" between countries. Electricity interconnection with neighbouring countries makes mutual assistance possible in periods of pressure on supply and demand and this limits the risks of failure. It is well known that the European Commission Directive recommends an interconnection rate of about 10% in terms of the installed electricity capacity of a country. The situation varies from one European country to another. The vulnerability of the "electricity peninsulas" (the Iberian, Italian, English peninsulas) is significantly higher than that of continental countries with many borders. Governance of an interconnected system is an important factor and if not managed properly can present a vulnerability threat in the form of a High Impact Low Probability event.

The third factor is the "net import rate", i.e. the percentage of electricity consumption, which is imported. About 60% of gas consumed within the European Union crosses at least one border while cross-border electricity only amounts to 7% of the electricity consumed within the European Union. Electricity long distance transport costs are high due to line losses and there is a maximum level of electricity imported that should be considered as politically acceptable.

As electricity cannot be stored, dependence on imports is sometimes considered to imply a great risk and such dependence on a strategic good is unacceptable to some countries. With a percentage of electricity imports amounting to 15%, Italy is now considered to be highly dependent on foreign countries. The blackout of September 2003 reopened the debate about the need to increase capacities of national supply (even if this blackout was due to problems with transmission, communication and information management and not to a shortage). Due to the high cost of the national supply, a large part of the demand was met by cheaper importation. This is a controversial topic. The challenge is to achieve a safe mutual dependency arrangement.

The ratio of investments to turnover represents a good indicator of potential vulnerability in the energy sector when it is maintained under a certain level. In the electricity and gas sectors, according to Capgemini (2005), this rate has been decreasing steadily over the past years falling from 10.3% in 1998 to 5.5% in 2004 within the European Union.

**Social Vulnerability**

Low-income households may be affected depending on the effectiveness of social protection measures.[3] The concept of energy poverty, also termed fuel poverty, has gained in importance during the recent past. It originated in early 1980s from the UK and Ireland's grass roots environmental health movements. With the energy crises of 1973/74 and 1979, low-income households experienced difficulties with increased heating bills.

The Fuel Poverty Concept is an interaction between poorly insulated housing and inefficient in-housing energy systems, low-income households and high-energy service prices. At the beginning of the 21st Century, the British Government set up a strategy on fuel poverty aiming at eradicating this phenomenon by 2010 (DTI/DEFRA, 2001) for vulnerable households and by 2016 for all English households.

According to the British standard definition that was adopted, a household is poor in fuel if it needs to spend more than 10% of its income on all fuel use to heat the home to an adequate standard and to meet its needs for other energy services (lighting, cooking, cleaning, etc.). This standard definition calls for comment.

Related to the fuel needs, the standard indicator of Fuel Poverty is based on the fuel households need to consume and not on how it is actually consumed. In the case of heating, the definition of internal temperature was compatible with the recommendations of the World Health Organisation (WHO, 1989). This definition varies according to

[3] Several parts of this section are extracts of Edgard Gnansounou's paper (2006a). Used with permission, see References.

**Table 2-4** Households Defined at Fuel Poverty, 1994-1997

| Country | Percentage of households | Range |
|---|---|---|
| Germany | 5.5 | (2.7 - 8.3) |
| Denmark | 3.9 | (3.2 - 4.5) |
| Netherlands | 7.2 | (3.2 - 11.1) |
| Belgium | 11.0 | (8.0 - 15.8) |
| Luxembourg | 5.0 | (3.7 - 6.3) |
| France | 10.4 | (8.6 - 12.2) |
| UK | 10.2 | (7.9 - 12.5) |
| Ireland | 9.6 | (8.3 - 12.4) |
| Italy | 12.5 | (10.6 - 16.1) |
| Greece | 29.7 | (24.6 - 36.0) |
| Spain | 26.3 | (20.6 - 43.8) |
| Portugal | 44.4 | (38.7 - 62.8) |
| Austria | 6.5 | (3.1 - 9.8) |
| Finland | 4.9 | (4.4 - 5.4) |

Source: Healy and Clinch (2002).

the type of households (see DETR, 2000). For example, 21°C in the living room and 18°C in other occupied rooms for the whole house:

- 9 hours a day for households in work or full-time education (standard heating regime)
- 16 hours a day, for households likely to be at home all day (full heating regime).

Related to the income, the indicator depends on the way the income is assessed (available or total income).

In England according to the standard indicator (from "Fuel Poverty Monitoring- Indicators 2006, DTI, DEFRA") the number of households poor in fuel decreased from 5,1 million in 1996 to 1,7 million on 2001 and to 1,2 million on 2004.

In spite of its imperfections (the 10% threshold is arbitrary), there is a need for generalisation of this concept to all European countries in order to make possible cross-country analyses and harmonisation of public policies.

From the research point of view, a few tentative composite indicators have been proposed from which preliminary comparison has been achieved. For example, the composite indicator is a weighted indicator including the following elementary indicators:

- unable to afford to heat home adequately (Key indicator);
- unable to pay utility bills on time;
- lack of adequate heating facilities;
- damp walls and/or floors;
- rotten window frame;
- lacking central heating.

## The Microeconomic Level: Supplier Vulnerability

The authors examined several scenarios corresponding to various weights associated with the elementary indicators. Based on the European Community Household Panel, they have estimated cross-country indicators for the period 1994-97. Table 2.4 gives the results obtained with equal weights associated with the elementary indicators. Figures in brackets gives the range obtained with different weights. It should be noted that these results are for illustration only as the data used is not representative of the present situation. Vulnerability can be analysed from the viewpoint of energy utilities and characterised by the risks to

Removal of bottlenecks that still exist in the electricity interconnections between the Union countries is a prerequisite for security of supply.

which they are exposed. At present, there are several forms of vulnerability affecting energy suppliers (until very recently, integrated public monopolies). As in first section, certain factors can be measured rather easily by indicators, others not so easily. Even if difficult to quantify, it may be useful to keep these factors in mind.

**Exchange Rate Vulnerability**

The example of the European investors in Argentina (Suez, EDF etc.) demonstrates that the drastic devaluation of the peso exerted pressure on the financial results of electric power generation and distribution firms. The selling prices, denominated in pesos, were frozen, and as these companies fell into debt in dollars, they showed insufficient profit to repay their loans.

**Unbundling Vulnerability**

Unbundling of the electricity production, transmission and distribution activities, currently legal and probably in the form of ownership unbundling in the near future, is a potential factor of vulnerability for many operators. Transmission and distribution are profitable regulated activities, which earn a large part of the profits of electricity (and gas) companies. Charges set by regulatory commissions for third party access to networks cover costs while ensuring a sufficient return on invested capital, with the aim of encouraging facility investments.

There is uncertainty concerning the production and marketing activities in the open market due to the volatility of spot prices and the uncertainty as of the market shares of each operator. Once the incumbent unbundling has occurred, they become more vulnerable. The electricity spot price escalation in the United States over the period 2000-2001 led to a capacity investment boom until 2003: more than 200 GW were built to achieve a total installed power of around 800 GW. This "boom and bust" phenomenon generated an electricity overcapacity that brought down the prices on the electricity spot market, causing the bankruptcy of numerous "merchant plant companies", hence the choice made by some companies to give up the pure producer model in favour of vertical integration.

Their view is that, in the face of market contingencies, the presence at all stages from production to marketing ensures a minimal return on investment, since the economic rent is recoverable either in the downstream or the upstream sector of the electricity chain. It is the same problem with natural gas. The integrated model is more profitable faced with imported gas price escalation. For example, by investing in the exploration-production in the North Sea and Egypt, Gaz de France hopes to control 15% of the gas supply and the growing gas import costs are thus partially compensated by the increase in the upstream sector margins, which justifies this integration strategy. However, this view is not universally shared.

**Vulnerability Related to Industrial Strategies**

Takeover bids are part of the risks inherent to a market economy. It is a new risk for incumbents in the electricity and gas sectors which for years benefited from the status of public corporations. The open market for network industries is often associated with an opening, at least partially, of the capital of the production and marketing companies of gas and electricity. When a company's capital is "floated", which means that the assets are allotted to the public, it is sufficient to hold 10 to 15% of the capital in order to control the company strategy. There is, therefore, a potential factor of vulnerability.

Consequently, the strategy of a group may be weakened as a result of the withdrawal by some shareholders (e.g. pension funds) or when a competitor takes control of the company and may try to dismantle it. In this respect, the energy sector in Europe has shown a certain vulnerability during the last years due to the numerous mergers and acquisitions. For example, the British operators were partly bought out by their German and French competitors. Although the idea is that it is sometimes necessary to achieve a "critical mass" to be preserved from hostile take-over bids ("too big to be eaten").

**Vulnerability Linked to Cross-Border Exchanges**

The goal of an open market for network industries in Europe is not to size-up 27 competitive markets but to create a single gas and electricity market in the long term within the EU. This implies a convergence, i.e. a levelling of gas and electricity prices for all the European consumers. Removal of bottlenecks that still exist in the electricity interconnections between the Union countries is a prerequisite for security of supply. These cross-border interconnections are generally defined as a potential factor in reducing the vulnerability of national electricity systems. They were, moreover, encouraged by the Union for the Co-ordination of Transmission of Electricity (UCTE), well before the introduction of the European Directives on the open market.

The advantages of interconnections are clear. However, the convergence of the electricity spot prices due to interconnection is sometimes perceived as a factor of vulnerability by some consumers who are afraid of losing a comparative advantage in the context of international competition. Thanks to nuclear power, the French industrial firms benefited from low electricity prices, took investment decisions according to the electricity price structure, but now risk losing this advantage.

**Vulnerability Related to Regulatory Uncertainties**

In some countries, the volatility of policies and regulations is a significant risk factor. In Russia, the lack of transparency, the complex interrelations between federal and regional law and evolving tax arrangements associated with the wish of the Government to regain control of the petroleum sector, are frequently mentioned factors of vulnerability for the petroleum operators.

In Europe, as a result of the European Directives, some of which are still in the course of preparation, and the progressive transposition of the Directives into national legislation, the regulatory framework is far from being definitive for electricity and gas operators. The uncertainty created by this continual change of regulation affects the strategies of the operators who cautiously hesitate to commit themselves in the long term. It is sometimes more difficult to adapt to regulatory uncertainties than to market ones.

Some tariffs continue to be regulated. Gas prices for retail customers in France remain subject to government approval. This could be a factor in

reducing the vulnerability of the historic operator Gaz de France. Although unlikely, a situation of production overcapacities, as in the refining sector, could drive market prices below average production costs in certain periods. Regulated tariffs should help to avoid corresponding losses.

In contrast, for political reasons regulated tariffs may be fixed at levels and so supply cost increases cannot be fully passed on. The decision in 2006 of the French Government to postpone the increase in domestic tariffs of Gaz de France is a good illustration of that situation. Applying a government measure caused the company Gaz de France to lose 250 million euros. Above all, it cast a doubt on the willingness of the government to behave in the manner of a "shareholder at common law". Consequently, the quoted price of the GDF share has suffered a downward trend.

## An Analytical Approach

An analytical approach has been proposed within this study. It involves listing the various events to which a country may be vulnerable, such as a revolution in an oil producing country or a terrorist attack on an energy production facility, refinery, or gasification terminal. The induced supply disruptions are estimated for each event. The cost of the various appropriate countermeasures, using a hypothesis on the policies installed, must then be calculated: cost of additional energy sources which can be enlisted, costs associated with reduced consumption and economic repercussions. The vulnerability indices proposed correspond accordingly to an expected value of the total cost for the country concerned. In short:

- Vulnerability = Sum of Likelihood that event occurs * Cost of consequences assuming the best policy.

Alternatively, it may be more useful and comparable to refer to it as a fraction of the business as usual cost (cost of supply and availability of energy consumed in normal periods).

The index is expressed as a series of 4 numbers (percentages) representing oil, gas, coal and electricity. These numbers are not added or aggregated, because a value greater than a nationally acceptable value in any one of the four components constitutes energy vulnerability; therefore it should not be masked or diluted by the addition of more favourable numbers in other sectors.

This approach demands a definition of subjective probabilities, which are particularly difficult to estimate, especially since the overall consequences of an event such as a war in the Middle East form a very broad continuum. The authors of the model argue that probability of a risk can be estimated and it has already been calculated by the market. This is why they call their indicators "Market Based Energy Security Indicators". They estimate that the application of risk and insurance techniques to the analysis of the likelihood and possible consequences of an energy vulnerability event is both relevant and achievable. They use risk indices of countries that supply Europe with oil and gas and data from a business risk data base, as developed for use by the Lloyd's of London Insurance Market.

The bulkiness of such a model is obvious. The chief merit of this approach is to construct an analysis of the various possible events and of their consequences. Despite the difficulty of quantifying the parameters for calculating indicators in absolute values, it should be useful for making certain comparisons.

## Conclusion

The concept of energy vulnerability takes various forms. It is undeniably linked to the degree of dependency on energy supplies, but cannot easily be depicted by a single indicator. At the macroeconomic level, the main indicators pertain to the concentration (or diversification) of supply, to the energy bill and to price volatility.

For the fossil energy consumer, vulnerability is naturally associated with stock levels, while that of the electricity consumer can be reduced mainly by means of production capacity surplus and adequate network interconnection. The various indicators that have been examined should be useful in drawing up policies to reduce vulnerability. It is only natural that the results of a policy will always be hard to appreciate using aggregate indicators. We have in fact observed a number of backlash effects.

It is important to distinguish between dependency and vulnerability. Thus, a reliance on domestic energy production to limit dependency on imports can lead to costlier solutions, penalising certain industries. It is important to reinforce the interconnected grids which may help to address various accidents. However, the growth of cross-border electricity exchanges does not have solely positive effects.

Finally, this report suggests a number of analyses and further research is needed to scrutinise certain issues. The subject of chapter 6, the drawing up of policies or measures designed to limit the vulnerability of a country or a group of agents cannot be restricted to the search for actions addressing any specific individual indicator.

# Part Three
# Vulnerability of European Users to an Energy Crisis

## Introduction

Energy is indispensable for economic growth and continued human development.

The availability of an adequate and affordable energy service is essential for eradicating poverty, improving human welfare and raising living standards. Customers are concerned with energy services rather than sources.

Energy services are achieved by a combination of technological advances, infrastructure, finance, labour, knowledge, materials and energy carriers. These are mainly determined by the following factors:

- **Economic structure**, income level and distribution, access to capital, prices and market conditions
- **Demographics** such as population, labour force participation rate, family size and degree of urbanisation
- **Geography**, and climatic conditions
- **Technology base**, level of innovation, access to research and development, technical skills and technology diffusion
- **Wealth** of natural resources and access to indigenous energy resources
- **Life style**, mobility, individual and social preference and cultural moves
- **Policy factors** that influence economic trends, energy, the environment, standards and codes, and social welfare
- **Law**, institutions and regulations.

The structure and level of demand for energy services, combined with the performance of end-use technologies, determine the size of final energy demand.

When considering the vulnerability of European energy users to a crisis it is important to analyse the structure of the European economy and determine how energy resources and prices influence consumer choice and behaviour and how this affects economic development and growth. High-energy prices in Europe can lead to increases in energy import bills with adverse consequences for business, employment and social welfare.

## Structure of European Economy

Economic growth in European countries reflects a long established trend of structural change. International trade, technological change and dematerialisation are some of the factors behind these developments.

Contribution by various branches of the economy to gross domestic product (GDP) shows the impact of restructuring, modernisation and adaptation to domestic and world market pressures.

Dematerialisation of European economics is partly responsible for the declining share of industry's contribution to GDP and the increasing use of higher quality materials. Technological progress is of critical importance to this process of dematerialisation and has a broader impact on the economy, altering the relative price difference between production factors. This ultimately affects

**Table 3-1** Evolution of European Economic Structure

| | | % Structure of Total Value Added | | | | |
|---|---|---|---|---|---|---|
| | | 1990 | 2000 | 2010 | 2020 | 2030 |
| Gross value added in industry | EU-15 | 21.5 | 20.8 | 19.8 | 19.8 | 19.8 |
| | NMS | 26.4 | 25.4 | 25.8 | 25.1 | 23.4 |
| | Bulgaria & Romania | 31.0 | 30.0 | 29.3 | 28.8 | 28.7 |
| | Norway & Switzerland | 20.0 | 25.3 | 25.1 | 25.1 | 24.9 |
| | EU-29 | 21.8 | 20.6 | 20.4 | 20.4 | 20.3 |
| Gross value added in services | EU-15 | 66.2 | 68.8 | 70.2 | 70.9 | 71.5 |
| | NMS | 51.3 | 57.4 | 59.8 | 62.3 | 65.2 |
| | Bulgaria & Romania | 36.2 | 43.7 | 50.3 | 52.2 | 53.0 |
| | Norway & Switzerland | 68.2 | 63.9 | 65.0 | 65.8 | 66.6 |
| | EU-29 | 65.4 | 68.0 | 69.4 | 70.0 | 70.8 |

Source: Energy in Europe. European Union Energy Outlook, to 2020

the choice in positioning new economic activities since it can lead to change in the best mixture of capital, labour, energy and other materials.

The economic structure of the EU 15 Member States (EU-15) and of Norway and Switzerland (N&S) differs from those of New Member States (NMS) and of Bulgaria and Romania (B&R) due to the restructuring of these developed economies away from primary and secondary sectors and towards tertiary services. This is assuming the trend will continue and the energy services sector exhibits the highest growth area in the foreseeable future.

As a result, the share of industrial value added in the European economy declines (Table 3-1), indicating the increasing importance of new industrial activities with high value added, lower physical inputs in most countries, and the increase of services in the economy (up to 70 - 71% by 2030). This growth in services in terms of GDP shares occurs to the detriment of others sectors of the economy, such as, agriculture, construction and energy.

As illustrated in Table 3-1, despite the significantly faster growth of services, the economies of NMS and B&R will rely more on industry and agriculture than the economies of EU-15 and N&S in the foreseeable future. This clearly reflects the existing structural differences in the economies in the period 1990 – 2000, differences that cannot be fully eliminated during the process of convergence among European economies over the next few decades.

Contributing factors affecting the separation of energy demand from economic growth can be observed in the further dematerialisation of European industry linked to structural change within sectors. Saturation effects for a number of energy users, improvements in thermal characteristics of buildings in the tertiary and domestic areas, the slowdown in transport activity growth and the impacts arising from the EU agreement with car manufacturers all contribute towards the separation of energy demand from economic growth.

After the first two oil shocks, the rise in price encouraged users to optimise and control their energy consumption by making efficiency gains.

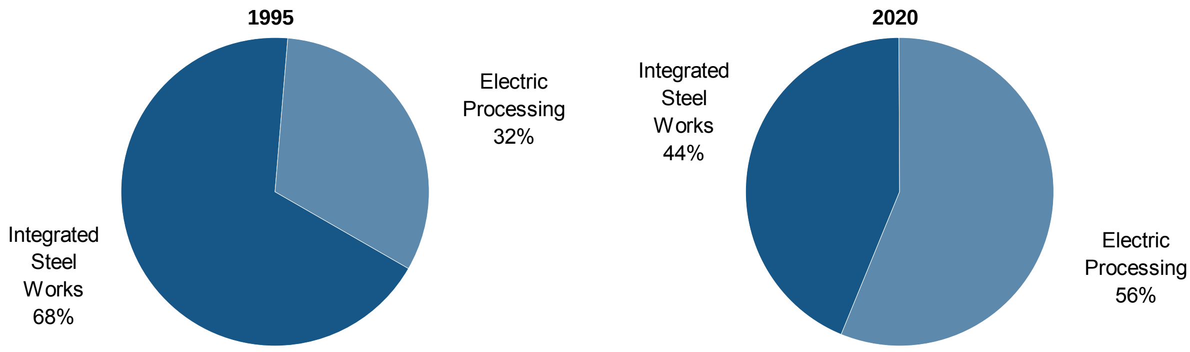
### Industry

Increasing globalisation of the world economy during the 1990s and the enhanced level of economic integration within the EU has influenced Industry.

Industry has various subsectors, with differing prospects subject to different driving forces. Energy use within the industry sector includes highly energy intensive subsectors (steel and petrochemical), as well as those for which energy is a negligible input (electronics).

**The European steel industry** is increasingly challenged by globalisation. This industry covers about 20% of global production but the subsector's significance for the European economy is less than 1% of GDP. The capability of this industry to face

**Figure 3-1** Changing Patterns of European Steel




Source Energy in Europe. European Union Energy Outlook, to 2020

future challenges is positive owing to the considerable efforts made to reshape the production structure, improve technological performance and utilisation of skilled human resources. By making strategic alliances, the industry has transcended national boundaries and developed a truly European production and market base.

Restructuring was characterised by a reduction in excess capacity by closing less competitive and usually older basic processing plants and shifting in favour of electric steelworks (arc furnace). This restructuring towards electric steelworks is expected to continue, as fragmentation and poor competition, which prevails in the European sector, is replaced by regional specialisation. Ultimately very few, and large sized vertically integrated steelworks will remain in Europe to process iron and cover the needs for basic processing.

Rather than constructing new plants, technology progress in the surviving blast furnace plants is likely to be made by retrofitting, given this sector's low profitability, excess capacity and high capital intensity.

Traditional steel producing countries are Germany (27,5% of EU production in 1995), Italy (18,1%), France (11,8%), UK (11,5%), Spain (9,5%) and Belgium (7,5%), with smaller plants in others.

The energy efficiency ratio differs substantially across countries reflecting structural differences in the sector. Italy, relying mainly on electric steelworks, needs half the amount of final energy per unit of production compared to those of the UK, which operate integrated steelworks.

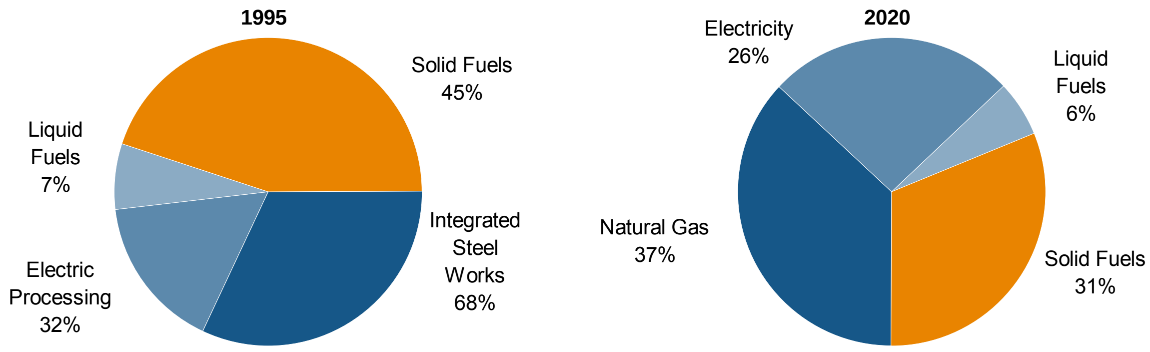
Ultimate advances in material productivity and substitutions in favour of new material will lead to the total separation of economic growth and steel production. Thus by 2020 steel production in European countries will only be slightly above its 1995 level of 153,150 ktn. Germany, France, Italy and the UK will remain the most significant producers of steel in Europe.

Specialisation and concentration are also likely to lead to the location of vertically integrated steelworks in fewer countries (Belgium for example); while specialised steel processing allows smaller countries such as Denmark and Greece to maintain electric steelworks. In Europe as a whole, the proportion of electric arc furnace steel production will account for about 56% in 2020, compared to 32% in 1995 (Figure 3-1).

In the iron and steel sector the autonomous improvement in energy efficiency is expected to be modest and to differ across member states, accelerating slightly in countries that have less efficient steel production due to the single market mechanisms, although this will contribute to the harmonisation of the industry's efficiency.

Technological improvements are expected by means of the introduction of new techniques in basic processing. Advanced techniques, like direct smelting, involve direct coal injection in the blast furnace, abandoning the process of coal conversion into coke and consequently, lowering energy losses.

**Figure 3-2** Energy Demand Structure in the Iron/Steel Sector




Source: Energy in Europe. European Union Energy Outlook, to 2020

In the European Community, energy intensity in the steel sector is expected to decline by 20% between 1995 and 2020. Total energy demand is likely to decline in the sector by 0.8% pa over the next 25 years, despite a small increase in steel production.

The fuel structure of the energy demand of the sector will be effectively determined by the sharp increase in the share of electric processing. Thus, the continuous decline in solid fuel demand will be compensated by the increase in electricity demand (Figure 3-2).

**The Non-ferrous metals** sector is involved in the refining and processing of a large number of metals. Europe's non-ferrous sector is reliant on the import of metal ores, due to insufficient local deposits. This may explain to some degree the limited contribution of this sector to value added, but also the importance of recycling waste and scrap non-ferrous metals. The EU-15 non-ferrous sector accounted for only 1.4% of total added value of industry in 2000.

Some non-ferrous metals (such aluminium, copper, zinc and lead) have seen their use rapidly develop within the transport, electric and electronic equipment sectors in recent year.

Production of primary aluminium is the most energy intensive process in the sector, involving the use of large quantities of electricity. Secondary aluminium production is less energy intensive by upwards of 6.5 times. This industry is highly capital and energy intensive, leading to the limited number of players in primary metal production in France, Germany, Spain, UK and Italy. Germany, Italy, UK and Spain are also important producers of copper.

During the past 20 years there has been a gradual relocation of the world's non-ferrous industry towards countries that combine low cost ore with relatively cheap energy. A more recent trend having had a significant impact on European producers is the export of large excess production from countries in transition, especially, Russia.

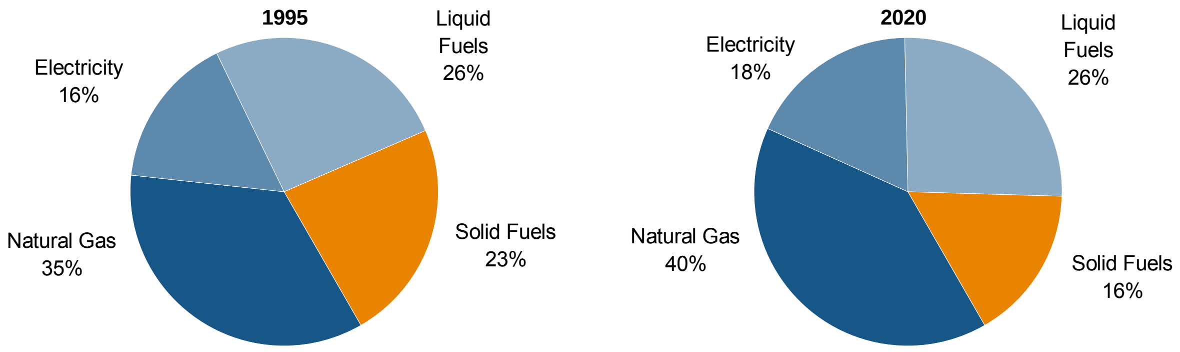
The non-ferrous metal sector is expected to experience significant growth up to 2020. Aluminium has captured a significant part of steel's market in construction and packaging and has now started intruding on steel's predominance in the manufacture of cars.

The structural shift towards the less energy intensive segments of the sector will cause a significant decline overall.

Changes in the structure of energy demand are forecast to be rather modest in the period 2005-2020. The most significant change is the rapid decline in the use of energy for primary aluminium production and the corresponding increase in the energy use for the recycling of aluminium.

By 2020 electricity will continue to account for almost half the overall energy use in the sector, while the share of gas will increase significantly. By 2020 natural gas will account for about 30% of energy use in the European non-ferrous metal sector. The use of solid fuels will decline significantly.

**Figure 3-3** Energy Demand Structure in the Building Material Sector




Source: Energy in Europe. European Union Energy Outlook, to 2020

**The Building material sector**, including cement, concrete and bricks as well as glass and ceramics, is related directly to construction. Sector size varies between 0.4 – 2.5% of GDP in different European Countries. In the EU-15 sector size was 1.1% of GDP in 1995.

Production of cement in 2000 was about 40% of sectoral production in EU-15, followed by production of ceramics (about 36%). The EU-15 is a net exporter of cement. France, Germany, Italy, Spain and UK produce important quantities of this commodity.

The prospects of the building sector are intimately linked to future activity and consequently, will experience high fluctuation in trends.

The primary cement and glass segments of the sector are highly capital intensive. These industries are already quite concentrated. There is little economic diversity in cement and ceramics production and these industries are likely to remain fragmented and confined within national limits.

In the long term, the stabilisation of Europe's population and the limited amount of new construction in this sector will lead to output lagging behind that of the economy as a whole by a significant margin. Most growth in the sector will occur in those segments that produce relatively high value added.

Growth, however, is expected to be especially rapid in cohesion countries (Greece, Portugal, Bulgaria, and Romania) and in countries with significant exports (Spain, Italy).

Due to the nature of the sector's output, the possibilities of recycling are limited to glass. Recycled glass production is the fastest growing area and is projected to double between 1995 and 2020.

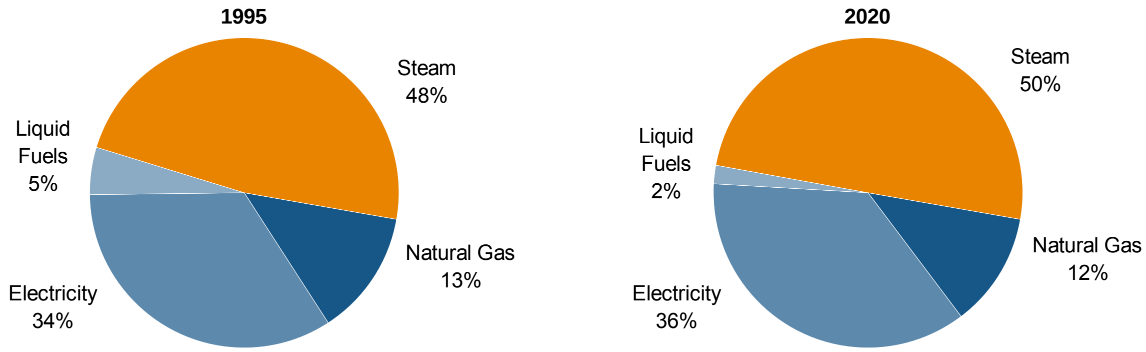
Basic processing for building materials and all sub-sectors is very energy intensive. For this reason significant improvements are expected in the efficiency with which building materials are produced. Improvements in efficiencies are especially slow up to 2010 because most of the industries in the sector are well established, energy intensive and use extensive energy saving schemes. After 2010, as new technologies mature, efficiency improvements in this sector are expected to accelerate.

Given these conditions it is expected that average growth of overall energy demand in the period 1995 - 2020 will be limited to about 0.6%. During this period the fuel structure will not change very dramatically (Figure 3-3): while the use of solid fuel will decline significantly, the increase in the share of electricity in energy will be limited.

**The chemical industry** in Europe is of strategic importance and a driver of economic growth. As the chemical industry operates in a highly competitive environment, energy efficiency discrepancies across the countries are small and reflect structural differences in the industrial output and processes.

The chemical industry has undergone considerable change, shifting in favour of high value added chemical commodities. Activities based on

**Figure 3-4** Energy Demand Structure in the Chemical Sector




Source: Energy in Europe. European Union Energy Outlook, to 2020

traditional energy-intensive processes are being restructured in order to benefit from economies of scale through vertical integration and through their locations in limited areas.

Sector size varies between 0.9 – 6.0% of GDP in different European countries. In the EU-15 sector size was 2.15% of GDP in 1995.

The overall output of this sector is expected to grow roughly in line with GDP in the long term. The German industry accounts for more than a quarter of the output in the EU-15 and will follow broadly its own GDP growth rate. The UK and the Netherlands are likely to be among the beneficiaries of the concentration of the industry in the longer term.

The restructuring of the industry is expected to continue, especially in basic petrochemicals. Petrochemical complexes will be concentrated in Germany, France, UK, and the Netherlands.

The imposition of carbon taxes or other severe environmental measures adopted by Europe will lead to an increase in the proportion of recycling and to greater efforts at energy saving.

The fertiliser segment of the industry is affected by the reform in the Common Agricultural Policy and will have low growth rate of 1.5% p.a. in the period 1995 – 2020.

Production of high value added and low energy intensive commodities, mainly addressed to final consumers (cosmetics, paints, etc.), is projected to double between 1995 and 2020.

These structural changes will lead to a significant reduction in the overall energy intensity of the sector.

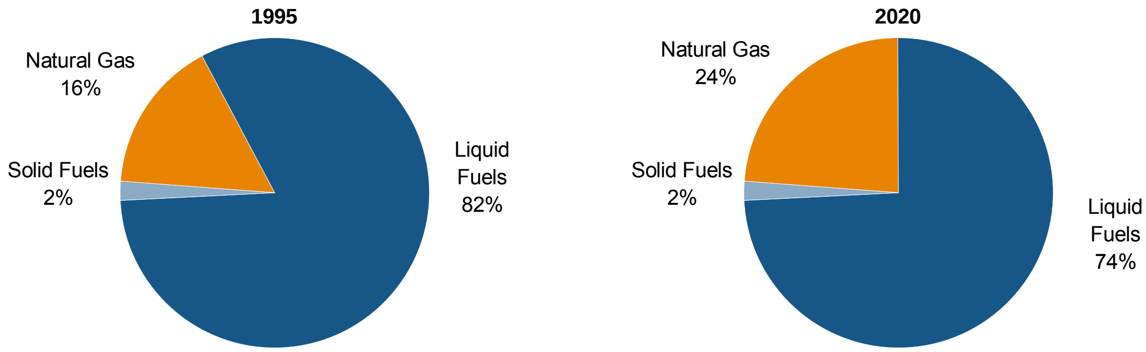
The use of solid and liquid fuels is already very limited in the chemical sector because of the technologies used and the numerous products available as energy sources (Figure 3-4). The sector relies on steam and electricity for more than 80% of its energy needs.

In most European countries petrochemical plants have been constructed on the basis of using naphtha, rather than natural gas, taking into consideration more economic feedstock. Given the difficulties with switching feedstock the requirements of the sector are expected to continue to be dominated by naphtha (Figure 3-5). This will be reduced by 2020 when natural gas will have a share increase in this sector to of nearly a quarter of total demand.

**The paper and pulp sector** accounts for about 2% of European GDP and varies between 0.9 – 5.2% of GDP for different countries. A disproportionate amount of the sector's output within the EU-15 is in Finland and Sweden due to availability of wood and plentiful primary energy. The European countries with the highest sectoral value added are the UK and Germany. In these conditions Europe has become a net exporter of paper and pulp.

The pulp and primary paper sectors are fairly concentrated. However, there are still more than 60 companies in Europe whose average size is less than half that of North American companies.

**Figure 3-5** Non-Energy Demand Structure in the Chemical Sector




Source: Energy in Europe. European Union Energy Outlook, to 2020

Over a longer term, the industry is expected to grow by about 2.0% in the period 1995 – 2020. Paper production will grow approximately 4 times faster than pulp production.

The degree of concentration in the industry is expected to increase. The imposition of environmental taxes will lead to further consolidation through the closure of older plants and the increase in competitive pressures from producers outside the European area. Such measures will lead to a further increase in the proportion of recycling and energy savings.

In terms of fuel shares, no significant changes are projected to occur in the period 1995 – 2020 because the energy technologies and economics of the sector make it dependent on electricity and steam (Figure 3-6), mostly through the use of waste products.

**The other industries sector** includes most of the industries with high value added and fast growth rates such as electronics, engineering, aerospace etc.

This sector accounts for more than 21% of European GDP varying from 17% in Denmark to more than 25% in Austria.

In the EU-15 the dominant sub-sector is that of engineering which accounts for nearly 58% of the value added in the sector as a whole. Engineering is of the modest size in only Greece and Portugal (25%) while it exceeds 60% in Austria, Germany and Sweden.

The significance of engineering is expected to increase up to 2020 and its share in the value added of the sector will increase to 63%.

Textiles may have further share loss in countries such as Greece and Portugal where the industry is based on mass production, but will maintain its share in Italy, where there is a high concentration on design and the production of material is not subject to competition from low labour cost.

Food processing will maintain share in the sector.

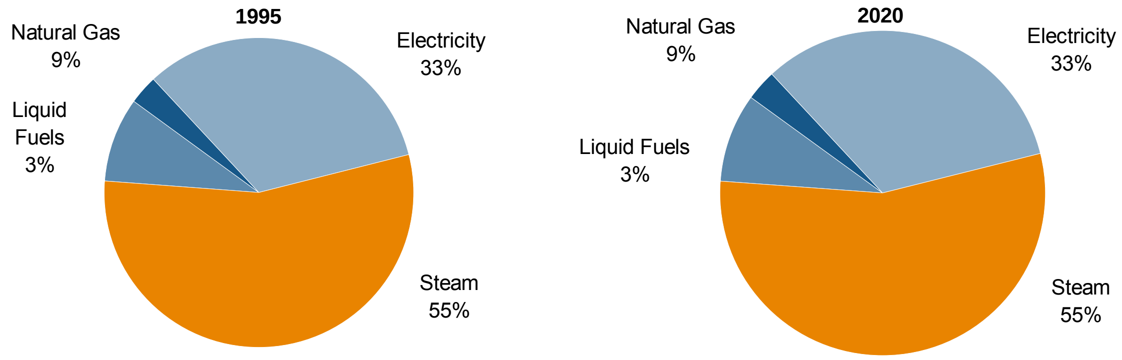
In general the industries in this sector are not energy intensive. Energy demand in the sector will reflect the faster improvement in energy efficiency after 2010.

The use of natural gas will increase up to 2020 and the share of solid and liquid fuels will decline (Figure 3-7).

In conclusion one may note that in 1990 the industry of the 29 European countries was the largest consumer of final energy but by 2000 this had changed with the transportation sector becoming the biggest consumer (see Appendix A). The changes in the structure of industry energy demand are projected to be rather modest in the period 2000-2030.

The most notable change is the rapid decline in the use of solid fuels, reflecting the decline in the iron and steel sectors.

**Figure 3-6** Energy Demand Structure in the Pulp and Paper Sector




Source: Energy in Europe. European Union Energy Outlook, to 2020

## Tertiary Sectors

In the period 1990 – 2000 the tertiary sector (services and agriculture) was the fastest growing sector of the economy for both the EU-15 countries and for the NMS. Growth in the services sector was the key driver for this trend having a rate of 2.4% pa for the EU-15 countries and 2.8% for NMS in this period. Agriculture grew at a rate of 1.2% pa for the EU-15 countries and 0.5% pa for NMS due to pressures related to the opening of EU markets to world competition. The tertiary sector share in the economy increased from 66.2% in 1990 to 68.8% in 2000 for the EU-15 countries and from 51.3%to 57.4 % for the NMS. The share of agriculture decreased from 2.7% in 1990 to 2.5% in 2000 for the EU-15 countries and from 6.4% to 5.7% for the NMS. Much of the future economic growth is likely to originate from the services sectors.

In the period 1990 – 2000 market services (+3.0% pa) and trade (+2.6% pa) were the main drivers for the growth whereas non-market services, strongly affected by the fiscal reforms undertaken in most EU Member States, grew at a slower rate (+1.6% pa).

The changes in the services sector structure determine the evolution of its energy requirements. The bulk of energy use in the sector is required for heating and cooling purposes. Of crucial importance is the increasing use of office electrical equipment (computers, printers, telecommunication systems etc.) which generate much of the increase in the sector's productivity.

Energy intensity benefits from the general switch to more efficiently used fuels. Electricity, which already accounts for more than a third of energy consumption by the EU-15, is projected to continue to grow faster than overall sector energy consumption. This can be due to the continued penetration of electricity in space heating and cooling and to the increase in the number and variety of electric appliances. Steam is expected to continue to make inroads into this sector due to changing market structure and technological developments, helping the penetration of advanced technologies. The share in energy requirements of the sector more than doubled between 1995 and 2020.

Natural gas consumption grew at 4.7% pa between 1990 – 2000. It is projected to decelerate to levels well below average in long run.

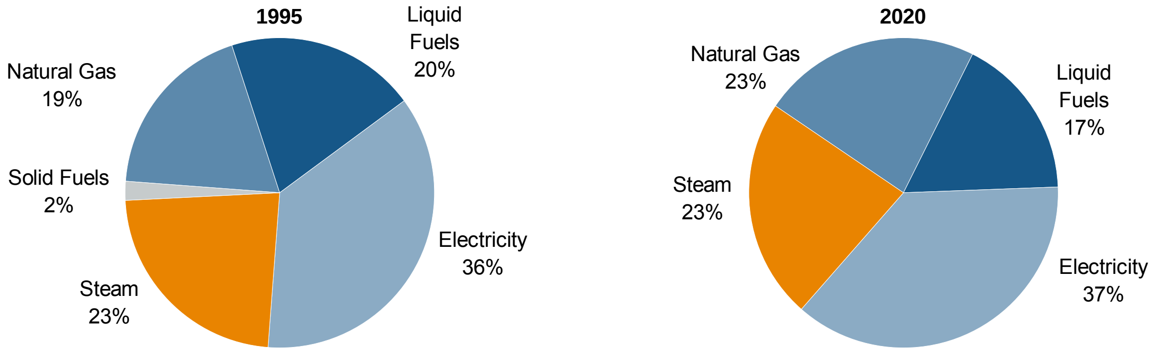
There are many factors leading to a substantial improvement in efficiency in the services sector. Significant progress is projected in terms of productivity by a further shift towards higher value added products.

The greater size of typical energy consumers in the services sector has important implications for technology choice and the implementation of potential policy measures.

**Transportation Sector**

The transportation sector is one of the most important from the viewpoint of energy consumption and environmental implications.

**Figure 3-7** Energy Demand Structure in Other Industry Sectors




Source: Energy in Europe. European Union Energy Outlook, to 2020

In 2000, it accounted for more than 30% and 18% of total final energy demand in the EU-15 countries and NMS respectively. Consistently it has been the fastest growing final energy demand sector and has proved to be quite resistant to a number of measures taken to reduce consumption, including extremely high consumer taxation.

Almost total dependence on oil products in this sector generates two main concerns: security of oil supplies (taking into consideration the increasing needs of the sector), and worries about climate change combined with problems of congestion, noise and urban pollution.

The structural shift of the EU-15 economy towards services and high value added manufacturing activities give rise to the separation of GDP and freight transport growth.

On the basis of present cost expectations and the absence of new policy initiatives, new fuel alternatives will not have a significant affect on transportation over the next 20 years.

The potential for technology improvements leading to higher energy efficiency is great. However, it is counteracted by the shift to faster and more energy intensive transport means, such as air transport, and by the increasing affordability of larger and safer cars.

Diesel use has increased continuously in the period 1990 – 2000, growing from 37.8% in 1990 to reach 44.6% in 2000, and become the main energy of use due to the increasing volume of goods transported by road and the progressive move to diesel in the car industry. This structural change occurred at the expense of gasoline, the demand for which declined by –0.3% pa in the period 1990 – 2000. The demand for aviation fuel grew by 4.7% pa in this period driven by transport activity growth.

Transportation activity will continue to expand in Europe, despite some saturation, although the rates of growth will be significantly less than historically observed. In terms of energy demand, there will also be some deceleration of growth in transportation. By 2020 energy demand for transport will account for nearly a third of the total in Europe.

Oil products will continue to account for nearly 98% of total energy use in the sector, despite the significant growth in electricity use for rail transportation.

The sector is also noted for its very limited price elasticity, which results in a very modest response to the use of market forces for any limitation. Consequently, in order to save energy and decrease emissions in the transport sector, regulation and voluntary agreements may have a number of advantages, when compared to a policy based exclusively on market forces.

The implementation of the 1998 voluntary agreement between the auto manufacturing industry and EU Commission could have a significant impact on European oil demand and emissions by 2010.

Novel fuel alternatives such as methanol, ethanol and hydrogen will increase but they remain

Liquid fuels are expected to remain the main energy feedstock overall primarily due to consumption in the transport sector.

insignificant in absolute terms even by 2030, taking into consideration economic indicators and the lack of infrastructure for the supply and distribution of such fuels.

In conclusion the transportation sector was the biggest final energy consumer in 2000 and will remain so up to 2030 (see Appendix A).

Liquid fuels are expected to remain the main energy feedstock overall primarily due to consumption in the transport sector.

**Households Sector**

Household energy demand in Europe accounted for approximately 26% of total final energy consumption. Apart from the significance for overall energy consumption, household energy is also important from a social point of view, being essential for satisfying fundamental human needs.

In most EU-15 Member States households have already satisfied most of their needs for heating and lightning. Further increases in income are likely to be absorbed by luxury good and services. As incomes rise progressively, consumers alter their behavioural patterns towards leisure activities which leads to a reduction in domestic energy related activity, through increased travel, staying in hotels and dining out.

Energy demand in households is expected to grow very modestly over the next 30 years because of the relatively stable population, changes in behavioural patterns, improved insulation standards in new buildings, saturation effects for some energy uses and energy efficiency gains.

The increase in air conditioning, especially in the southern EU countries, as well as the greater number of electrical appliances per household are the main reasons for increased electricity demand.

There has been a dramatic decline in the use of oil and coal in the household sector since the early 1970s.

The greater availability of natural gas in urban areas is perhaps the largest single change over the past decades for fuel choice in the domestic sector. In future the share of liquid fuels in domestic energy demand will continue to decline modestly.

The great diversity in fuel choice among European countries reflects historical and cultural reasons as well as price incentive. Countries like Greece, Portugal, Finland and Sweden, with no urban networks until recently, will have a very limited increase in gas use and rather high degrees of dependence on electricity. Natural gas tends to maintain its share in countries with a tradition in gas use, such as Belgium, Germany, Italy, the Netherlands and the UK. Most countries will tend to reduce their relative dependence on liquid fuels in the period 2005 - 2030.

## Increased Prices of Energy Resources and Electricity

The vulnerability of energy users to increased prices for energy resources and electricity has both

## The increase in world fuel price has a negative economic impact.

long and short-term aspects. A long-term rise in fuel price has different implications for an economy than sudden price hikes or large price volatility.

The increase in world fuel price has a negative economic impact. Various types of players, (employees, entrepreneurs, shareholders, consumers, investors, etc.) absorb this impact in different proportions.

Looking at the GDP growth rate, a general correlation between higher oil price and lower GDP growth rate with one or two-year time lag is quite clear. After any crisis a negative impact on GDP growth seems evident.

The IEA estimated in 2004 that a $25 to $35 increase in the barrel price causes a two years drop in GDP of 0.3 percentages points in the United States, 0.4 %points in Japan and 0.5% points in the Euro zone countries considered as a whole.

The magnitude of economic costs of an oil price increase depends on many factors among which are: the level and the duration of the price increase, the response of the oil markets, the proportion of energy in GDP and the flexibility of the energy sector.

An increase in the world fuel price leads to an increase in import prices with three major effects:

- A direct effect on revenue by spending more on the energy bill
- A financial effect through the rise of inflation and interest rates
- A trade effect through the increase in import bill, which worsens the trade balance.

Indirect effects at the macroeconomic level may involve a fall in tax revenue and, as a result of rigidities in government expenditure, an increase in the budget deficit, driving interest rates up. Further, more because of resistance to real declines in wages, a fuel price increase typically leads to upward pressure on nominal wage levels. Wage pressure and reduced demand tend to lead to higher unemployment. These effects are greater given a sudden price increase and more inflexible labour market and are magnified by the impact of higher fuel prices on consumer and business confidence.

International trade is affected because the rising price of one of its most widely traded commodities upsets the terms of trade between the net exporting and importing countries.

In terms of national economies, a rise in the price of crude oil is passed on in the price of petroleum products. From the consumer standpoint, the energy bill of the agents (household, industry and government) grows, whereas from the production standpoint, companies have to contend with a rise in unit costs. As to demand, the result of the increase will be a slowing down in consumption expenditure, unless the price change is perceived as short-lived and the agents prefer to maintain their standard of living by reducing their savings or

Given the very limited flexibility of the transport sector in terms of altering the fuel mix, it is obvious that the evolution of liquid fuel will be heavily influenced by trends in the transport sector.

by borrowing (which would exert upward pressure on interest rates). In terms of the supply of goods and services, a rise in energy price causes a drop in productivity. This rise is then passed on through real wages and employment; selling prices and core inflation; profits and investment, as well as stock market capitalisation.

Energy price is a key driver for the development of EU-29 energy demand. Higher relative energy prices will lead to reduced competition by EU-29 industries in the global market for goods and services.

The energy system reacts to higher energy prices, leading to higher energy costs both on the demand and the supply sides, through changes in the fuel mix as well as in terms of improving energy intensity.

The most important changes in the primary energy balance occur in the fuel mix. The impact of higher oil and gas prices is significantly more pronounced for natural gas demand due to liquids being almost exclusively fuel for transportation and the petrochemical industry being difficult to substitute.

Given the very limited flexibility of the transport sector in terms of altering the fuel mix, it is obvious that the evolution of liquid fuel will be heavily influenced by trends in the transport sector.

The projected shifts in the primary energy needs of the European-29 energy system, towards the greater use of solid fuels, renewable energy forms and nuclear power indicate significant potential improvements as regards import dependency.

It is important to take into consideration the period of time over which the changes of international oil and gas prices occur. If the changes are projected over a long term the energy system reacts to them through changes in the fuel mix as well as in terms of improving energy intensity. Energy users as economic agents should successfully anticipate the changes in prices so that the energy using capital stock over the projection period is one planned in advance by agents.

The tertiary and domestic sectors are the most responsive to price change, whereas both industry and transport sectors exhibit a limited reaction to price increases.

The increase in price of energy resources and electricity imposes, not only the use of capital for structural and behavioural changes for the consumer, but also changes in the fuel mix and adoption of more efficient equipment.

The shift towards the use of electricity and steam usually occurs because structural change in power generation leads to absorption of additional costs imposed on the energy system as a result of higher fuel prices. The increases in the price of electricity are much less than that for oil and gas, making the use of electricity and steam at the final demand level a more cost-effective solution compared to that of normal fuel prices.

Apart from energy intensity gains achieved by the adoption of more efficient technologies, higher fuel prices lead to a decrease in the rate at which consumers move towards higher comfort standards and use more capital for environmental protection.

The transport sector is the least responsive on the demand side for the highest fuel price. The reaction of energy consumers in satisfying their transport need is rather limited. Oil generally remains the most important fuel source for transport. The transport sector is vulnerable to higher oil prices or a lack of oil. However, high prices or a lack of oil lead to some acceleration in the use of new types of fuels (biofuels). Behaviour change extends to rational use of conventional private cars in the cities, to alternative transport modes (i.e. rail) becoming more competitive compared to road transport, thanks to infrastructure investment, market liberalisation and improving public services.

The social cost of energy disruption relating to electricity shortage is easier to distinguish because of the immediate negative impact. The social cost of an electricity disruption depends on the existence and quality of various factors: the extent of the duration, the availability of advance warning and information. Many sectors are affected by blackouts including public health and education, public transport and administrative offices, etc.

## Conclusions

Society cannot survive without a continuous supply of energy. Energy is a vital component of economic development.

The EU economy reflects the structural change brought about by modernisation and adaptation at global economic pressures. The share of industrial value added in the EU economy will decline modestly in the future taking into consideration the increasing importance of new industrial activities with high value added and a lower materials base (for example computer equipment, cosmetics etc) in most countries. The long established trend of the restructuring of the EU economies away from the primary and secondary sectors and towards services will continue.

Although the industry contribution to the GDP is relative low in comparison with services, industry is an intensive demander of energy and many sectors will continue to be energy intensive in the future.

European energy users are vulnerable to energy crises. The degree of vulnerability depends on various factors such as energy intensity, flexibility in terms of changing fuel mix and the ability to anticipate an energy crisis. European industry is perhaps better prepared than European transportation for an energy crisis in terms of the structure of supply.

Energy price is a key driver for the development of energy demand. The different players (employees, entrepreneurs, shareholders, consumers, investors, etc.) absorb higher energy prices in various proportions.

In Europe energy systems react to higher energy prices: by increasing costs both on the demand and supply sides, by changes in the fuel mix and by improving energy intensity.

The vulnerability of the energy users should be assessed with indicators defined in the subchapter 2.3 taking into consideration how these users are supplied and what their social requirements are.

# Part Four
# Europe's Vulnerability to Shortages

## Introduction

Primary energy resources are unevenly distributed around the world. Europe is particularly poor in terms of energy resources and so is heavily dependent on imports.

Considering the case of oil in 2004, energy reserves represented only 1.6 % of world reserves and production 7.6% while consumption amounted to 18.9 %. There is a similar situation with natural gas where low-level reserves, (1.5% of world total) are being intensively exploited, reaching 8% of total world production. However, that production level was not sufficient to cover the constant increases in demand. The ratio between reserves, production and consumption of coal is more balanced (Figure 4-1).

## Oil

### Oil Reserves

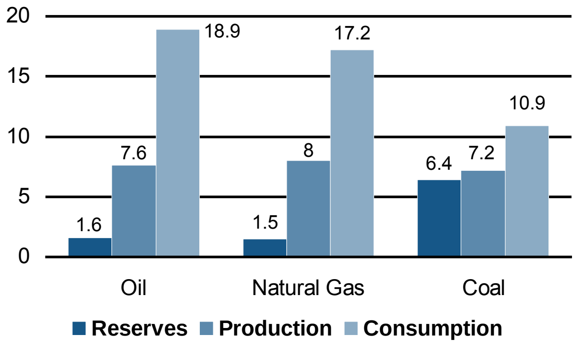
World proven reserves of oil as of end 2004 amounted to 1,188.6 thousand million barrels (Table 4-1). The majority of reserves (61.7%) are located in the Middle East, with Saudi Arabia's reserves amounting to 262.7 thousand million barrels or 22.1% of total world reserves. In Europe, the major reserves are located in Russia (72.3 thousand million barrels). Excluding Russia, only the Norwegian reserves (9.7 thousand million barrels) are significant. Among the EU member states, some reserves are located in the United Kingdom with 4.5 thousand million barrels and Denmark with 1.3 thousand million barrels. Information is provided in Table 4-1 below.

According to RWE's "World Energy Report" it is unlikely that there will be a major increase in total reserve potential from new discoveries of large reservoirs as the Earth's crust has been explored to a great degree. New technologies for extraction from existing fields will probably lead to a 10 to 20 % increase in the total remaining amounts over the next twenty years. This will delay the depletion by several years, after which it might no longer be economically feasible to increase production from the existing fields.

In certain regions, considerable amounts of existing reserves have already been exhausted. The German Federal Institute for Geosciences and Natural Resources (BGR) estimates that more than 60 % of the total potential has been extracted in North America and almost 50 % in Western Europe. On the other hand, this figure is only 26 % in the OPEC countries. Since they own more than 60 % of the remaining oil potential, they will play an increasingly prominent role in meeting demand for the coming decades. In other words, the rest of the world will become even more dependent on OPEC supplies.

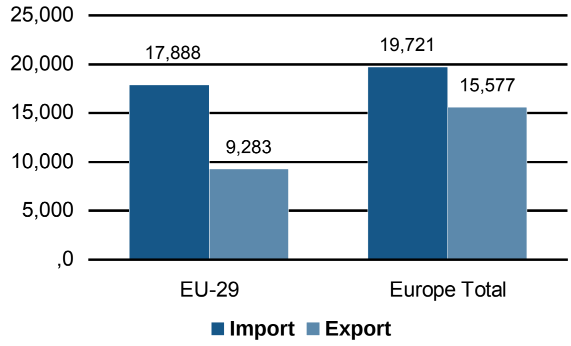
The potential for using non-conventional petroleum deposits is considerable and has hardly been tapped. These non-conventional sources include heavy oils, oil sands and shale oil. During the period 1990-2000, when oil prices dropped to US$ 10/barrel, it was still significantly more expensive to produce liquid combustibles and motor fuels from these sources than to use conventional petroleum.

**Figure 4-1** Proven reserves, production and consumption of the EU-29 (% of world total)




Source: WEC Study Group based on BP Statistical Review of World Energy, 2005, and World Oil and Gas Review, 2005.

**Figure 4-2** Imports and Exports of oil in Europe and EU (000 barrels/day)



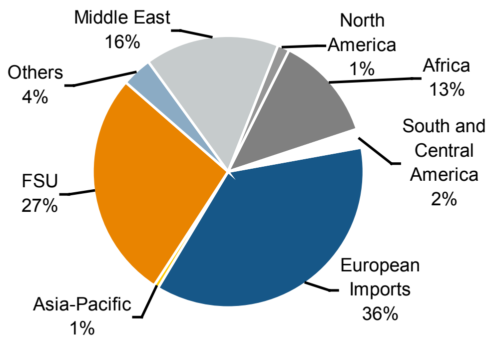

Source: World Oil and Gas Review, 2005.

**Table 4-1** Proven Reserves of Oil, 2004

| Region | | Reserves [thousand million barrels] | Share of total [%] | Reserves/production ratio [years] |
|---|---|---|---|---|
| Europe | | 91.5 | 7.7 | 16.0 |
| out of which: Russia | | 72.3 | 6.1 | 21.3 |
| North America | | 61.0 | 5.1 | 11.8 |
| out of which: USA | | 29.4 | 2.5 | 11.1 |
| South and Central America | | 101.2 | 8.5 | 42.0 |
| out of which: Venezuela | | 77.2 | 6.5 | 70.8 |
| Central Asia | | 47.7 | 4.0 | 66.8 |
| out of which: | Azerbaijan | 7.0 | 0.6 | 60.2 |
| | Kazakhstan | 39.6 | 3.3 | 83.6 |
| Middle East | | 733.9 | 61.7 | 81.6 |
| out of which: | Iran | 132.5 | 11.1 | 88.7 |
| | Iraq | 115.0 | 9.7 | >100 |
| | Kuwait | 99.0 | 8.3 | >100 |
| | Qatar | 15.2 | 1.3 | 42.0 |
| | Saudi Arabia | 262.7 | 22.1 | 67.8 |
| | United Arab Emirates | 97.8 | 8.2 | >100 |
| Africa | | 112.2 | 9.4 | 33.1 |
| out of which: | Libya | 39.1 | 3.3 | 66.5 |
| | Nigeria | 35.3 | 3.0 | 38.4 |
| Asia Pacific | | 41.1 | 3.5 | 14.2 |
| out of which: | China | 17.1 | 1.4 | 13.4 |
| World Total | | 1,188.6 | 100.0 | 40.5 |

Source: BP Statistical Review of World Energy, June 2005.

**Figure 4-3** Crude Oil and Product Imports to EU-29, 2004




Source: BP Statistical Review of World Energy, June 2005.

Since 2003, with high oil price increases, their commercial production became a reality in Canada and Venezuela. Consequently, technical development in their extraction and processing has advanced, allowing significant reduction in production costs. The BGR estimates the remaining potential of non-conventional petroleum in order of 310 billion toe. By exploiting available non-conventional resources, it might be possible to delay the depletion of conventional petroleum reserves, perhaps sometime to the second half of the 21st century.

### Oil Production, Consumption, and Trade

In 2004, the biggest oil producer in the world was Saudi Arabia with production of 10.1 million barrels/day. Russia was second, producing some 9.2 million barrels/day. Among the top twenty countries producing 83.6% of the world oil total only two were European countries: Norway (3.2 million barrels/day or 3.9% of the world production) and the United Kingdom (2.0 million barrels/day or 2.5% of the world production). In total, the EU-29 produced 6.1 million barrels/day, representing some 7.5% of the world oil production.

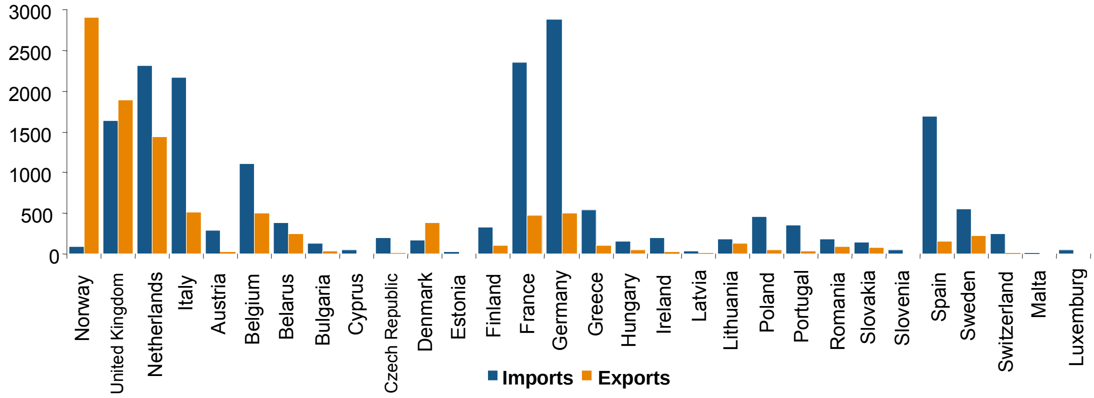
Total European oil consumption in 2004 exceeded 19.6 million barrels/day. The largest consumers being Germany (2.68 million barrels/ day), France (2.05 million barrels/ day), Italy (1.88 million barrels/ day), United Kingdom (1.86 million barrels/ day) and Spain (1.57 million barrels/ day). Based on the above-cited figures, the oil production-consumption ratio (p/r) was dramatically low, 0.39 only. It means that over 60% of oil consumed was imported from other regions of the world. Only two EU countries produced more than they consumed: Denmark with production/ consumption ratio of 2.11, and the United Kingdom with 1.10. During the

**Table 4-2** Imports and exports of crude oil and oil products, in 2004 (000s barrels/day)

| | Import | | | Export | | |
|---|---|---|---|---|---|---|
| Region | Crude oil | Oil products | Total | Crude oil | Oil products | Total |
| Europe | 10,170 | 2,368 | 12,538 | 913 | 1,080 | 1,993 |
| FSU | 6 | 90 | 96 | 5,093 | 1,347 | 6,440 |
| North America | 10,971 | 3,098 | 14,069 | 1,650 | 1,489 | 3,139 |
| South & Central America | 757 | 562 | 1,319 | 4,138 | 1,166 | 5,304 |
| Middle East | 184 | 131 | 315 | 17,099 | 2,531 | 19,630 |
| Africa | 737 | 434 | 1,171 | 6,488 | 721 | 7,209 |
| Asia Pacific | 14,324 | 4,278 | 18,602 | 1,245 | 1,843 | 3,088 |
| Unidentified | | | 0 | 521 | 786 | 1,307 |
| Total World | 37,149 | 10,961 | 48,110 | 37,147 | 10,963 | 48,110 |

Source: World Oil and Gas Review, 2005.

**Figure 4-4** Imports and Exports of Oil Products of EU-29, 2004 (000 barrels/day)




Source: Energy in Europe. European Union Energy Outlook, to 2020

same period the average production/consumption ratio for the 25 European Union member countries was only of 0.19. In other words, 81% of consumed oil was produced outside the European Union.

In 2004, Europe (excluding former Soviet Union countries) imported 10.17 million barrels/day of crude oil and 2.4 million barrels/day of oil products (Table 4-2). The European imports constituted 26% of total world oil imports. Europe exported only around 2.0 million barrels/day of oil (mainly oil products) i.e. 4% of the world oil exports.

The main sources of Europe's supply in oil are shown in Figure 4-3. In 2004, the European countries (excluding those of the former Soviet Union) imported 19.6 million barrels of oil per day of which: 36.4% internal transfers, 27.1% from the FSU and 16.2% from the Middle East. Therefore the imports from former Soviet Union countries (both European as well as those of Central Asia) were 5.3 million barrels/day. The imports from Middle East amounted to 3.2 million barrels/day and that from Africa 2.5 million barrels/day.

The European Union member states (EU-25) imported 17.3 million barrels/day of oil (including transfers within the EU) while exports of oil and oil products were at the level of 6.3 million barrels/day. In the EU-29, the import to export ratio was at the level of 1.92. The data concerning imports and exports of particular countries from the same group is shown in Figure 4-4.

### Oil Supply to Europe: The Risk Factors

Vulnerability is a multi-dimensional phenomenon, and could be defined by a large number of risk factors. Distinctions should be made between, the risks of physical disruption and those of economic, social and environmental nature.

In the case of oil, the primary risks that might cause disruption of supplies and limit economic growth in the oil consuming countries are considered to be geopolitical. Europe is highly dependent on oil imports mainly from those regions generally perceived as presenting higher geopolitical risks. Political instability and regional conflicts are ranked first among risk factors; for example they were the cause of the first two oil shocks of the Israeli-Palestinian conflict and the Iranian revolution and Iran-Iraq war.

The recent instability in Nigeria and Iran's nuclear policy have raised the geopolitical risk factors with economic consequences to consumers, which explains the price increases observed in early 2006. The possibility of terrorist attacks on oil infrastructure should be also considered as a serious risk factor, the consequences of which might lead to temporary disruption of supply.

Oil price volatility is another hard to predict risk factor. OPEC policy, availability of additional production and refinery capacities, as well as global economic development will continue to be major factors influencing oil prices.

In the medium and long term, uncertainties regarding the geological constraints of petroleum resources and accessibility to them represent an essential risk. The recent downward reclassification of reserves made by a number of major oil producing companies led the most pessimistic

## Long distances between major production and consumption regions led to the early development of a global market for petroleum. The economic dependence on a steady supply of oil has made this market volatile.

analysts to believe the date of peak oil production to be not far off. Latest estimates by the United States Geological Survey (USGS) indicate an availability of about 2,000 billion barrels of conventional oil; this includes 1,000 billion barrels of proven reserves and 1,000 billion barrels yet to be confirmed. Many experts consider these figures to be fairly optimistic, bearing in mind that no one large-scale oil reservoir has been discovered, over last 2-3 decades. If the USGS forecasts were confirmed, the production could reach its peak around 2020. This peak could be delayed by a decade or more by using non-conventional petroleum.

Lack of investment in the oil sector over the last two decades has been another risk factor seriously disturbing the balance between supply and demand. Oil prices were too low to justify investments, especially in exploration in deep water and remote regions. No new refinery capacities have been built during this period in Europe. The current trend towards constantly high demand and prices attract fresh investment in these areas.

Risk factors threatening consumers are largely created by them. Oil has one captive market, namely transport, but also has a strong impact on electricity without really being used in this sector. While power generation has never returned to using oil even when its price dropped to US $ 10, the transport sector and its policy makers have not taken appropriate measures to search for alternatives. In mitigation of vulnerability to oil dependence and higher prices, the European economies need to formulate and implement sound energy policies in a combined approach that includes reducing energy demand by improving energy efficiency and seeking alternative energy solutions.

**Market and Infrastructure**

Long distances between major production and consumption regions led to the early development of a global market for petroleum. The economic dependence on a steady supply of oil has made this market volatile. Powerful market players, with the USA leading the way, began to pursue policies aimed at ensuring a secure supply of petroleum for their respective economies. Gradually, the oil markets were becoming the battlefields of geopolitics and have since been subject to major shocks, as reflected in the oil crisis caused by OPEC from 1973 to 1974; the nationalisation of the oil industries in various countries; the revolution in Iran with the ensuing round of increases in OPEC prices in 1979; the first Gulf War in 1990; the political crises in Venezuela and Nigeria and, since 2003, the persistent geopolitical uncertainties resulting from the war in Iraq. The response of major oil companies and industrialised countries to these challenges was to attempt to secure and diversify supplies via fast moving, transparent trading markets for crude oil and petroleum products. Since the late1980s, the liquid financial derivative markets have bolstered these efforts.

The futures and derivatives markets are primarily based on the NYMEX and IPE in which trading is being done not only by industrial firms, but also by hedge funds. The impact of speculators on price volatility is sometimes debated, but there is no doubt that there is significant boost to market liquidity.

## Today, oil prices are determined on spot and futures markets, and are no longer set according to the list prices issued by oil-producing countries.

In 2004, some 60% of petroleum production and consumption was traded internationally, either as crude oil or as petroleum products. Major trading routes run from the Middle East to East Asia, Western Europe and North America, from Russia to Western Europe and from Venezuela to the USA.

Russia is planning to modernise its existing infrastructures and to transport more oil by pipeline and less by rail. 90% of the country's oil is exported to Europe but Russia wants to increase its sales to the United States as well to China and Southeast Asia.

Algeria, another major exporter of hydrocarbons, is expanding. Oil production has risen to 1.4 million barrels/day, from 1 million barrels/day in 1999. 1.5 million barrels/day was production in 2006, and output is expected to reach 2.0 million barrels/day in 2010, with domestic consumption amounting to less than 0.2 million barrels/day. Algeria also wants to double its refinery capacity by 2010: increasing it from the current 460,000 barrels/day to 900,000 barrels/day. Planning of two refineries has begun, with capacities of 5 million and 15 million tonnes per year. Two new coastal installations accommodating the docking of very large tankers should boost the oil exports.

Theoretically the main drivers determining the path of oil prices over the long term are marginal production costs outside OPEC. Due to the impact of imbalances between supply and demand, political events and – increasingly – speculation, prices for crude oil will fluctuate sharply around this theoretical path.

For example, capacity bottlenecks and fluctuating demand in 2004 to 2005 were mainly due to the massive growth in Chinese demand, and political instability in some of the key producer countries occasionally pushed up the price of "Brent dated" crude oil to over US $ 70 per barrel.

According to estimates by the Centre for Global Energy Studies, the long-term marginal costs of petroleum extraction, outside of the OPEC space, range from US-$ 6 to US-$ 15 per barrel. While more and smaller deposits are being forced into production under difficult geological and geographical conditions, the inflationary impact of this trend on oil prices is balanced by increases in productivity, generally based on technical improvements. Nevertheless, price levels are expected to be higher than earlier anticipated over the medium term, bearing in mind the marginal production costs and price fluctuations.

Imported crude oil and petroleum products make up a significant share of the European Union's energy and difficulties with supply could seriously disturb economic activities. Facing this problem, all member states are required to keep stocks of petroleum products and crude oil with reserves of a minimum of 90 days (Council Directive 68/414/EEC, amended by Directive 98/93/EC). Member states can co-operate with the private sector using an agency to hold stocks. These stocks do not have to be maintained within the member state, but based on intergovernmental agreements they must be located within the EU.

While oil is inexpensive to transport, the seaborne trade in hydrocarbons does raise a different issue

**Table** 4-3 Proven Reserves of Natural Gas, 2004

| Region | | Reserves (trillion m3) | Share of total (%) | Reserves/Production Ratio (years) |
|---|---|---|---|---|
| Europe | | 54.89 | 30.6 | 59.7 |
| Out of which: | EU 25 | 2.75 | 1.5 | 12.8 |
| | Russia | 48.00 | 26.7 | 81.5 |
| North America | | 7.32 | 4.1 | 9.6 |
| Out of which: | USA | 5.29 | 2.9 | 9.8 |
| South & Central America | | 7.10 | 4.0 | 55.0 |
| Out of which: | Venezuela | 4.22 | 2.4 | >100.0 |
| Central Asia | | 9.13 | 5.1 | 69.4 |
| Out of which: | Turkmenistan | 2.90 | 1.6 | 53.1 |
| | Uzbekistan | 1.86 | 1.0 | 33.3 |
| Middle East | | 72.83 | 40.6 | >100.0 |
| Out of which: | Iran | 27.50 | 15.3 | >100.0 |
| | Iraq | 3.17 | 1.8 | >100.0 |
| | Kuwait | 1.57 | 0.9 | >100.0 |
| | Qatar | 25.78 | 14.4 | >100.0 |
| | Saudi Arabia | 6.75 | 3.8 | >100.0 |
| | United Arab Emirates | 6.06 | 3.4 | >100.0 |
| Africa | | 14.06 | 7.8 | 96.9 |
| Out of which: | Algeria | 4.55 | 2.5 | 55.4 |
| | Nigeria | 5.00 | 2.8 | >100.0 |
| Asia Pacific | | 14.21 | 7.9 | 43.9 |
| Out of which: | Australia | 2.46 | 1.4 | 69.9 |
| | China | 2.23 | 1.2 | 54.7 |
| | Indonesia | 2.56 | 1.4 | 34.9 |
| | Malaysia | 2.46 | 1.4 | 45.7 |
| Total World | | 179.53 | 100.0 | 66.7 |

Source: BP Statistical Review of World Energy, 2005.

of vulnerability; that of pollution. After the tanker Exxon Valdez ran aground off the coast of Alaska, the United States passed a series of laws in 1990, the most notable of which was a ban on single-hull tankers. Much later, in 2002 and 2003, the European Union also adopted a regulation imposing a double hull requirement for access to European ports, but this will not become obligatory until 2010. New directives were proposed in autumn 2005 aimed at reinforcing the prevention of accidents and pollution and improving the handling of accident follow-up.

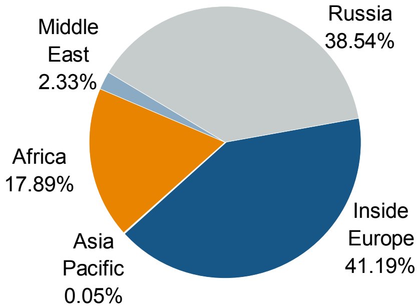
## Natural Gas

At end of 2004, the world proven reserves of natural gas amounted to 179.53 trillion cubic metre (Table 4-3). The biggest proven gas reserves are located in Russia (48.0 trillion cubic metre and 26.7% of the world total), another 40.6% in the Middle East. The European Union reserves amount to 2.75 trillion cubic metre and constitute only 1.5% of the world total reserves. In the EU-29, only Norway's gas reserves (2.4 trillion cubic meters) are of significant quantity. The world gas reserves may last for the next 60-65 years, at the present level of production and without new reserve exploration.

The natural gas resources are not distributed evenly among the various regions of the world. The three countries with the largest natural gas reserves – Russia, Iran and Qatar – account for 56% of the world's total remaining natural gas.

The flipside of the coin is that "traditional" gas reserves typically located in production fields close to consumers, such as the Dutch and British North Sea and the USA, are dwindling.

**Figure 4-5** European Gas Imports by Supply Region, 2004




Source: World Oil and Gas Review, 2005.

### Gas Production, Consumption, and Trade

The total European gas consumption in 2004, (including the former Soviet Union) was 1,022, BCM of which the EU-29 consumed about 532 BCM or about 49% of total consumption). The average gas production/consumption ratio was 0.67 and only three countries produced more gas than they consumed, namely Denmark with a p/r of 1.78; the Netherlands, with 1.65; and Norway with 19.5. In United Kingdom, the production was lower than consumption (0.99).

The world's biggest gas producer was Russia, in 2004, with production of 620.0 BCM.

Among the top ten world producers, there were only three in the EU-29, namely: the United Kingdom (101.2 BCM); Norway (80.6 BCM) and the Netherlands (84.4 BCM).

Total European gas imports amounted to 380.5 BCM. Pipelines (89.5%) delivered the bulk of imports. Imports of liquefied natural gas (LNG) were only 40.0 BCM. The EU-29 imported 355.1 BCM or about 90% of total European imports. Diversification of gas supply sources to Europe is shown in Figure 4-5.

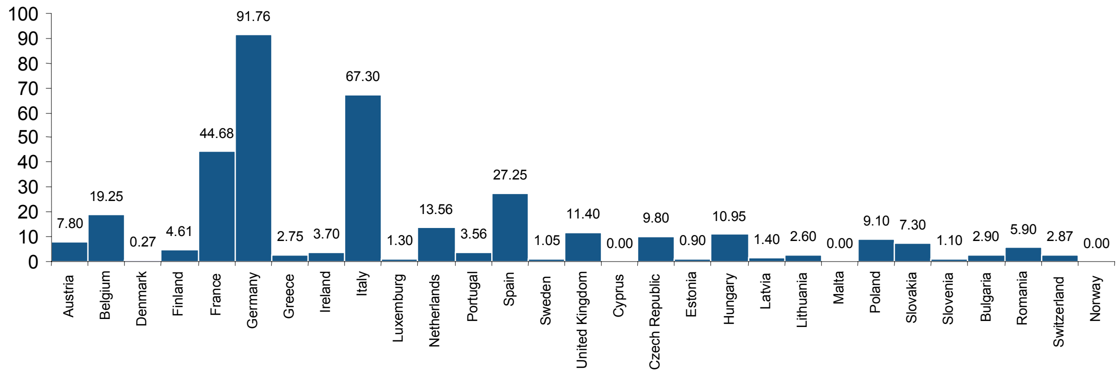
In the new 12 EU member states, regional production covered the consumption up to 17%. Only gas imports to the European countries are shown in Figure 4-6.

In 2004, the internal gas trade between European countries reached a high level, about 154.2 BCM or 40.6% of total imports. This was due to the well-developed gas pipeline networks. The second highest supplier of gas to Europe is Russia. Russia will continue to play a major role in the world natural gas supply due to its huge reserves and geographic location (Russia may export to Western Europe as well as Asia and the United States) and is exceptionally well positioned to arbitrate between markets. Most of the natural gas that Russia produces today comes from shallow layers of huge deposits in the Nadym-Pur-Taz area of Western Siberia, which entered their depletion phase in the mid 1990's. Several options are being considered to make up for the declining output and boost production. All require major investment for exploitation of the deeper layers of the huge deposits currently in production; for the development of smaller deposits around the very large ones; for the development of new regions of production within the Yamal peninsula (deposits include Bovanenkoe, Kharassarey, Kruzenstern, etc.); and finally for the Barents Sea (Stockman deposits, at the top of the list). Gas imports from Africa reached 68.8 BCM - the main suppliers were Algeria, Libya and Nigeria. Only Spain and France imported liquefied natural gas (LNG) from the Middle East. Due to lack of pipelines, the supplies to Europe from that region were only 2.3% of total imports. Imports from other regions are marginal. In 2004, Spain imported 0,2 BCM from Malaysia.

### Gas Supply to Europe: The Risk Factors

Major risk factors and uncertainties related to gas supply to Europe are not so different from those to oil supply: gas and oil to Europe are supplied from the same geopolitical regions. A disruption may occur for the same reasons, e.g. political instability, regional conflicts or terrorist attacks on the

**Figure 4-6** Imports of Natural Gas to EU-29, 2004 (billion cubic metre)




Source: World Oil and Gas Review, 2005.

infrastructure and production capacities. The difference is that the risk of disruption in the case of gas is much higher when it is transported by pipelines crossing more than one country. Consequences for the consumers might be more significant. Generally speaking the economic damage would be closer to electricity blackout occurrence than to oil supply disruption. LNG and oil disruption would have a similar impact on the market.

Economically, gas price volatility is a high risk factor; following more closely that of oil, than coal or uranium. Recent price increases make natural gas less attractive in comparison to coal and uranium for large-and medium scale capacities for electricity generation. Fuel cost will remain the principal economic factor in choosing a technology in power generation.

**Market and Infrastructure**

Over the last decade, natural gas has demonstrated the highest growth in consumption. However, there are a number of favourable factors: improvements in supply and distribution infrastructures; low prices seen in Europe and North America; improvements of efficiency in most gas applications; cost reductions throughout the LNG value chain; and the environmental advantage compared with coal and petroleum. All these have made gas more competitive.

Most forecasts indicate that natural gas will continue to expand its market share over the medium term. The IEA, for example, forecasts that natural gas consumption will continue to rise, at a world average annual rate of 2 %, until 2010. In countries, which have already developed an efficient gas market, such as Germany, the future increase in domestic and industrial consumption will be more moderate. It is not foreseeable, however, whether natural gas in the large-scale power plants will remain competitive if gas prices stay high.

In Europe, the key demand drivers for natural gas are the heating market, industrial applications, district heating and power generation. In recent years, natural gas has also won market shares from oil in the industrial and domestic heating. The importance of gas to the transport sector (gas-fuelled vehicles) remains negligible. The trend of demand increase will likely continue in the coming years, the rate depending on the effectiveness of policy measures and market solutions to encourage energy efficiency and reduce consumption.

Consequently, European gas markets will gradually become more and more dependent on gas imports. Natural gas will have to be transported from increasingly remote production fields. Many new deposits marked for development are situated in inhospitable areas with harsh climate conditions, thus posing significant technical difficulties and higher costs in their exploitation. Such new gas fields waiting for development are located in the Barents Sea, the Siberian Yamal Peninsula, or in deep offshore areas. The development of gas production fields from these regions will require enormous investment.

Due to the long distances between consumers and source of supply, the gas specific transport costs (i.e. cost per unit of energy) are higher than for coal and petroleum. Presently there is no coherent global market for natural gas, although the last price reductions in the LNG value chain are pushing towards higher market integration. The following four fragmented regional markets are only loosely connected with each other, and obtain their natural gas from completely different sources to supplement their own domestic production:

**North America** (i.e. the United States, Canada and Mexico) used to be self-sufficient for the most part. Due to the decline in reserves, the USA in particular will become increasingly dependent on natural gas imports, mainly LNG deliveries. A number of projects for building LNG terminals are under development.

**South America** could possibly, once it satisfies the domestic market, export LNG to North America and Europe.

**East Asia and Australia** import the majority of their natural gas from the Middle East, but also draw on reserves in their own region (e.g., Indonesia, Malaysia, China and Australia).

**Europe** imports large quantities of natural gas from Russia and North Africa and runs its own production operations, primarily in the North Sea. In order to meet future incremental gas demand Europe needs more potential sources of supply. From where and who can Europe ensure this?

Firstly Russia, Europe's major supplier, is planning to increase export capacity by opening new production fields, unfortunately from remote regions. Other solutions include reducing domestic consumption, which presently absorbs about two-thirds of the output, and/or developing imports from Central Asia into Russia. Foreseeing increase in natural gas consumption in Europe, Russia plans developing its own infrastructure network. The new trans-Baltic pipeline (the North Stream) will connect Russia and Germany as of 2010, and it may be extended to the Netherlands, the UK, the Scandinavian region, France and even to Spain. Russia will by then bring the Stockman field into production, expected to commence production in 2010. Russia is also considering developing its LNG exports with projects in Sakhalin, Shtokman and in St. Petersburg.

Algeria remains the second source of gas supply to Europe and expects to increase its exports from 60 BCM/year in 2005 to 80 billion BCM/year in 2010. For this purpose, two new routes are envisaged for construction, namely: Medgaz (Algeria – Spain, with an initial capacity 8 BCM/year) and Galsi (Algeria – Italy via Sardinia, a project under study). Also, there is a programme to raise the transport capacity of existing installations. These include: Enerico Matter (Algeria – Italy), to increase the current pipeline capacity of 8.5 BCM/year to 12.5 BCM/year, and subsequently to 20 BCM/year; and (b) Duran Farell (Morocco – Spain), with initial capacity of 9 BCM/year to 13 BCM/year).

A strong distinction could not be made between these four regional markets for the future, as new international transport routes (e. g., pipeline projects between Siberia and China or the Sakhalin project), blur boundaries between regions. Due to technical progress the cost of transport has

The rate of expansion of the LNG industry is spectacular. According to EIA estimations, over the past five years, LNG trade flows have increased by 29% (+40 billion cubic metre), the liquefaction capacity by 48 BCM/year, the LNG fleet has grown by 75%. By increasing LNG share the European energy markets may not only favourably diversify the present energy mix, but also their sources and routes of supply from more remote gas markets that would otherwise be inaccessible.

recently declined and this has been a driving factor, especially true for the transportation of natural gas in liquid form (LNG) by tanker ships.

Many factors contribute to the growing use of LNG. They include the distance between producing and consumption areas, declining reserves in traditional consumption regions, increased competitiveness from enhanced gas-pipeline performance (greater flexibility and spectacular gains along the entire cost chain), and reduced geopolitical risks related to the installation of gas pipelines in some unstable regions.

**The Increasing Role of LNG**

Liquefied natural gas (LNG) is presently considered to providing an alternative solution in ensuring gas supplies to consumers worldwide. Similar to petroleum in nature, it is particularly suitable for long-distance transportation (over 3,000 km). In liquid form, natural gas only takes up about 1/600 of the volume of gaseous natural gas, and therefore it can be cost-effectively transported in large quantities by ship.

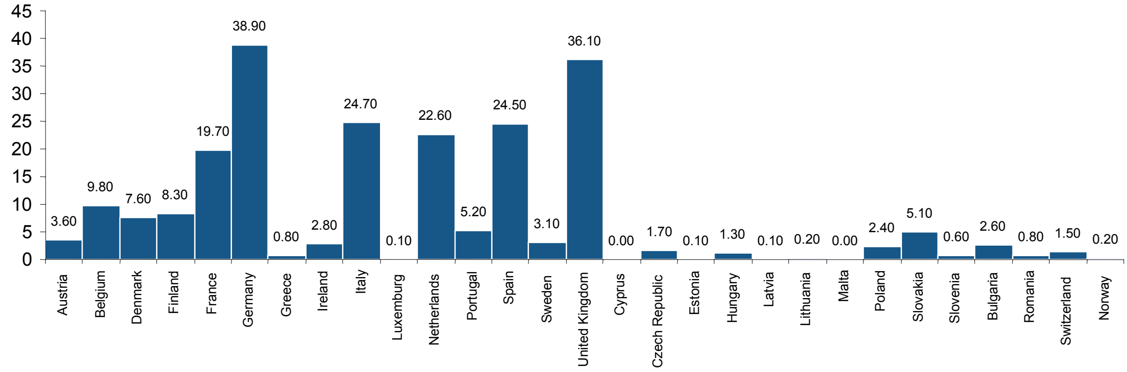
With current transport cost reduction due to the use of new large vessels, natural gas could basically now be "shifted" from one consumption region to another, depending on the prevailing market conditions. Consequently, the international trade in LNG is expected to grow significantly beyond these four main regional markets and a spot market for LNG is expected to emerge. Today, LNG accounts for 21% of total international trade in gas, compared with only 6% in the early 1970s, and its share is expected to rise to one-third, by 2020. By 2010, demand may vary from a range of 325-375 BCM/year, after being approximately 200 BCM in 2005. By the same date, all the plants, currently under operation, construction and planning would account for a liquefaction capacity between 400 and 500 BCM. This would be more than twice the LNG production in 2005 (192 billion cubic metre). The re-gasification capacity would reach more than 775 BCM: the current ones are of order of 475 BCM. The LNG maritime transport capacity is also expected to grow by 90% by 2010.

Technical performance is improving throughout the entire LNG value-added chain: use of larger plants and vessels to further reduce costs. The economic attraction of LNG transport can be expected to grow in the future. In the UK, plans currently call for the construction of LNG import terminals with an annual capacity of at least 20 billion cubic metre. The fleet of LNG tankers is also being expanded. Currently, there are 204 LNG tankers in operation and 139 more are firmly ordered.

As in the case for oil, Europe will reduce its regional dependency on gas supply as the LNG market increases and gas will change its market fundamentals: the market will move from local to global and gas can be delivered to a country/region where the best prices would be offered. The increased share of LNG will undoubtedly ease tensions in the gas market since natural gas fields distant from the existing infrastructure will be developed for the world market.

LNG is an opportunity but also a challenge for Europe: by broadening the gas supply source in this way, substantive unexpected investments

**Figure 4-7** Coal Imports to the EU by Region, 2004 (million tonnes)




Source: IEA, Coal Information, 2005

could be involved, moving beyond a system that is strictly continental and even national in scope. Since financial markets are rather driven by a profits approach, political support is required to ensure the long-term investments. Although the European re-gasification capacity is expected to double in the coming years, Europe needs to significantly enlarge its storage capacities where possible. Furthermore, the European Governments and European Commission should also develop and provide the market with a stable regulatory framework.

## Coal

### Coal Reserves

Coal reserves are abundant throughout the world and more equally distributed among different geographical regions than those of oil and gas. Coal reserves are also much bigger in terms of quantity. At the end of 2004, the average world reserves/production ratio was 164.0. The world proven coal reserves amounted to 909.1 billion tonnes (broken down by regions in Table 4-4).

The figures shown in Table 4-4 concern not only the high quality coal being internationally traded (anthracite and bituminous), but also lower quality coal (generally not traded internationally) such as sub-bituminous and lignite. Those coals, being used in the region of its occurrence help to fulfil local demand for energy and allow freeing of high quality coal for exports.

The only geological region where no coal deposits have been discovered is the Middle East.

Relatively low-level coal reserves are located in Central Asia (3.4% of the world reserves), mainly in Kazakhstan which, in 2004 was ranked as the ninth world producer (82.9 Mt). The European reserves are relatively high (28.1% of the total world reserves), but more than half of them are located in Russia, the sixth highest producer of hard coal (210 Mt). Significant reserves of coal are also available in Ukraine (34 Gt) and in Poland (14 Gt).

### Coal Production, Consumption, and Imports

In 2004, coal consumption in Europe was 726.4 million tonnes coal equivalent (tce)[4]. The average production/ consumption ratio was 0.77, i.e. 23% of consumed coal was imported from other regions of the world. Among the countries with the highest coal consumption rate in the EU-29 were Germany (122.3/Mtce), Poland (80.8 Mtce), the United Kingdom (53.5 Mtce), Spain (30.8 Mtce), the Czech Republic (28.8 Mtce) and Ireland (24.5 Mtce).

The total coal production in Europe was 559.6 Mtce and that of the EU-29 amounted to 292.0 Mtce. Major coal producers were Poland (99.1 Mtce), Germany (83.8 Mtce) and the Czech Republic (33.6 Mtce). Only in two countries (Poland and Czech Republic) was coal production higher than consumption. China remained the largest coal producer in the world.

Europe is a net coal-importing region. In 2004, coal imports to Europe amounted to 270.2 Mt. The main

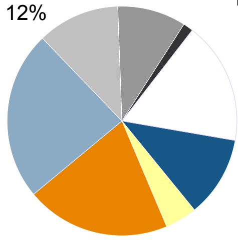
[4] Available statistics on coal production and consumption use usually coal equivalent to quantify coals of different quality. Coal equivalent is a coal of 7000 kJ/kg calorific value. 1 tce = 0.7 toe (tones of oil equivalent)

**Table 4-4** Coal Imports to EU-29, 2004

| Source | EU-25 | Bulgaria, Romania, Norway, Switzerland | EU-29 |
|---|---|---|---|
| Inside Europe | 25,157 | 414 | 25,571 |
| Russia | 36,519 | 2,003 | 38,522 |
| Former FSU | 2,192 | 1,248 | 3,440 |
| North America | 20,896 | 477 | 21,373 |
| South and Central America | 26,608 | 105 | 26,713 |
| Africa | 53,230 | 163 | 53,393 |
| Asia Pacific | 45,520 | 77 | 45,597 |
| Non specified | 9,244 | 524 | 9,768 |
| Total import | 219,366 | 5,011 | 224,377 |

Source: Energy in Europe. European Union Energy Outlook, to 2020

**Figure 4-8** Coal Imports to EU-29, 2004




importers were Germany (around 38 Mt) and the United Kingdom (36 Mt). Figure 4-7 and Table 4-5 show imports of coal to the EU-29. Figure 4-8 shows the geographical regions that are supplying coal to the EU-29. Over 53 Mt (23.8% of total coal imports) come from South Africa (representing 11.9%).

The second supplier is the Asian Pacific region (mainly Australia and Indonesia), delivering nearly 46 Mt, or 20.3% of the market share and Russia is the third (more than 38.5 Mt). Other important suppliers to the European market are Venezuela and Colombia. Share of South America's coal in the total EU-29 imports was 11.9%. The world hard coal trade in 2004 was at the level of 755 Mt. Inside Europe, imports include mainly those from Poland (approximately 20 Mt).

### Market and Infrastructure

Coal is the fossil fuel with the largest reserves, but expanding the use of coal is limited by increasingly strict environmental standards. While there have been great advances in the development of "clean" coal technologies over recent decades, the current environmental policy and the Kyoto Protocol commitments will pose new, major challenges for coal to face as the use of coal as an energy source causes the highest level of specific $CO_2$ emissions.

To a far greater degree than oil or natural gas, coal is generally used near extraction sites. International trade in coal consists of two segments, which are clearly distinguished from each other: coking coal and steam coal. As there were insufficient amounts of coal suitable for the production of coke in many steel manufacturing locations, international trade in coking coal was developed much earlier. International trade in steam coal, on the other hand, only began to pick up after the oil crises, borne by a renaissance in coal use and an increase in its share of electricity generation.

Seaborne trade represents roughly 16 % of global coal production. Global trade in coal is expected to grow considerably. International trade in coal is restricted almost exclusively to bituminous coal with medium to high calorific values. According to the IEA forecasts, over 20 % of global coal production will be traded on international markets, by 2020. The international trade in steam coal is projected to grow faster than production and consumption.

There are three major regional markets for international trade in steam coal:

- **The Pacific Basin**, with Australia, Indonesia, China and South Africa as the main suppliers, and Japan, South Korea and Taiwan as the countries with the strongest demand. The Pacific Basin is by far the largest regional market
- **The Atlantic Basin**, with South Africa, Colombia, Poland and Russia as the main suppliers, the EU member states and several other Mediterranean countries, as buyers. In the last decade, the USA has gradually lost its leading position as supplier

"Steam coal will once again be available on the global market at relatively low prices."

to this market, although formerly, the USA was the main exporter of coal to Europe

- **The inter-American market**, still relatively young and driven by increasingly strict environmental regulations imposed on the power plants in the USA, has opted for using a high quality Colombian and Venezuelan coal, to meet environmental requirements. This market is small, compared with the other two regional markets.

These regional markets are independent of each other to a limited degree only. If prices diverge and freight-shipping costs are relatively low, arbitration between markets quickly gains momentum, levelling out prices. South Africa can supply both large regional markets, and considerable amounts of Australian steam coal regularly wind up in Europe's ports.

The global coal market is open and, in contrast to the markets for petroleum and gas, is relatively free of political influence and the effects of cartels. Consequently, the long-term price trend is determined by marginal costs of production on regional markets. During the last decade, these costs have taken a downward trend. Productivity in many of the coal producing countries has increased strongly, and most newly developed deposits exhibit favourable geological conditions, resulting in low production costs. There is no indication that this situation will change radically soon. Steam coal will once again be available on the global market at relatively low prices.

The trend described above shows some cyclical fluctuation, but the volatility of coal prices was less pronounced than that of oil prices.

Cyclical fluctuations are the result of temporary imbalances between supply and demand. During periods of high prices, growth in production capacity usually outstrips the development of demand, so that, several years later, when this new capacity arrives on the market, prices collapse. Some market analysts now feel that there may be a weakening of this "hog cycle" due to the marked increase in concentration on the supply side, over recent years.

The steam coal market bottomed out in the middle of the year 2002. China has turned out to be a factor of uncertainty in matters of coal demand. Initially, the surprisingly strong increase in Chinese coal exports in 2001 and 2002 contributed significantly to the steep drop in coal prices around the world. Subsequent to that, a number of small mines were closed in several countries, and investment in the production of newly discovered reserves stopped. But the steel manufacturing boom in China (now clearly the world's largest producer of steel) led to a major increase in iron ore imports and freight rates for dry bulk, which affected shipping rates for steam coal as well.

Furthermore, the loading facilities for steam coal at certain Australian key ports, such as Newcastle and Dalrymple Bay, were pushed to the limits of their capacity in 2004. Over the medium term, the projected expansion of production and freight capacities should relieve the tensions on the global coal markets.

# Asia – in particular India and China – will continue to dominate the hard coal market.

Looking at the longer-term, trend prices for steam coal will probably rise modestly at best, in keeping with increases in marginal costs. As a result, coal will continue to be a viable competitor on the power generation market, unless the use of coal is significantly hindered by political intervention motivated by environmental concerns.

In contrast to crude oil, coal deposits are much less concentrated in the world. The hard coal production capacities are operated by many companies, in different regions. The ten largest private companies nevertheless account for 25% of hard coal production. Only 16% of the world output is traded on the international market, the remainder is consumed in the countries of production. The hard coal market has continuously grown. The East Asian economic region accounted for over 50% of the volumes traded with the European Union.

- With approximately 4.6 Gt/year consumption, hard coal currently accounts for 24.5% of global primary energy consumption. Around 60% of the coal output is used for electricity generation.
- As a result of globalisation, the coal market, is also undergoing structural change characterised by a concentration of supply in the hands of export countries such as Australia, Colombia and South Africa, with a growing importance of the transition economies (China, India and Russia).
- The world hard coal market will continue to grow. Annual growth rates may exceed the 5% that was maintained during the last few years. Annual growth rates of up to 8% are likely to be achieved by 2010.
- Bottlenecks related mainly to limited port and sea freight capacities. Open cast mines may face shortages in mining equipment in the market.
- China and India will be the most important hard coal importing nations of the future.
- Australia, Indonesia and Colombia have a great export potential with their low-cost mines and sufficient coal deposits. China and Russia, too, have theoretically the potential to enhance their position in the coal market. With high economic growth rates of approx. 8% per annum, China is likely to become a net hard coal importer rather than a net hard coal exporter.
- China's hunger for raw materials has led to overheated, prices especially that of coke and cooking coal, traded on the spot market. The prices paid by Germany for the imported coke rose from € 70/ tonne in May 2002, to € 160/tonne in May 2003 and reached over € 400/tonne, in March 2004. However they went down quickly again from € 300/tonne in May 2004, to € 250/tonne in October 2005. The coke market still remains very volatile.

Research in clean coal technologies that led to development of the so-called zero emission coal-fired power plants could be one of the ways to reach the Europe's ambitious targets in $CO_2$ reduction. With such technologies, coal will be able to hold and even strengthen its role as a key, low-cost source of energy, in particular, for power generation.

## Uranium

### Uranium Reserves and Resources

The total discovered uranium resources worldwide (so-called "reasonably assured resources (RAR) + estimated additional reserves" amounted to 4.75 million tonnes of uranium (MtU)[5]. Secondary sources of uranium supplied to nuclear power plants come from existing civilian and military stockpiles: e.g. from dismantled weapons, depleted uranium recycled after re-enrichment, and reprocessed uranium from spent-fuel. This is sufficient to supply the existing nuclear power plants over the world.

The uranium reserves/resources are distributed among a limited number of countries world-wide but they are considered to have a longer life cycle than that of hydrocarbons. Almost 99% of the reserves extractable at a cost of up to US $ 40 per kg of uranium are located in 10 countries headed by Australia (646.000 t U, approx. 41%), Canada (265.000 t U, approx. 17%), Kazakhstan (232.000 t U, approx. 15%), and South Africa (118.000 t U, approx. 8%). Over 80% of the global reserves are concentrated in these four countries.

### Uranium Production and Consumption

Unlike the fossil fuel market, for several years the uranium market has been characterised by a large gap between production and consumption.

During the last five years, the annual world mine production ranged from 32,200 t to 40,600 t of uranium, while annual consumption exceeded 60,000 t. The gap was filled by stocks from civilian and increasingly strategic (military) applications primarily from Russia. The stocks had been formed in anticipation of a growing civilian consumption, but also for military purposes. They are now successively consumed. The uranium made available in the process of nuclear disarmament, and uranium and plutonium resulting from the re-processing of spent fuel could play a certain role in future consumption. However, their utilisation depends on political decisions.

At world level, the current rate of uranium consumption (65,000 t/year) widely exceeded the world mining production of 36,000 t/year in 2004. Large consumer countries, such as the United States, France, Japan, Germany and the UK either have only limited mining facilities (United States) or are wholly dependent on imports (Japan, France, Germany). The continuing price increase will put an end to the trend of concentrating uranium mine production in a few countries with deposits that can be mined at low costs (Canada, Australia, Kazakhstan, and Uzbekistan).

Europe is and will remain strongly dependent on uranium imports as it consumes more than 28,000 t/year while it produces less than 5,000 t/y (Russia and the Czech Republic). The consumption of nuclear fuel in Europe will evolve as a function of the installed capacity. According to the World Nuclear Association (WNA 2005 report on "Global Nuclear Fuel Market") the total nuclear capacity in Europe is assumed to remain nearly constant from 173 GW in 2005 to 178 GW in 2020, therefore, the fuel consumption will remain nearly at the same level, over the next 15 years.

[5] According to the OECD/NEA-IAEA report (Red Book, June 2006).

# In relative terms, the share of renewable energy, including large hydro, remains below 5% in the current total primary energy mix.

The eight largest mining companies produced approx. 82% of the uranium output in 2004. It is worth mentioning that two leading world uranium companies are based in Europe, namely Rio Tinto (UK) and AREVA NC (France), the second and third world producers behind Cameco, the Canadian Company. They operate uranium mines mainly in Canada, Australia, Niger and Namibia. By country, Canada accounted for 28.5% (11,596 t) of the world mine production while Australia, Niger and Russia together produced another 39.1%. The majority of world conversion capacities (conversion of uranium oxide to UF6) also operate in Europe (France, Russia and the UK) and increase in production should not pose problems in the future.

**Uranium Market**

The uranium market is subject to the usual commodity cycles, in which rising prices provide a signal for new investments. If, at the beginning of this decade, the international uranium prices were as low as US$ 20/kg (=US$8 per pound of yellow cake, U3O8) they were climbing to more than US$100/kg, in 2006.In the near future, the start-up construction of large low-cost mines (for example, the Olympic Dam extension in Australia and Cigar Lake in Canada) would likely drive prices downward. It is worth mentioning that the uranium price volatility does not affect the cost of nuclear power generation at the same rate fossil fuels do, as the fuel cost is much less as a share of the operational costs.

## Renewable Resources

Renewable energy is energy that is derived from natural resources and is constantly replenished; in other words, the renewable energy sources (RES) generally include all non-fossil energy sources. The most important among them are hydropower, biomass, wind, solar, geothermal and waste.

In Europe, renewable energy sources have considerable potential and they could make an increasingly substantial contribution to supply diversification, emission reductions, security of supply and sustainability of the energy sector as a whole, over a long-term perspective. Both, solid biomass and hydropower combined provide around 80-85% of the total renewable energy supply in Europe. While geothermal and hydropower have already reached their potential development capacities, others, namely wind and solar, have significant potential for further development.

Certainly, the potential for renewable energies in Europe is large, but to what extent and how quickly might renewable energies increase their market share? According to numerous scenarios developed by United Nations Organisations, International Energy Agency, International Atomic Energy Agency and World Energy Council, the share of renewable energies will grow but renewables will still remain, in the foreseeable future, a complement to, rather than a replacement for, fossil fuels.

**Hydropower**

In 2004 hydropower provided 16 % of the world's electricity supply (2,809 TWh of worlds total 17,450 TWh). At world level, only 33% of hydro potential has been developed. In Europe, there is limited potential for further large-scale hydropower, but the local conditions in a number of countries offer opportunities to build small capacities, in the order of 5-10 MW. This is encouraged by the adopted Directive on Renewables (2001/77/EC).

In the EU-29, the installed hydro capacity of approximately 180 GW produced 492 TWh of electricity energy in 2004. The biggest installed capacities are in Norway (28 GW), France (25 GW) and Sweden (16 GW).

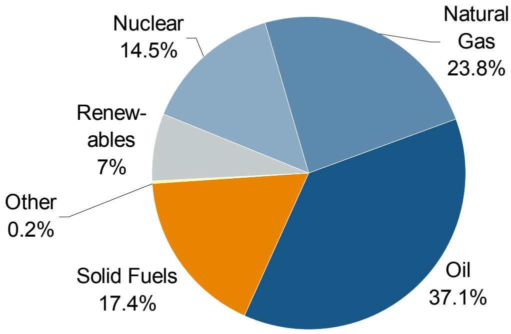
The main priorities for the hydropower sector today are extending the life of the existing plants and adding small capacities, where possible. Restrictions against building new large-scale hydropower plants are mainly based on environmental aspects, and lack of potential in Europe. This can change in the future taking the security of supply aspect into further consideration.

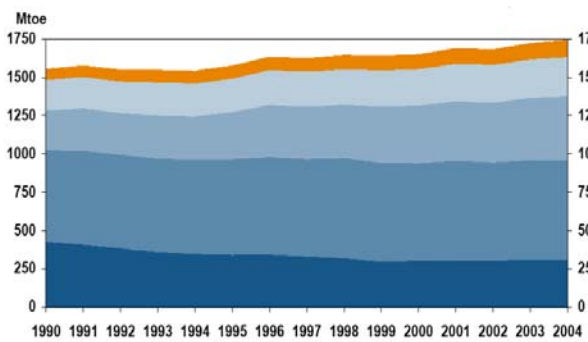
**Other Renewable Resources**

In Europe, the contribution of other renewable energy sources to the energy mix is limited: biomass is used in the forms of wood and wood wastes (between 1 and 3%) while wind and solar together represent below 1%. Despite that, their penetration has progressed by an annual rate of 20-25 %, over the last five years. This is particularly valid for wind power. By increasing the size of wind turbines from 70 kW in the early 1980s, to 3 MW in 2005 and reaching today 5 MW, the costs of electricity were significantly reduced. The total annual capacities exceeded 30 MW, wind farms are built mainly on the coastal areas in Germany, Denmark, Netherlands, the United Kingdom and Spain and their construction is extending to Central and Eastern Europe. Currently, onshore wind energy is the lowest cost renewable energy source. The solar energy potential is enormous (2,895,000 EJ) and compared with the potential of remaining renewables (325,300 EJ) or any of solid fuels, for example, the most abundant-coal (185, 330 EJ) it seems incredible. Since 1997, due to technological improvement, the cost of solar energy has dropped significantly for domestic applications, but is still far from being commercially competitive. For example, in Switzerland, the difference in cost between that of solar and hydro is a factor of four or five.

While wind, small hydro, biomass and solar applications can be successfully deployed in specific areas under favourable conditions, their widespread use will continue to be constrained by economics and, to some extent, environmental factors. Under present market conditions, renewable energy sources are, on the whole, not competitive and their widespread use cannot be accelerated without the provision of direct or indirect subsidies. Some participants in the energy market argue that this would undermine basic market principles while others, mostly proponents of renewable energies, claim that targeted subsidies for a limited time period are needed to encourage the development and use of renewables (needed for "take off").

**Figure 4-9** Gross Inland Consumption of EU-29, 2004




Source: Energy and Transport in Figures, 2006

## Consumption of Primary Energy by Sources

Since 1990, the gross primary energy consumption in the EU-29 has been rising at a slower rate, by 0.7% per year (Figure 4-9).

Renewable energies showed the largest annual increases (3.0%) followed by natural gas (2.8%) and nuclear energy (1.8%). Mineral oil registered annual increases of 0.5%. The demand for solid fuels decreased by an annual rate of 2.2%.

In 2004, oil remained the main source of energy with a 37% share of the primary energy consumption, followed by natural gas with 24%. Other significant energy sources of the European Union power supply are solid fuels with a share of 18% and nuclear energy with a 14% share. Renewable and other energies accounted for 7%. There was a considerable difference in each national energy mix in the 29 member states. For example, the share of natural gas ranged from zero in Cyprus and Malta and 2% in Sweden to almost 45% in the Netherlands; that of oil ranged from less than 20% in Slovakia and Estonia to 60% in Portugal and almost 100% in Malta and Cyprus; and the share of solid fuels ranged from 1% in Switzerland and 5% in France to 30% in Greece and to 60% in Poland.

The primary energy consumption, by source of energy and by country as well as the structure of the energy mix (2004) is presented in Appendix A.

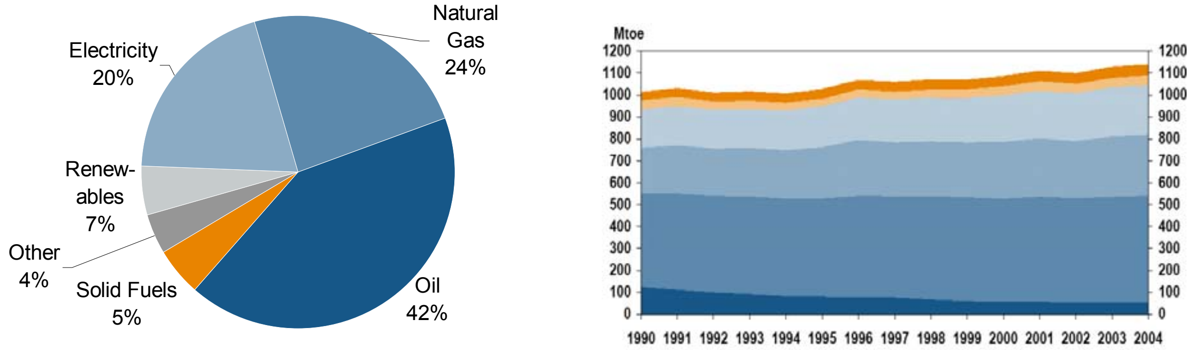
Since 1990, the final energy consumption has grown annually by approx. 0.7% (Figure 4.10) below. Renewable energies saw the largest annual increase of 2.8%, although their relative share is 5% only. Also, in final consumption, natural gas has shown strong annual increases of 1.7%, electricity, too, saw an increase by 1.7% and crude oil by 0.8%. Solids saw a strong annual decrease of - 5.8% in this area.

In 2004, oil also remained the main source of energy in the final consumption with a share of 43%. Natural gas saw strong consumption with a share of 24%, followed by electricity with 20%, while solids comprised 5%, renewable energies 4% and derived heat 4%. There were similar differences in the structure of energy consumption between countries. The final energy consumption by source of energy, for EU-29 (2004) is presented in Appendix B.

The final energy consumption by sectors (Figure 4-11), show the following characteristics: since 1990, the energy consumption of the transport sector rose by 1.8% annually, that of the service sector by 0.8% and the domestic sector consumed 1.2% more energy per annum. In contrast, the energy consumption of the industry decreased by 0.7%.

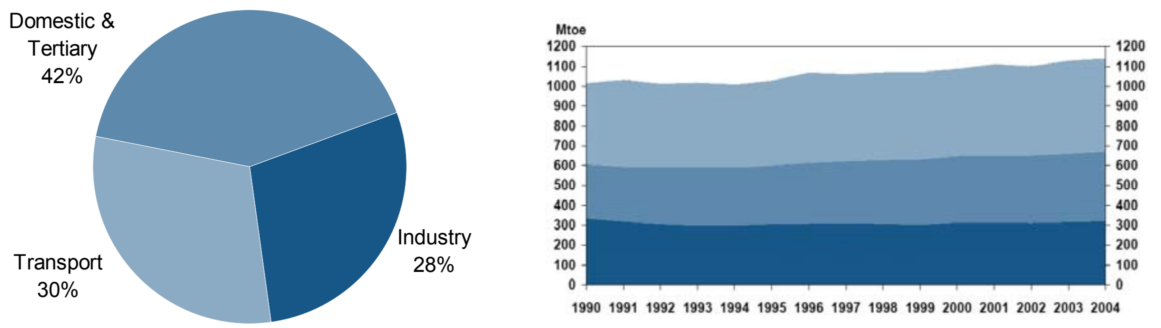
In 2004 the largest consumer group was the domestic and tertiary sector with a share of 41%, followed by the transport sector with 30% and, the industry with 28%. The final energy consumption by the EU-29 consumer groups, as well as their relative shares, in 2004, is represented in Appendix C.

## **Figure 4-10** Final Energy Consumption by Fuel of EU-29, 2004




Source: EU Energy and Transport in Figures, 2006.

## **Figure 4-11** Final Energy Consumption by Sector of EU-29, 2004




Source: EU Energy and Transport in Figures, 2006.

## **Table 4-5** Import Dependency of EU-29, 2004

| | 1995 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| | **All Fuels** | **Solid Fuels** | **Oil** | **Natural Gas** | **All Fuels** | **Solid Fuels** | **Oil** | **Natural Gas** |
| EU-29 | 33.9 | 22.0 | 55.0 | 36.2 | 38.4 | 37.8 | 59.4 | 38.7 |
| EU-25 | 43.5 | 21.4 | 74.7 | 43.9 | 50.5 | 38.2 | 80.2 | 54.5 |
| Belgium | 80.5 | 109.3 | 99.5 | 98.2 | 78.9 | 101.4 | 99.8 | 99.9 |
| Czech Republic | 20.7 | -25.9 | 98.3 | 98.0 | 25.3 | -17.2 | 93.6 | 91.1 |
| Denmark | 34.5 | 117.9 | 13.4 | -47.2 | -47.9 | 101.4 | -116.8 | -79.7 |
| Germany | 57.4 | 11.9 | 96.5 | 78.6 | 61.3 | 32.3 | 94.8 | 83.7 |
| Estonia | 36.0 | 8.9 | 105.2 | 100.0 | 28.5 | 6.2 | 73.8 | 100.0 |
| Greece | 65.8 | 10.5 | 98.4 | 0.0 | 72.7 | 5.1 | 104.8 | 97.5 |
| Spain | 71.6 | 46.9 | 101.1 | 97.4 | 77.4 | 67.2 | 99.4 | 97.8 |
| France | 47.9 | 58.9 | 96.9 | 93.0 | 50.5 | 94.4 | 98.3 | 96.2 |
| Ireland | 68.7 | 63.1 | 100.2 | 3.6 | 86.5 | 78.2 | 93.4 | 81.2 |
| Italy | 82.3 | 105.8 | 93.7 | 63.9 | 84.5 | 101.1 | 9393 | 83.8 |
| Cyprus | 99.0 | 130.8 | 101.0 | - | 94.6 | 70.7 | 98.8 | - |
| Latvia | 69.2 | 62.3 | 101.9 | 98.9 | 63.5 | 94.0 | 99.2 | 130.5 |
| Lithuania | 64.1 | 64.0 | 114.5 | 100.0 | 48.0 | 91.4 | 94.2 | 100.0 |
| Luxemburg | 97.7 | 100.0 | 98.2 | 100.0 | 98.2 | 100.0 | 99.6 | 100.0 |
| Hungary | 48.8 | 30.7 | 71.5 | 60.3 | 60.8 | 32.9 | 76.8 | 79.2 |
| Malta | 104.5 | - | 104.5 | - | 100.0 | - | 100.0 | - |
| Netherlands | 19.3 | 98.1 | 85.4 | -77.4 | 30.7 | 98.7 | 95.5 | -67.7 |
| Austria | 66.5 | 76.2 | 89.4 | 84.8 | 70.8 | 95.1 | 95.0 | 78.8 |
| Poland | -0.2 | -30.1 | 95.6 | 64.6 | 14.7 | -26.8 | 94.0 | 68.3 |
| Portugal | 89.0 | 108.7 | 100.6 | - | 83.6 | 95.2 | 97.8 | 100.0 |
| Slovenia | 49.8 | 13.3 | 97.8 | 100.5 | 52.1 | 21.8 | 101.6 | 99.5 |
| Slovakia | 70.6 | 76.3 | 106.2 | 86.8 | 67.6 | 83.2 | 91.9 | 103.3 |
| Finland | 52.9 | 63.4 | 94.6 | 100.0 | 54.4 | 73.3 | 96.0 | 100.0 |
| Sweden | 37.5 | 91.8 | 95.4 | 100.0 | 36.5 | 85.3 | 97.8 | 100.0 |
| United Kingdom | -16.3 | 22.9 | -57.3 | 1.0 | 5.2 | 59.0 | -15.3 | 1.7 |
| Bulgaria | 57.2 | 31.6 | 100.0 | 99.5 | 48.0 | 40.4 | 98.3 | 95.8 |
| Romania | 30.9 | 26.6 | 49.3 | 24.9 | 30.2 | 34.0 | 46.6 | 29.5 |
| Norway | -642.9 | 84.0 | -1485.6 | -716.5 | -746.7 | -110.1 | -1300.6 | -1482.8 |
| Switzerland | 55.1 | 82.9 | 97.7 | 100.0 | 56.6 | 100.0 | 100.3 | 100.0 |

Source: EU Energy and Transport in Figures, 2006.

## Import Dependency of the EU-29

Europe is highly dependent on energy imports. That is why the Import Dependency Indicator (Part Two) is considered as a primary indicator for determining the vulnerability of a country or region to energy crises. It is generally defined as a ratio between the net imports and the gross domestic consumption and stored supplies.

In total, the import dependency of the EU-29 in 2004 had increased from 33.9% in 1995 to 38.4%, in 2004. The highest import dependency is on oil (59.4%), followed by natural gas (38.7%) and solid fuels (37.8%). Within the European energy market, Norway, United Kingdom and Denmark were the main net energy exporters; they produced more energy than they consumed. The Czech Republic and Poland were net exporters in solid fuels and the Netherlands exports natural gas. Otherwise, the EU member countries were and are dependent on imports.

Most EU countries have an import dependency on oil of over 90%. Only Norway, Britain and Denmark are self-sufficient. Romania has a relatively low oil import dependency (46.6%). In dependency on natural gas, the situation is a similar one: most of the EU countries have a high import dependency, more that 80%. Once again Romania has a relatively low dependency on natural gas – 29.5%. It is only with regard to solid fuels that the import dependency of individual EU- countries is more varied. It ranges from zero import dependency of Poland and the Czech Republic, rising to 20% and 40% dependency of Germany, Hungary, Slovenia and Romania, finally reaching 100% dependency, of Luxembourg and the Netherlands.

The energy import dependencies of individual EU-countries, by type of resource is shown in Table 4-5, with comparison between the years 1995 and 2004.

## Conclusions

### Oil

The vulnerability of the oil market and supply to Europe is linked to a large number of risk factors and uncertainty, related to physical disruption and, more frequently, to price volatility. To alleviate the vulnerability of oil dependence and price volatility, the European countries must reply with strong policies, including the reduction in transport consumption and other areas of the economy where oil-based products are used. This can be complemented by alternative energy solutions and enforcing efficiency regulations for all sectors of the national economy.

### Natural Gas

From a geological point a view, the world possesses enough natural gas to ensure sufficient consumer supply for decades to come. However, new gas supplies are mainly located in remote areas, and some in harsh climatic conditions. This will lead to higher production costs and enormous investment in a transport infrastructure.

In Europe, demand for natural gas will continue to grow. The main market will be the heating market including district, industry, and electricity generation. Recent gas price volatility raised some fears about the future competitiveness of natural gas in the large-scale electricity generation. To match the demand, Russia, Norway and North Africa (Algeria, Egypt, and Libya) will be the key regions of supply and new infrastructures must be developed both for pipelines and LNG. These new infrastructures will require a stable and predictable regulatory framework, to ensure long-term commitments. The growing development of LNG capacities will change the gas market from local to global.

The vulnerability of gas supply has become a concern in Europe. To ease this vulnerability, it is essential to develop more underground storage capacity to integrate energy companies throughout the entire gas value chain. It is essential to maintain good political and commercial relations with producing countries and to develop further LNG facilities in Europe, in order to diversify gas regions and routes of transport.

**Coal**

The world coal market continues to grow. Coal is abundant and has a lower disruption risk compared to that of hydrocarbons. Europe still has significant reserves, and has maintained access to the closed coalmines. In addition, there are no storage problems. With recent gas price increases, coal looks like a credible option in the power generation and it could remain as such, after 2015-2020.

The carbon capture and sequestration is the real challenge for the European coal industry in the future, and if commercialisation succeeds then coal will continue to play a key role in reducing Europe's vulnerability to energy crises.

**Nuclear Resources**

Uranium and thorium resources are plentiful and do not pose a constraint to long-term deployment of nuclear power.

**Renewable Resources**

Renewable resources are more evenly distributed and accessible than fossil and nuclear resources but their widespread use continues to face mainly economic and technical constraints.

The further penetration of renewable energies in the market will bring significant benefits, to complementing the bulk of energy supply and contributing to the shift of the present energy sector to a more sustainable development path. Further deployment should be encouraged, as it will undoubtedly lead to reducing vulnerability, in particular that related to energy import dependence. However, under the present market conditions, RES are still, on the whole, not competitive and their deployment faces difficulty.

# Part Five
# European Electricity Market Vulnerability

## Introduction

Security of electricity supply may be defined as the ability of the electrical power system to provide end-users with a specific level of continuity and quality in a sustainable manner – relating to the existing standards and contracted agreements.

It must be emphasised that electricity is a necessary commodity for modern society. Electricity may easily replace any other form of energy and can often be easily and cheaply distributed.

In a liberalised market provision must be made to deliver electricity at a competitive price, be of a reasonable technical quality and produced in a way that impacts minimally on public health and the environment. The electricity industry is not constrained by national borders.

To ensure a regular supply of electricity in the foreseeable future there are three prerequisites: sufficient generation to meet demand, adequate infrastructure to deliver the power and robust technical and administrative operational procedures.

Electricity markets are often characterised by fragile supply and demand, therefore wholesale prices tend to be volatile. One characteristic of the electricity market is that the planning horizon is extensive, therefore it is necessary that permissions to build new power plants and transmission infrastructure are efficiently allowed. A completely opposite characteristic is that there is no lead-time between demand and production. This means that "light on and off" happens simultaneously and signals the operating system.

Shortages of electric power and supply could occur for the following reasons: an inadequate number of generating facilities, limitation in the transmission and distribution system or insecure supply. The latter can be caused by a lack of rain, fuel shortage or some damage in the power plant. Investment is necessary to ensure system adequacy and improve supply security.

Europe has already enjoyed secure electricity supplies for many years. Prior to liberalisation, the electricity supply security in a given geographical area was usually ensured by a single, vertically integrated enterprise often publicly owned. Security of supply risk borne by consumers was virtually nil, but the customer was obliged to bear the entire price-risk relative to investments.

In the present liberalised structure, investments are triggered by market decisions in a competitive framework but transmission investments are still triggered by regulatory action or incentives. For electricity utilities, the advent of competitive pressure, falling prices and the consequent economic risks have impacted significantly on financial performance. The analysis of the status of the European power sector in the last years showed that economic value creation (as measured by the increment of the return on capital employed over the cost of capital) became negative, or at least fell, for most electrical utilities since 1997.

European countries are in the process of changing their electricity markets from many more or less

**Table 5-1** Net Electricity Generating Capacity, 2003-2004

| | 2003 | | 2004 | | Growth |
|---|---|---|---|---|---|
| | MW | % | MW | % | % |
| Nuclear | 139,331 | 18.3 | 139,107 | 17.9 | -0.2 |
| Conventional Thermal | 401,792 | 52.8 | 411,495 | 53.1 | 2.4 |
| of which: Hard Coal | 134,676 | 17.7 | 135,752 | 17.5 | 0.8 |
| Lignite | 53,843 | 7.1 | 53,896 | 6.9 | 0.1 |
| Oil | 71,130 | 9.3 | 71,192 | 9.2 | 0.1 |
| Natural Gas | 142,143 | 18.7 | 150,655 | 19.4 | 6.0 |
| Hydro | 178,798 | 23.5 | 180,4 | 23.2 | 0.8 |
| Other Renewable | 41,140 | 5.4 | 44,388 | 5.8 | 9.0 |
| Total EU-29 | 761,061 | 100.0 | 775,623 | 100.0 | 1.9 |

Source: Eurelectric

separate monopolistic markets with national supply into one single liberalised market. The implementation of the first liberalisation Directive (96/92/EC) has resulted in fully liberalised electricity markets in some Member States. There are still markets where not all liberalisation aspects are in place. Following the new electricity market Directive (2003/54/EC) the process of integrating the national electricity markets (in parallel with the natural gas markets) is reinforced and in 2007 all customers will have the right to choose their supplier. In fact both these market changes of liberalisation and integration have an effect on market investment. Liberalisation brings new challenges while integration provides more choice of investment between import possibilities and building generation.

It is necessary to build up enough interconnections and transmission capacities to ensure the positive effect of liberalisation and improve security of electricity supply.

Certainly the electricity sector in Europe could be described as a long-term moderate-return sector, yet it remains highly capital-sensitive. With continued growth in demand, ageing power plants gradually being removed from the system and increasing requirements for extensive network refurbishment and expansion, most experts forecast the continued need for very substantial power investment over the next twenty years. These investments must be made in a changed economic environment.

In order to establish the vulnerability of the electricity market in Europe at a moment of primary energy shortage it is necessary to analyse the structure and characteristics of the electricity sector against external and internal trade patterns. This will be addressed in the next chapter.

## Structure and Characteristics of Electricity Sectors

### Capacity and Generating Structure

The aggregated existing net electricity capacity in the 29 countries of Europe for 2003 and 2004 by primary energy sources is shown in Table 5-1. In 2004 the installed capacity of Europe's power plants amounted to 775,623 MW of which 17.9% were in nuclear power plants, 53.1% were in thermal power plants, 23.8% were in hydropower plants and 5.8% in other renewable plants.

The installed capacity of conventional thermal power plants was 411,495 MW in 2004, of which 46.0% of the plants burned coal, 17.3% of the plants burned oil, 36.7% of the plants burned natural gas.

The growth rate of the installed capacity for 2004 was 1.9% in total, new thermal power plants burning natural gas (6%) and other renewables (9.0%). Electricity consumption continues to grow in Europe. Its structure of production technologies is shown on Table 5-2.

The growth rate of electricity production from the differing generating sources varies greatly, the largest being "other renewables" at 18.1%.

A global shortage of fossil fuels will only affect conventional thermal plants burning imported fuels

**Table 5-2** Net Electricity Production, 2003-2004

| | 2003 | | 2004 | | Growth |
|---|---|---|---|---|---|
| | TWh | % | TWh | % | % |
| Nuclear | 970 | 30.1 | 983 | 30.0 | 1.3 |
| Conventional Thermal | 1,682 | 52.2 | 1,694 | 51.6 | 0.7 |
| Hydro | 475 | 14.7 | 492 | 15.0 | 3.6 |
| Other Renewables | 94 | 2.9 | 111 | 3.4 | 18.1 |
| Total, EU-29 | 3,221 | 100.0 | 3,280 | 100.0 | 1.8 |

Source: Eurelectric

**Table 5-3** Share of CHP

| | Total TPP Installed Capacity | Share of CHP | |
|---|---|---|---|
| | MW | MW | % |
| EU-15 | 338,836 | 78,643 | 23.2 |
| NMS | 57,257 | 15,719 | 27.5 |
| EU-25 | 396,093 | 94,362 | 23.8 |
| CCN | 15,402 | 6,323 | 41.1 |
| EU-29 | 441,495 | 100,685 | 22.8 |

Source: Eurelectric

such as oil and natural gas. Increased generation by nuclear energy and renewables should therefore improve the security of supply. There is enormous political support in Europe for investment in renewable energy sources (RES).

The situation in Europe differs from country to country. Circumstances may also differ between synchronous interconnected systems and island systems. The capacity targets and the future portfolio of RES depend on the national situation. The greatest growth potential is for wind energy. Expectations of the European Wind Energy Association show an increase from 28.5 GW in 2003 up to 180 GW in 2020. This capacity tends to focus particularly on specific regions in Europe due to different support-schemes for RES, restrictions in licensing and the limitation in the number of suitable sites.

New RES often require new grid infrastructure. New wind farms will often be built at a distance from the main load centres. Therefore it will be necessary to build new transmission lines in order to transport the electricity to the consumer. Intermittent contributions from wind power must be balanced with separate back-up generation capacity. In regions with a lot of hydropower the supply system can include more wind power than elsewhere. For example in Sweden, with an electricity production around 150 TWh, it is possible to have 10 TWh wind power without disturbing the balance in the system. This will be balanced by hydropower.

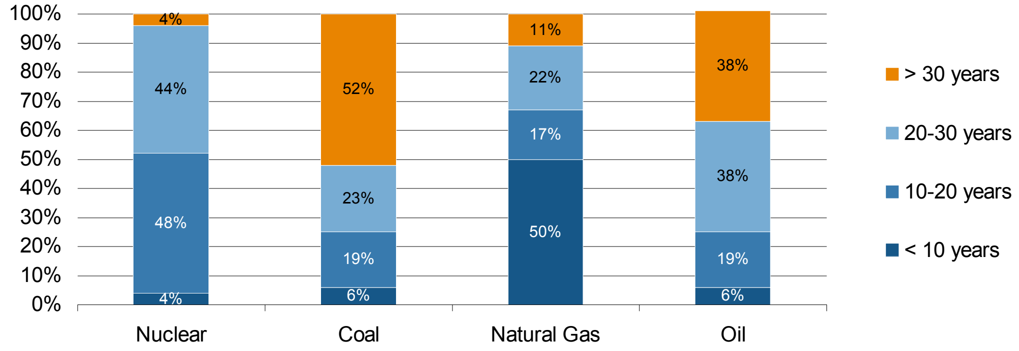
Traditionally investments in RES have been stimulated through direct or indirect subsidies and/or feed-in tariffs. Italy, Norway, Sweden, UK, Belgium and the Netherlands have recently introduced green certificates. A great advantage with green certificates is that the system is market-based and the government does not need to pay subsidies (in some cases subsidies can be obtained during a transitional period). Green certificates are an economically efficient mechanism for implementing RES targets.

The main electricity generating RES source (except hydro power plants) is wind. The total installed wind generating capacity in the EU-15 at the end of 2003 was 27,422 MW. However this capacity is concentrated mainly in two countries – Germany and Spain. The installed capacity of wind turbines in Germany is 15,387 MW, which is more than 50% of the EU total wind generating capacity. In Spain 5,945 MW are installed, which is about a quarter of EU total capacity.

In 2003 the EU generated 44,258 GWh from wind turbines, equivalent to the average production of 6,000 MW of conventional thermal or nuclear power plants. Among the 17 Member States offering this source of electricity production, Germany and Spain were clearly producing most. The combined production from wind generation in these two countries accounted for close to 70% in the EU, with 18,859 and 12,075 GWh respectively.

Tables 5-1 and 5-2 point out that in 2004 approximately 53% of the total installed generating capacity in 29 European countries generated about 51.6% of total net electricity production. Of the total installed capacity in conventional thermal power

**Figure 5-1** Age Structure of Installed Capacity in EU-29




Source: Eurelectric

plants about 23% was in combined heat and power plants (CHP) (Table 5-3).

The share of CHP in the most of the EU-15 is lower than in the other European countries. However these countries plan to develop combined power and heat generation following the new EU Directives. At present these types of plant only have a greater share in Denmark (75%), Finland (40%) and the Netherlands (33%).

The New Member States have a more developed district-heating network, the average share of CHP being about 27%.

The group of non-members, which includes, Switzerland and Norway, has a share of CHP – about 40%. The reason is the very high share in Romania, until recently a non-member, of about 50%. There is a significant technical potential in the big cities of Europe to develop plants with combined power and heat generation, acknowledging the EU Directives.

The European Commission is seeking to promote the use of co-generation by requiring Member State to step up their efforts to develop this technology, with a focus on its utilisation, energy efficiency, fuel flexibility (including renewable energies), reduction of construction costs and other such areas. Natural gas is very often the preferred fuel for co-generation because it is clean, cheap, easy to transport and simple to use.

Beside CHP facilities, whose total energy efficiency can reach 85% to 90% of the primary energy used (compared with 40% of conventional power plants), there are also plants that generate power with combined–cycle gas turbines, whose excellent efficiency often exceeds 55%.

The age structure of the existing thermal power plants in Europe–29 is shown in Figure 5-1 below. It is seen that only the share of new TPP on natural gas is significant–about 50%. All other types of thermal power plants are too old–10-20 years and more. They need vast rehabilitation to improve their efficiency.

Considering the age of the existing power plants in the EU-29 and the expected growth of electricity consumption in the period 2006-2030 (1.5% per year), the maximum net installed capacity needs of the interconnected European systems will be 843 GW in 2030, assuming a normal reserve margin and availability.

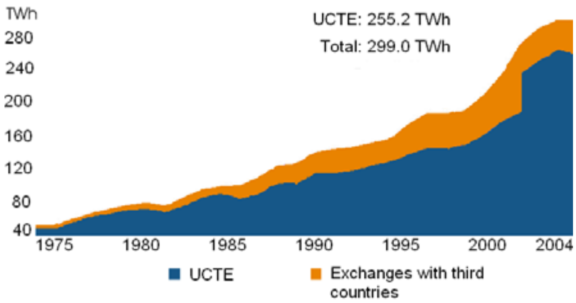
In order to increase the installed capacity by 265 GW requires major investment in new power plants. The real need for investment is perhaps roughly double, as many older power plants will be retired by 2030 or will have to close because of stricter environmental rules, political decisions, higher costs due to the emission trading system or lower profit because of low efficiency. EURELECTRIC's projection is that around 520 GW of new generation capacities must be installed by 2030.

**Table 5-4** Import and Export of Electricity for EU-29, 2000-2004

| | TWh | | | | |
|---|---|---|---|---|---|
| | **2000** | **2001** | **2002** | **2003** | **2004** |
| Import of electricity | 268.7 | 268.1 | 296.8 | 310.7 | 315.4 |
| Export of electricity | 240.2 | 255.3 | 276.7 | 314.0 | 299.0 |

Source: Eurelectric

**Figure 5-2** Sum of Exchanges in Europe, 1975-2004




Source: UCTE Statistics

### External and Internal Trade Patterns

European Institutions have clearly identified the need for increased cross border (CB) transmission capacity. Practical support for this policy is provided by the Trans European Networks (TENs) programme, which identifies certain priority projects of European interest, and the call for CB capacity of at least 10% of national demand to be installed for each Member State.

Several contributory factors exist that can increase demand for new network infrastructure and management facilities. Although they vary somewhat between transmission and distribution investments some typical elements can be identified:

- Connection of new plants or users
- Refurbishment of existing networks to maintain integrity and security standards
- Improvement in power quality
- Electricity demand growth (1% to 2% across Europe, up to 6% in some countries)
- Development of dispatching infrastructure (state estimators, online data collection etc.), adequate power line control equipment and protection systems in substations
- Metering infrastructure (usually for the wholesale electricity market)
- Market operator infrastructure
- Telecommunication infrastructure
- Ancillary services (frequency control, voltage control etc.).

It is seen that the need for imports is increasing. The UCTE forecast is that this tendency will hold over the next years. In the same period the possibilities of export for the European countries are reduced because reserve margin declines.

The sum of exchanges in Europe for the period 1975 – 2004 is shown in Figure 5-2.

The main net exporters and importers in Europe in 2003 and 2004 are presented on Tables 5-5 and 5-6.

It is expected that the power system security in Europe will slightly degrade during the period 2007 to 2010. When drawing this conclusion, two elements must be taken into consideration:

- It is still possible to decide on new investments for this time horizon. There is a need of approximately 8-10 GW reliable available capacity to maintain the reserve margin at the existing level
- Decommissioning may occur during the period especially as a result of the effect of new environmental requirements.

**Table 5-5** Main European Net Exporters

| | 2003 | | 2004 | |
|---|---|---|---|---|
| | TWh exported | % of demand | TWh exported | % of demand |
| France | 66.4 | 14.3 | 55.1 | 11.4 |
| Czech Republic | 16.2 | 27.0 | 15.7 | 25.5 |
| Poland | 10.1 | 7.4 | 9.3 | 7.1 |
| Germany | 8.0 | 1.6 | 5.3 | 1.0 |
| Lithuania | 7.5 | 63.1 | 7.2 | 70.3 |
| Bulgaria | 5.5 | 15.2 | 5.9 | 18.9 |

Source: Eurelectric

**Table 5-6** Main European Net Importers

| | 2003 | | 2004 | |
|---|---|---|---|---|
| | TWh exported | % of demand | TWh exported | % of demand |
| Italy | 50.8 | 15.9 | 50.7 | 15.5 |
| Holland | 17.0 | 15.4 | 15.6 | 14.2 |
| Hungary | 6.9 | 18.0 | 7.5 | 19.6 |
| Belgium | 6.3 | 7.5 | 7.9 | 9.0 |
| Austria | 6.1 | 11.9 | 5.5 | 10.1 |
| Croatia | 3.9 | 24.3 | 3.9 | 16.8 |

Source: Eurelectric

## Vulnerability of the Electricity Market

The definition for security of electricity supply given in the introduction to this chapter clearly shows that the electricity market is without borders.

Security of upstream energy supply for power generation is a matter of how well markets function. Electricity is mainly produced from coal, natural gas, uranium and hydropower. While oil was a major fuel for electricity generation, the share has decreased to insignificant levels. The global coal market is competitive, resources are abundant and it can easily be stored. Uranium can also easily be stored. Natural gas resources are concentrated in few countries, storage is relatively costly and it has been grid bound. Natural gas is of increasing importance to electricity generation. A potential risk is that the total electricity generation system could become too dependent on natural gas but recent price increases have slightly cooled ambitions.

Whether there is adequate generation capacity to meet total demand at all times depends on whether investments are made at sufficient volumes, at the right location and in a timely fashion. There is reason to believe that competitive electricity markets can provide incentives for timely and efficient investment. However, the European Transmission Service Operator (ETSO) showed in May 2006 in their Generation Adequacy Report, that "without any additional commissioning program, the remaining capacity at ETSO level may not respect the adequacy reference margin by 2012."

Networks tend to be natural monopolies. Investment in networks depends largely on the regulatory framework and incorporated incentives.

Time, location, volume and quality of supply determine the value of electricity to the consumer. Liberalised electricity markets can set prices in terms of the first three factors, but quality is so far a product delivered to all consumers regardless of price signals.

In 2003 and 2004 there were some remarkable blackouts and incidents related to system security. In each of these cases official investigations do not blame market liberalisation.

Electricity market liberalisation is not an event. It is a long process that requires strong and sustained political commitment, extensive and detailed preparation and continuous development to allow for necessary improvements while sustaining on-going investment.

Focus on operational and financial flexibility has increased. Today's market players show a preference for less capital-intensive and smaller units. Finally a more diverse electricity system is beginning to emerge.

EURELECTRIC conclude that the liberalised market will manage to take care of the security of supply issue, if it is allowed to function in a proper way and some preconditions are met. The regulatory framework must be predictable and, along with a proper market design, encourage investments. In electricity markets with local capacity problems there is the possible use of the toolbox in the IEM Directive such as tendering for new capacity.

Long-term security of electricity supply covers access to primary fuels, system and market adequacy while short-term security of electricity supply relates to the actual delivery.

A key issue in ensuring the security of supply in the liberalised market is to clearly define the roles and responsibilities of different actors. For example EURELECTRIC suggest that the European Union should develop and maintain a wise geopolitical agenda in order to facilitate access to primary fuels and also keep all energy options open. Regarding the roles and responsibilities of member states, EURELECTRIC suggest that the member states should ensure an efficient and timely authorisation procedure.

A key challenge seems to be how to find a way to commit to long-term (30- to 60-years) investments in a market environment that mainly looks forward to short-term profit. A generally prevailing view is that only long-term investment can be made in well-functioning competitive markets.

The EU is attempting to promote security of supply and is at the same time also pushing forward the internal energy market.

Previously, national gas and electricity markets were separate markets where supply and distribution were in the hands of monopolies. Now, markets have been opened up to competition and national borders in energy markets are disappearing. A competitive energy market also supports efficient energy use.

The so called trans-European electricity network is a way of allowing society to pay for a system that is necessary for the internal electricity market to work, but costs more than any single energy company or one country is willing to pay for. You could say that society smoothes the market place so that the actors can react with more efficiency. However, it is important that there is strict regulation on the financing of such transmission and how to set tariffs, otherwise there is a risk that such transmission lines will lead investment in the wrong direction and could produce a long-term negative affect on the security of supply.

The emission trading system in Europe is unique. Caps on the amount of emissions of carbon dioxide have now been applied. Companies exceeding their emissions allowance can trade with others who have not used up their allowance. The system was set up, following the commitments that European countries made to the Kyoto Protocol, to fight against climate change, and show that Europe takes a leading role on this global issue. But the consequences of trading schemes for the end-users, especially in industry, were initially undervalued. For a long time the prices of emissions allowances have been much higher than expected and the impact on electricity prices has, therefore, also been much higher than expected. That implies remarkably higher costs for the energy intensive industries. Therefore, the competitiveness of this sector will decrease compared to that in other parts of the world. If this industry was to decide to move from Europe it could have negative

A major disadvantage with the current emission-trading scheme is that it is very short sighted. The trading system only defines the period 2008-2012. The present system covers less than 50 per cent of the total carbon dioxide emissions in EU-25. In the long term it will be necessary to include all emissions, especially those in the transport sector.

consequences for the European economy and employment in Europe.

The electricity demand could decrease and a lot of investment already made in power stations will be lost.

One problem that suddenly occurred during the spring of 2006 was the market price volatility of the emissions allowances. The prices dropped by more than 50% based on reports that some countries emitted far less $CO_2$ than the market initially anticipated.

Another major disadvantage with the current emission-trading scheme is that it is very short sighted. The trading system only defines the period 2008-2012. The present system covers less than 50 per cent of the total carbon dioxide emissions in EU-25. In the long term it will be necessary to include all emissions, especially those in the transport sector.

As conducted today the emissions trading scheme is limited in many respects. Encouraging a majority of the world economies to participate in the emission trading system is therefore vital. The wise solution for curbing climate change impact should be sought among them for combining technology development, finance and implementation of policy incentive. If the international community could achieve it, then a world-wide carbon dioxide market should become reality.

Consideration should be taken of the present installed capacity in Europe. Results show that about 53% of the electricity consumed in 29 European countries is generated by use of fossil fuels. A significant and growing proportion of these fuels come from outside of EU. The dependence on imported fuels could rise and could also increase the vulnerability of the EU.

The key word to describe the mitigation of the vulnerability of electricity markets in Europe is flexibility of diversification of sources, technologies and resources. Flexibility should be a tool in the hands of all the major players: for the consumer, the efficiency of energy consumption; for the producer, the flexibility of combining different fuels in power generation, according to a given circumstances; for the distributor, the success in ensuring a robust, adequate network. The cost of a flexible system is certainly higher than that of any other without, but the way to look at that is to view the cost as an insurance payment. It is important for manufacturers, energy companies and society to invest in enough research and development, in order to provide a flexible electricity system for the future.

Competition in the electricity market aims at taking away the expensive over capacity that was built up by the former monopolies and improving the cost efficiency of the business. Taking this measure could also reduce the costs for the customers. The strategy works well, the over capacity in the liberalised markets has decreased rapidly, even to such a degree that some actors now are fearful of a future lack of generating capacity. The cost of operation has also decreased with higher efficiency.

Lack of electricity is unacceptable for a modern society that is very dependent on a continuous

## One cannot expect that long-term liberalisation and competition may lead to lower prices than long-term marginal costs.

supply of electricity. That earlier over capacity has decreased and the balance between supply and demand is becoming narrow; that the reserve capacity is decreasing does not mean, however, that the market does not work well.

If demand reaches the capacity ceiling there are two existing ways of maintaining system stability. One is to attempt the temporary increase in demand. The other is to increase peak power capacity. The preferred way is a question of economy.

Short operation times and resulting large investment risks produce a fear that reserve capacity will not be built up in the new competitive market.

With harmonised rules in different countries and regions it is important to achieve peak power capacity. The rules could vary in particular regions with different base load systems (in some regions hydropower dominates and others thermal power). The rules must be based more on physical assumptions than on national borders.

Rules must be considered set for the long term and procurement from the system operator must not destroy the conditions for new investment. The principal solution for financing is that the actors depending on peak power capacity also pay for it in some way.

It has yet to be proven that market forces will deliver new capacity when needed. It is important that the authorities closely monitor development. It is equally important to let the actors know that the decision-makers are fully committed to the market forces, and that there will be no intervention in the market unless it has proved not to work. Intervention would not only have a negative impact on the competitive market function, but would also have a negative effect on cost efficiency in operations. The consequence of intervention could easily cause the costs to return to the pre-liberalisation situation.

In this context it is worth mentioning that the lead-time to build new capacity is several years. A first time-consuming obstacle is obtaining the necessary permissions to build the plant. Sometimes this time could be almost half the total lead-time and is unsatisfactory. In an efficient electricity market it is also necessary that permissions are granted in an efficient way otherwise the nature of the deregulated electricity market is jeopardised.

Regulatory uncertainty is one of the most important risk factors for investors, and investment in generation is very long term and capital intensive. Hence the risk calculations become very important in investment decisions. If investors feel temporary conditions during some period of the life span of an investment might cause the rules of the game to change; they are more reluctant to make an investment. Alternatively, they may demand such a high-risk premium of generation investment that the investment comes later and prices become higher. Therefore, it is crucial for all stakeholders to agree on the future development of the electricity market.

Market prices will fluctuate above and below the cost – including risk premium – of building new generation capacity. Lead-times for new investments in generation capacity are normally long, and there is a fear that this could lead to a price cycle, i.e. long periods of very high and low price fluctuation. However it is possible for investors to plan a number of years ahead, and reduce the potentially cyclical behaviour of the market. Therefore, the credibility of the future pricing mechanism is very important for price stability.

It is possible that prolonged lead-times for new investments in generation capacity could appear, e.g. the licensing procedure may lead to temporary higher prices. The price for the customer could therefore be modified depending on flexibility of the customer. For instance if the customer wants the flexibility of instantly varying the load from zero to maximum he must be willing to pay a premium price. If the customer accepts a predestined load curve he will pay a lower price. Finally, if the customer accepts disconnection there will be a substantial discount. In such a system the flexibility increase and premises for planning, investment and financing will be better. Such a system does not exist but is worth working towards.

It is not yet possible to decide if incentives in the market are enough to maintain the generation system security of supply at a sufficiently high level. That situation must be carefully investigated and monitored in the future.

If the conclusion is that there is a need for measures to keep the security of supply for electricity generation at a certain level, it is very important to construct these measures properly. They may risk disturbing the market function or pricing mechanism and destroying the investment conditions for new plants. The measures themselves might therefore reduce the security of supply.

Theoretically there are different ways of ensuring enough capacity, but the establishment of a wholesale market framework with adequate numbers of competitors providing suitable price signals for investment and consumption is certainly the best way forward.

There is a need for a uniform set of solutions for the whole of the EU, even though they have to provide sufficient flexibility within given different regions in order not to distort the competition between the actors on the market.

The grid is characterised as a natural monopoly and as such has no competition. To reach an effective electricity market it is necessary that the tariffs for the grid are set in a balanced way in different areas. All actors should pay the same tariff to reach the network. The tariff should include the costs at all levels in the grid. The point being that all transport costs are paid for in the net tariff and the price for electricity is independent of these costs. The area of the electricity market where competition exists can then work efficiently.

As mentioned above the grid is a natural monopoly. Regulators have an important role and it is necessary that they working as effectively as possible to build efficient electricity market.

The unbundling of generation and transmission breaks the earlier planning link for an integrated company, where there was a choice between interconnection reinforcement and more generation to cover the need for more electricity within an area. On the opposite side, the system operator has no influence on the localisation of new generation, other than the tariffs for connection and for feeding electricity into the network.

Resultant liberalisation in the earlier planning method, when each integrated generation and transmission company was normally self-sufficient, is replaced with a system where electricity is localised and generated at the most economic site. This means that transit flows are increasing and transmission links are frequently operated near their limits. Blackouts also become more difficult to contain in smaller areas. System operators must take that into account in planning, and this may mean e.g. that they must strengthen the dimensioning criteria. When blackouts have occurred they may also have to increase the demands on generators to rapidly regain the system operation.

Liberalisation and increased transit flow also put much higher demands on the co-operation and co-ordination of system operators. Systems can no longer be operated as if they were independent and could be separated in case of an incident.

## Conclusions

The most important conclusions that the WEC working group has drawn are:

***The internal electricity market should be well designed to work smoothly.***

There exists no clash of interest between a well functioning liberalised electricity market and security of electricity supplies. As matter of fact the liberalised electricity market could be seen as a prerequisite.

To gain as much benefit as possible from electricity usage it is therefore necessary that the internal market is allowed to work smoothly and well and be disturbed as little as possible by national legislation and measures. Each such distortion will make the European electricity market sub-optimal and can also result in unnecessary high electricity prices for the customer.

***The price of electricity is the most important signal for investors in a deregulated market.***

In the European single electricity market it is necessary to have a common methodology of price formation. It disturbs the market if national borders influence electricity prices.

The competition authorities must be strong to promote fair competition so that the price of electricity reflects the true marginal cost of the whole supply system. Otherwise newcomers are unable to participate in investing in new capacity.

A spot market with good liquidity and many actors must be organised to ensure the short-term marginal cost to the market. For long-term contracts it will be effective to organise financial markets to allow investors the ability to hedge the price. Surely the consumers can also use the financial markets to hedge their cost of electricity.

It is also very important that all investors have a fair and cost effective connection to the grid. This cost would preferably be constructed in such way that connection will also be a connection to the market (nodal tariff). A strong regulator must control these tariffs.

If bottlenecks appear in the network it is preferred that the system operators with counter contracts eliminate these. If this is not possible the markets should be split with different prices in different market areas.

***The process in obtaining permission to build new capacity must become reliable, smooth and fast, to promote security of supply.***

In an efficient electricity market it is necessary that authorisation procedures function in an efficient way otherwise the nature of the deregulated electricity market is jeopardised. The consequence could be that the necessary new capacity would not be built in due time. The result would be a shortage of electricity supply with accompanying higher prices.

It is important that the time taken in gaining permission to build new capacity is as short as possible so that the investor is able to purchase and use the most modern technology. Permission should also be given in such a way that new technology could be adapted after that permission is granted.

It is also important that all options of energy must be available for all investors but that is not possible if public opinion in a particular country wants to abandon one or several options.

***Environmental and social policy must be as market orientated as possible in order to achieve reliability.***

The most important environmental constraint is the Emission Trading System (ETS) introduced in Europe 2005. This system must soon be global otherwise the heavy electricity dependent industry in Europe will suffer against other world competitors. A global ETS will also provide the market with effective prices on emission allowances that reflect the true marginal cost of reducing $CO_2$.

Another important environmental constraint involves the different support systems for renewable energy. The most cost-effective method for customers is a European certificate system. With such a system the price of certificates will decrease as the price of electricity increases.

If for social reasons a country wants to set tariffs for the cost of electricity they must be very careful not to jeopardise the security of supply. With minimal prices the demand for electricity will be maximised and harmful to the incentive for investing in new capacity.

As the ETS will internalise the cost of climate change and as all other environmental costs are already internalised in the electricity price there is no reason to punish electricity consumption with extra taxes. Taxation of production for fiscal reasons should be avoided. A fair and harmonised tax on consumption could be an effective way to provide enough income for the states.

# Part Six
# Energy Strategies and Vulnerability Mitigation

The concept of vulnerability, which indicates the potential to sustain future shocks described by indicators in chapter 2, can serve to highlight key areas for a pragmatic and ambitious European energy policy. This chapter aims to describe political, industrial and economic tools to increase resilience to short-and long-term shock both, at national and European levels.

## Which European Strategy?

The European energy strategy traditionally explores four main areas of energy security policy to alleviate Europe's vulnerability to energy crisis or shortfall namely:

- management of demand (in particular by tapping "pockets of potential savings" that still exist in the domestic, industry and transport sectors; a White Paper on transport was published in September 2001)
- diversify European supply sources (by developing and maintaining alternatives: nuclear, coal, renewable energies, hydropower etc.)
- greater efficiency in the domestic market (by developing interconnections and encouraging fair competition)
- management of external supplies (through dialogue with neighbouring and distant production countries).

Outside these areas – although the European directive of 2004 recognises that the classic laws of the market may be inadequate to induce the investment necessary to ensure sustainable security of supply – the principle of subsidy is not called into question. Each Member States is requested to decide individually what action will be useful to balance supply and demand during periods of strong market tensions.

The instruments of government energy policy are generally meant to act on supply and demand. On the question of supply, security firstly requires a sustained policy of diversifying the energy mix to avoid dependence on a single energy and to reduce sensitivity to crises.

On the question of demand these instruments fall into four categories, namely:

- Awareness and information campaigns directed at domestic and industrial customers
- Increased government funding to support and finance investment in energy production, transmission and similar areas;
- Laws restricting speed limits, that effect mandatory recycling, that impose severe environmental protection rules and similar constraints
- Financial measures to promote alternative and renewable energies and reduce energy consumption. This last weapon is obviously most effective in the short term, provided that this energy policy does not undermine economic policy objectives (by provoking a business slowdown or subduing domestic consumption). Outside any economic consideration the primary objective seemingly should be to improve this

situation by striving for lower energy intensity. Active support in the form of funding to achieve this goal of investment in energy conservation has often proved effective.

It is then obvious that European Union energy policy is split between:

- Global policy vs. subsidiary
- Liberalised markets vs. increasing global and restrictive policies.

Such an uncomfortable position has often set the boundaries of European capacity for pragmatic and immediate reaction in case of crisis or emergency. The lack of a real energy policy has indeed often been pointed out.

From this point of view and towards this aim, in March 2006, the Green Paper on a "secure, competitive and sustainable energy policy for Europe" has outlined some major challenges for a common future European approach to questions specifically relating to security of energy supply and climate change. High oil and natural gas prices, European energy dependency on OPEC and Russia, new insecurities concerning long-term availability of fossil fuels and the urgency of advanced measures for amending greenhouse gas emission have indeed re-opened a debate on the need for a European Energy Policy. The new Green Paper speaks for greater co-operation and integration of EU energy policies, and identifies six priority areas that should lead to the development of a "reinvigorated European Energy Policy", namely:

1. A common European external policy for security of energy supply, including the creation of a High Level Council Strategic Energy Policy group, improving use of existing EU energy dialogues (such as with OPEC and Russia), having an annual Commission communication on the security of EU energy supplies and creating a "wider-Europe Energy Community"

2. A common European internal policy for security of energy supply, including the idea of setting up a European Energy Supply Observatory (to identify shortfalls in terms of infrastructure and supply) and a European Centre for Energy Networks (to co-ordinate and improve transmission systems)

3. An increase in the use of clean and indigenous energy sources, including new initiatives to stimulate the uptake of renewable energies

4. A strategic plan for European clean energy technologies

5. Europe-wide action on energy efficiency

6. A confirmation of the agenda of the full opening of internal European electricity and gas markets by 2007 (including ideas for a Strategic European Internal Energy Market Plan and propositions to develop a single European grid).

# Cooperative Efforts to Ensure Supply Security

**The Need for Cooperation between Producer and Consumer Countries**

The liberalisation of gas and electricity markets has changed the political rapport between EU Members States and non-European producer countries. Unlike the oil sector, the gas and electricity sectors have functioned largely through long-term relationships, both at the domestic level (monopolies) and at an international level (long-term contracts with producer countries). Consequently, energy security has mainly been considered relative to events in the Middle East and oil price fluctuation. This influences energy policies and relations with countries exporting raw materials. It is in the interest of producer countries to exploit their resources, especially where there is a scarcity. To develop these resources, they need access to technology and finance from the West, which means opening their borders to foreign investment. It is important for European companies to make small investments in non-European producers in order to develop technological co-operation between suppliers and purchasers (increase of production, deep offshore etc). In order to minimise the contractual risk and create a sustainable industrial environment they must move from a mutually dependent, supply-demand relationship to one in which there is genuine interaction.

Clearly the security of Europe's energy supply depends not so much on the energy policies of importing countries as on the investment policies of companies operating cross-border and the policies of producer countries on exploration, production and transport. In this respect, a key to energy security for the industrialised nations is to enable the participation of the producing countries in major trade flows of world economy and diversifying the economic base, which is the only thing likely to envelop them in the network of interdependent commercial relations. Foreign policies should be formulated to help achieve this goal by means of economic, financial and diplomatic initiative.

In all respects, these types of initiative could lead to a wider prolonged partnership between Europe and producing countries. This could be achieved by notably improving regulatory and legal framework issues (non-discriminatory access to energy transportation networks and to greater transparency of tariff structures, fiscal frameworks for exploration and production activities); introducing mechanisms for financing joint projects and private-public interaction (security instruments, availability of long-term contracts, eligibility rules for Production Sharing Agreements,); ensuring tax optimisation (allocation of energy efficiency benefits).

If the member states of the European Union truly grasp that their own interests are served by a stable world market, the process of opening the producer countries to foreign companies could be advanced through co-operation that would bring about more balanced economic development in these countries. This is one objective of the dialogue initiated between the European Union and

Talks between the European Union and non-European producer countries must consider the issue of sustainable security of supply for Europe.

Russia in 2000. It is also an overriding goal of the co-operation by some Mediterranean countries

(Algeria, Morocco, Tunisia, Spain, France, Italy, Greece and Turkey) in the Barcelona process, as they work towards progressive integration in their markets. It is one of the objectives of negotiation with the Gulf Co-operation Council aimed at setting up a free-trade zone between the two sides (in particular through transfers of technology).

**Is the Attraction of the European Market Threatened?**

In a similar vein, it is important to assess precisely how relations with non-European producers have changed under the new rules in the European market, particularly in the case of natural gas. It is worrying that some non-European producers are no longer willing to deliver their gas FOB, a refusal often due to the difficulty they have in gauging how the liberalisation process will benefit them. In fact, contract terms like these shift the management of the risk of supply security to the producer, who is not necessarily bound by the same rules as the distributors in this area. It is therefore vital that the natural gas market in Europe remains attractive. The trade in LNG is rapidly expanding, and Europe is definitely in competition with the two other world natural gas markets – America and Asia – for new sources coming on line in the future. This is borne out by the possibility that natural gas produced in the Caspian Sea region in the future could flow to Asian markets.

In response to this situation, joint EU deliberation and action is called for to keep the European market attractive. Talks between the European Union and non-European producer countries must consider the issue of sustainable security of supply for Europe.

This will depend on having strong operators with sufficient size and credibility to take on very large commitments and assume the role of genuine partners in industrial and commercial relations with the producer countries. The issue has political, economic and industrial dimensions, and addressing it effectively will call for solid companies backed up by a firm and jointly developed industrial policy: industrial negotiations must have both political and industrial components if they are to achieve truly ambitious and long-lasting results.

## Energy Investments, Market Risks, and Government Policy Risks

**A Need for Colossal Investment**

Markets are opening up to competition, but this will only exist if there is sufficient infrastructure to ensure market liquidity and flexibility, while guaranteeing greater security of energy supplies.

In the natural gas sector – the main focus here – it will be necessary to have satisfactory conditions in which to transport the additional 200 billion cubic metre or so of natural gas required to satisfy demand over the next 20 years. This will mean accumulating nearly EUR 350 billion to invest in the production, transport, storage and distribution of natural gas in the future. Thus, despite the trend toward commoditisation, colossal investment will be needed. There is a similar situation in the electricity sector (see chapter 5). The fact that the industry has launched large-scale projects to build new infrastructures proves that there is a positive view of the future. However, there is a real risk that investment will be inadequate, principally because market competition tends to encourage investments yielding quick returns.

Between 1998 and 2004, European operators reduced their investments in production and transmission infrastructures for natural gas. During that time the investment/revenue ratio fell from 10.3% to 5.5% and maintenance outlay from 10% to 7%. Apparently three conditions must be met if the need for new infrastructure is to be fully satisfied:

- The regulatory framework must inspire confidence among both European and non-European operators and investors by virtue of stability and understanding the geopolitical and contractual issues specific to the natural gas market. Profitability in the energy sector must be commensurate with the perceived risks if investors are to provide the required financing. This will demand sufficiently high returns on investments, efficient financing mechanisms and favourable investment conditions.
- Under the rules of EU directives, the market liberalisation process must allow the active presence of operators-traders of sufficient size and credibility who will make very substantial commitments, e.g. long-term purchase contracts with a take-or-pay clause and long-term reservations of capacity on transport infrastructure.
- Infrastructure projects must be truly European, with multiple operators participating in order to reduce individual risks and avoid a situation in which two or three operators dominate a strategic infrastructure. This will maximise the security of supply while allowing open competition.

These conditions, specifically pertinent to the natural gas industry, are likely to encourage essential investment in the sustained and efficient operation of the European network because there is a long-term focus. Apart from regulatory stability, what these conditions mean in concrete terms for gas transmission operators is that authorised rates of return for regulated activity must offer sufficient incentive for investment and be guaranteed for an extensive period. The developers of gas transmission networks must also have the means to forecast the fill rate of any future pipelines (a vision of shipping needs backed up either by long-term capacity reservations or insurance through the regulatory mechanism). The promoter of a LNG terminal or storage installation will similarly seek security for his investment and finance by requiring in advance long-term reservations and visibility on revenues for a significant share of the capacity.

**Different Energies, Different Policies**

An astute regulatory analysis of energy markets must assess the particularities of each specific type of energy. There is logic for natural gas differing from that of oil or renewable energies. These specifics must be clearly investigated to advance an efficient policy.

A Green Paper published in March 2006 on a "secure, competitive and sustainable energy policy for Europe" outlined the necessity for the development of strategic reserves to reduce risks during sudden or lasting crisis. Like the IEA, Europe co-ordinates the development of emergency stocks and their use during an oil supply crisis. European policy is even more restrictive, as the 90-day obligation applies to three categories of product: gasoline, middle distillates and heavy fuel oil. Natural gas is not included in the strategic reserves of any country.

Four main reasons for this follow:

1. Unlike oil, natural gas does not have a captive market for any use

2. A sufficient number of mutual contractual obligation tends to reduce the risk of short-term disruption; this explains the lack of supply disruption since imports to Europe began

3. Natural gas is more expensive to store than oil

4. The strategic supply needed for a response to a sharp demand cannot be calculated as it is dependent on too many factors (the season, domestic production capacity, import capacity, provisions for interruption).

Even if the conditions outlined above are all provided, one must guarantee a rational and sustainable development of infrastructure. In the gas sector, two points must be emphasised.

The first concerns transmission infrastructure. Unbundling the natural gas value chain is not conducive to the creation of new, large-scale supply networks crossing the state borders of several transmission service operators (TSO). Such networks demand substantial financial commitment from shippers for large volumes over extensive periods. Give these conditions the followings situations arise:

- If the promoters are natural gas producers from outside Europe, will they want to be involved in transmission and have to deal with regulations concerning access for external parties and the unknowns involved in requesting Article 22 exemptions? While the answer might be yes for an LNG terminal or an offshore pipeline, such involvement appears less likely when it is a matter of constructing a gas pipeline across several countries.
- If the only business of the promoters is marketing natural gas, they will have an incentive to secure resources to satisfy customer needs, but they will not necessarily have the expertise to manage such projects.
- If the promoters are transmission service operators, they will be unable to go ahead with such projects without commitments from future shippers, with whom they must be able to deal with in a flexible manner.

The second addresses the issue of over-amplifying infrastructure capacity to provide security margins, i.e. capacity that is rarely used. If such an infrastructure lacks the flexibility provided by such built-in reserve margins, it will be unable to adjust to deteriorating conditions. It will also be noted that it is often due to these margins that fluidity and short-term increases can be provided.

However, no client is prepared to pay for surplus infrastructure capacity, since the cost is disproportionately high in relation to the frequency of use, which is both low and unpredictable. Standard economic models do not factor in any gains from this surplus capacity; more importantly, they do not show the real cost effectiveness of the absence of supply disruption.

This points to the reason it is important for the regulatory regime to include ample provisions to support the sector over the long term. Without them, investments to improve security of supply in the future could be jeopardised by hard-to-resist pressures to lower costs in the short term.

In both cases, only an approach built on co-operation among transmission service operators, shippers and suppliers-producers will allow such projects to be undertaken, as ambitious as they are necessary.

**Strategic Storage: From Myth to Reality?**

The Green Paper published in March 2006 highlighted the necessity and emergency for setting an active policy for gas storage in Europe in order to deal with a possible shortage.

Potential strategic gas storage should not be compared to that of petroleum products, whose main characteristics could be stressed in a comparative approach.

Considering EU obligations on oil storage, one must say that almost every Member State has an individual approach. Globally it could be noticed that:

- Members of the IEA are required to hold stocks of crude oil and/or finished products equivalent to a minimum of 90 days of net imports.
- EU Member States have an obligation to hold stocks of crude oil and/or finished products equivalent to 90 days of average daily consumption based on the previous year. EU countries that are IEA members thus have a dual obligation.

In every case, the product use (heating, transport, industrial production, etc.) has no bearing on how the obligation is calculated. Countries are obliged to hold some of this amount in finished products for each of the three selected categories (petrol, distillate and heavy fuel-oil). Applying the principle of subsidiarity, each country decides how on the constitution of these stocks.

Three main systems exist. A country will sometimes use at least two of:

1. Private stocks: Operators fulfil their obligation independently, using personal resources or those of another.

2. Government stocks: Japan, Germany, Finland and the USA until 1998. The product is financed by the state, which thus has complete control (but the temptation exists to use this stock as a variable in budget adjustment).

The European Commission has made no declaration on the definition or level of risk coverage, leaving the decision to each Member State. European utilities have expressed no official position on the subject.

3. Agency stocks: The obligation is managed by an agency, a body governed by law. Operators pay the agency a proportional fee to cover their charges.

In the case of natural gas, strategic storage remains hard to define, leaving the issue open to a variety of interpretations. In practice, the reality represented by "strategic storage" expressly depends on the specific industrial history of each country. This is because:

- storage is not the only way of securing supply; alternatives include interruptible demand, flexibility of importation by means of supply contracts, and diversifying supply sources;
- no standards exist on secure supply levels.

The European Commission has made no declaration on the definition or level of risk coverage, leaving the decision to each Member State. European utilities have expressed no official position on the subject.

Only three European countries have begun to build up strategic reserves, which, in theory, covers the risks of both an interruption to supply and extreme temperature change. These reserves vary from one country to the next:

**Spain**: LNG stocks equivalent to 10 days of consumption (with a target of 50 days of consumption by 2011);

**Italy**: 5.1 $Gm^3$ for supply security needs, stored in depleted gas fields, which can be used only with the agreement of the Authority;

**Hungary**: around 900 $Mm^3$ covering 45 days of consumption.

In practice, stocks covering the risk of extreme temperature are often larger than strategic stocks. Operators have a habit of combining these risks and only clearly presenting climatic risk[6]. Concerning gas storage, one can underline the following subjects for attention:

- The capacity to develop storage depends highly on the (existing or remaining) geological potential.
- Probable gas stocks can only be developed after a long phase of exploration and, in any case, not before 2015 for most potential target countries.
- Pending the publication of a study by the Trading Business Unit on European geological resources and the corresponding transportation infrastructure, Europe seems unable to provide strategic storage capable of covering simultaneously climatic risk and a

[6] The figures given in this document come from a Global Insight study that defines strategic storage as coverage against a two-month interruption of supply from the main non-European supplier. However, it should be noted that this study does not include Poland and the central and eastern European countries (CEEC).

two-month interruption in Russian supply. This will be the case until at least 2015.

The Global Insight study on western European countries (Belgium, Germany, Italy, France, Spain, the Netherlands and the UK) identifies the following needs by 2015:

- Apart from strategic stocks, a surplus of around 6 $Gm^3$ (taking into account all storage development projects, which for the most part are based in the Netherlands);
- Strategic storage needs of 23 $Gm^3$ (of which 17 $Gm^3$ from Russia).

The best short-term solution appears to lie in promoting proven tools: the need for diversified supply sources, energy efficiency, more fluid markets (developing new infrastructures in the CEEC). Long term serious studies must be made to set a pragmatic and relevant gas storage policy for Europe and to finance bigger and more expensive infrastructures beyond 2015.

## Policy to Encourage Domestic Resource Production, Including Renewable Energy Sources

A major goal of European energy strategy and policy is to support the diversification of sources of supply and promote the use of renewable sources of energy, with the aim of developing and consolidating an energy model based on security, quality and sustainability.

### European Policy on Renewable Energies

In the context of uncertainty of supply, of global increasing dependency on oil and gas imports, of constantly rising oil prices and considering European commitments to reduce greenhouse gas emissions, the development of renewable energy remains a major objective of European energy policy. However, the take-off of renewable energy is still on hold with prospects of only 9 to 10% for the share of renewables in the European Union energy mix by 2010 instead of the 12% target. Consequently, the European Commission:

- proposed an ambitious biomass and biofuels action plan
- called on Member States to do more for the generation of green electricity.

In December 2005, the European Commission adopted a plan designed to increase the use of energy from forestry, agriculture and waste materials in three major areas of consumption: heating, electricity and transport. This plan is aimed at reducing Europe's dependence on imported energy and cutting greenhouse gas emissions and protects jobs in rural areas, extending the European position in these technological sectors. Regarding transport biofuels, in particular, the global European plan promotes "biofuels obligations" (through which suppliers include a minimum proportion of biofuels in the conventional fuel they place on the market). The EU market share is currently 0.8% which leaves small chance to achieve by 2010 the target of 5.75% that was set for the EU as a whole, in the 2003 biofuels Directive.

# Renewable energy technologies (solar, wind, biofuel, geothermal, hydroelectricity, hydrogen) are the main factors in achieving a balanced and sustainable global energy future. They could notably contribute to the diversity and security of energy supply and to socio-economic development.

At the same time, the Commission adopted a report on the different support schemes of electricity from renewable energy sources. Conclusions underlined that governments need to step up efforts and provide more support for green electricity (more than 50% of the Member States are not giving enough incentives in this sense), co-operate and optimise their support schemes as well as removing administrative and grid barriers for green electricity. Member States are therefore requested to co-ordinate existing schemes at European level. Administrative requirements should also be reduced: clear guidelines, one-stop authorisation agencies, pre-planning mechanisms and simpler procedures are needed. Transparent and non-discriminatory grid access must be ensured and necessary grid infrastructure development should be undertaken, with the associated cost covered by grid operators.

### Pragmatism and Effectiveness

Renewable energy technologies (solar, wind, biofuel, geothermal, hydroelectricity, hydrogen) are the main factors in achieving a balanced and sustainable global energy future. They could notably contribute to the diversity and security of energy supply and to socio-economic development.

Looking backward, if we consider government energy RD&D budgets in IEA member countries, there is a clear increase following the oil price shocks of the 1970s. By 1987 however, budgets had declined to about two-thirds of their peak level and thereafter stagnated until 2003. The share of renewable energy technologies in total energy RD&D spending remained relatively stable, averaging 7.6% for the whole period. Among renewable energy technologies, the shares in global funding of biomass, solar photovoltaic and wind have increased, while those of ocean, geothermal and concentrating solar power have declined – broadly reflecting the evolving consensus as to where the greatest potential lies. Of course, there are great variations in the balance of spending of individual countries, reflecting resource potential and national energy policies.

To substantially enhance the share of renewable energy technologies in the energy mix, it is imperative to adjust a pragmatic agenda for the future decades. On the one hand, countries must indeed improve their market deployment strategies for renewable energy technologies and above all, increase targeted renewables R&D. On the other hand, national and regional objectives must take into account the reality of energy markets in a sound and realistic programme (not only from a political or environmental point of view but also from an economic, industrial and technical). To succeed with a national or European renewable policy, dogmatism must be rejected: a cost-effective approach is an essential condition to facilitate market deployment of new and improved technologies and to increase the global share of renewables in the energy mix. Main subjects of attention are to:

- Prioritise national or European efforts for renewable energy (according to the existing national energy mix and natural energetic wealth): each country has personal RD&D priorities based on particular resource endowment, technology expertise, industrial strengths and energy markets;

- Set a relevant and consistent frame of incentive for energy efficiency & renewable sources (Green Certificates, White Certificates…) in order to provide energy actors clear objectives and practical means in a multidimensional based approach;
- Co-ordinate grid connection and adaptation (with base-load production): in particular, manage intermittence (generally common to a range of renewable energy technologies);
- Develop joint public (governmental, international or European) and private sector (industry) RD&D programmes with the aim of promoting commercialisation and competition in the market;
- Insist on instructive and direct communication and take into account issues of public acceptability (NIMBY), which have become a key factor of the energy sector because of the growing and legitimate will of populations to be more informed, consulted and associated to decisions.

## Policy Incentives to Reduce Intensity and Enhance Efficiency, Particularly in Transition Economies

**Indispensable Efforts to Save Energy**

The reduction of energy intensity, combined with more efficient energy consumption, has been on the EU agenda since the first oil shock. The aim is to weaken the link between GDP growth and the growth in energy demand. Vigorous government policies have succeeded in reducing energy intensity by 40% in Germany and Denmark and by 30% in France. There are three arguments in favour of strengthening the policies now in place, namely:

1. The steady rise in oil (and therefore gas) prices and their excessive volatility amplify the impact of energy prices on economic growth, while seriously hampering competition
2. Since there is little surplus capacity (the main reason for the present price surge), it is essential to reduce demand in order to break the stranglehold and diminish the price risk that burdens the security of supply
3. The legitimate and rising concerns of environmentalists over greenhouse gas emissions make it imperative for all governments to take action to reduce the consumption of hydrocarbons (oil and coal in particular).

In view of Europe's growing energy dependence, the European Commission has decided to make energy conservation a priority, with the objective of reducing energy consumption by 20% by 2020 (equivalent to EUR 50 billion per year). The European Commission took a step in this direction in April 2005 by deciding to include initiatives favouring renewable energies, clean coal technologies and intelligent energy in the Seventh Framework Programme for Research and

Energy efficiency thus depends on comprehensive, coherent and interrelated measures that do not contradict each other.

Technological Development. Projects in the programme will focus on fuel cells, distributed production, intelligent energy networks, improved efficiency of fossil fuel power plants, biofuels, and similar subjects. Micro-cogeneration technologies should also be more taken into account.

A Green Paper published in June 2005 identifies three areas where improvements can be made:

- In the transport sector (which is 98% dependent on the oil market and the source of 26% of carbon dioxide emissions): the passage of tax laws favouring fuel-efficient or "clean" vehicles; limitations on vehicle fuel consumption; improved traffic management (road and air traffic); improved vehicle energy performance and tyre efficiency; more funding for research and development in the field of alternative fuels; the introduction of vehicle tolls in cities (as in London) or selective express lanes (as in Madrid) and promotion of public transport ;
- In the building sector: improved energy efficiency in lighting (one-third of energy consumed); labelling domestic appliances to provide energy information for the consumer; better insulation for public and private buildings; lower standby electricity consumption; lower consumption during peak hours and periods of electricity shortage;
- In the industrial sector, introduction of a favourable tax regime for companies that invest in more efficient technologies (exemptions, reductions, subsidies, financing instruments...); better regulations; information and awareness campaigns for professionals to focus on positive cost-benefit results and the (sometimes very short) pay-back periods for investments in energy efficiency enhancement.

Energy efficiency thus depends on comprehensive, coherent and interrelated measures that do not contradict each other. All methods are acceptable and worth trying: taxes, subsidies, incentives, "white certificates" and numerous others, as long as they are: consistent with existing policies and do not distort the market, not counterproductive and remain, once again, in a coherent and homogenous frame of incentives. The reason being that while financing appears to be the primary issue for all three sectors (transport, building and industry), it is preferable to encourage innovation and competition (among energy operators and industrial firms in the concerned sectors) through a non-discriminatory and motivating framework. Similarly, the regulatory regime should be of the kind to encourage investment in research and development, which are top priorities in the effort to advance energy efficiency and clean technologies, but do not always provide an immediate return on investment.

### A Different Situation in Each Country

The average energy intensity in Europe obviously does not reflect the difference between countries in the region. Energy intensity, which expresses the relationship between energy consumption and GDP, depends on specific economic aspects (energy policy, the relative importance of the industrial sector) and on the level of energy efficiency in each country. The potential for

**Figure 6-1** Energy Intensity, 2000, 2003

| | Energy intensity (toe/1000 Euro 95) | |
|---|---|---|
| | **2000** | **2003** |
| Bulgaria | 1.901 | 1.769 |
| Czech Republic | 0.893 | 0.894 |
| Estonia | 1.215 | 1.179 |
| Latvia | 0.756 | 0.730 |
| Lithuania | 1.205 | 1.187 |
| Hungary | 0.600 | 0.582 |
| Poland | 0.676 | 0.656 |
| Romania | 0.337 | 0.331 |
| Slovenia | 0.926 | 0.937 |
| Slovakia | 1.455 | 1.368 |
| EU-15 | 0.193 | 0.189 |
| EU-25 | 0.212 | 0.208 |

Source: Energy sector of the Central & Eastern Europe, Warsaw, November 2005

improving energy efficiency in new Member States of the European Union is thus very high (see Table 6-1). On a broader scale, a majority of the transition economies have plenty of scope for progress in linking economic growth with energy efficiency.

Outside the European expanded market there is an interest in drawing the attention of other regions with high-energy consumption to the issue of efficiency. With energy consumption exploding in China, India and Brazil, this has become a critical economic and environmental matter. The present period – in which energy is expensive and could remain so – should provide the opening of debate on this subject, since all consumer countries (the United States and Japan included) must now endure rising oil prices and competition for limited energy sources. For this reason, it is urgent to loosen the link between economic and social growth, on the one hand, and the increasing demand for energy, on the other. Accordingly, discussion on energy conservation, which is already on the agenda of meetings between Europe and its partners, should be combined with increased financial co-operation, exchanges and technological assistance. The Green Paper on energy efficiency published in June 2005 should be noted in this regard. It proposes strengthening the role of international financial institutions by giving them more responsibility, e.g. supplying technical or financial assistance to a country could in part be dependent on the measures taken to manage energy demand and energy efficiency.

## Market-Led Solutions and Innovation, Including Insurance, Contracts, Capital, and Trading

### Long-Term Solutions

Possible solutions and choice of tools to deal with an eventual shortfall in the energy supply depend on whether the urgency of the situation is short-, medium- or long-term. In the long term, it is obvious that market mechanisms do not provide adequate signals to guide investment decisions and ensure that the overall system of supply and demand will continue to function rationally. Addressing the issue of long-term market equilibrium requires that national governments and European bodies make certain decisions.

### On the supply side:

- A stable and motivating legal framework is essential to encourage investment (see subchapter 6.4).
- Renewables must be politically encouraged (to ease important costs for industry) in transport and energy production.
- Nuclear energy is an important energy option. It satisfies climate change policy requirements, and there is little reason to

fear that supplies would be exhausted in the near future.

- The long-term supply of fossil fuels will be influenced by the development of technologies for exploiting non-conventional resources. Exploration and eventual production of deep-lying deposits for, example, more than 5,000 to 6,000 m will necessitate improved seismic tools and drilling techniques. Developing the production of liquid fuels from coal will no doubt involve capturing and storing carbon dioxide gas. If these techniques are to be available in time, support for research and development efforts is essential (the same is true for the sources of diversification such as the biofuels).

## On the demand side:

- Presently the measures being taken to manage energy are crucial in maintaining the balance between supply and demand.
- The Green Paper on security of supply considers control of demand to be the key long-term tool, and notes that the objective is not only to reduce the volume of demand, but also to change the profile, since demand spikes are the main reasons for additional capacity.

**Short and Medium-Term Solutions**

Medium-term solutions depend on investments that market players are willing to make in new infrastructures, and particularly in additional capacity, to prevent excessive volatility during periods of peak demand. These investments are closely linked to the provision of a regulatory system that is sufficiently stable, motivating and capable of ensuring good financial returns on the projects. In the short term, efforts to optimise infrastructure and margins of flexibility are the most classic means available to the electricity and gas industries to supplement bilateral transactions in the wholesale market. Improving the performance of existing installations calls for taking better account of such things in the demand calendar, anticipating opportunities to substitute one fuel for another and bringing electric power plants back into service (in particular coal-fired plants). Flexibility by mutually dependent parties can be incorporated in long-term contracts with other operators, but they also can be obtained through "interruption" clauses in contracts with industrial and domestic customers.

Trading exchanges tend to be used more during periods of tension in the energy market. These exchanges provide a solution for combating a critically sharp rise in demand in a liberalised market. The appearance of organised markets is the most tangible evidence that competition has arrived in the electricity and gas industries. By increasing the number of operators in the market, liberalisation introduces uncertainty in each market share and compels the need for trading. Nevertheless, the spot market, even though it was expanding, accounted for no more than 6% to 7% of European gas trading in 2003. All the market does at present is introduce more flexible trading and, more importantly, provides a way of adjusting the supply portfolio, which is of interest both to incumbent operators (diversification of sources)

## In rising to the future challenges faced by Europe a debate is now underway on the need for a common European Energy Policy.

and new entrants (responsiveness and flexibility). With the opening up of markets, exchanges - which function satisfactorily at low levels of supply - have reached a critical point in their ability to accelerate market penetration by new entrants and help improve the short-term security of electricity and gas supply (notably during periods of strong demand). To achieve this, exchanges must have sufficient supplies of gas to maintain fluidity, and the infrastructure (storage or multiple resources) must be adequate to provide emergency supplies needed to ensure energy security.

**Which Risk-Management Tools for Tomorrow?**

European operators must now make their strategic decisions in an environment of multiple risks (as shown previously). They will need tools for analysing and controlling these risks. Widespread uncertainty in the energy sector has an increasing impact on the strategies and investment decisions of European operators. For example, the use of net present value (NPV) as a decision-making tool is based on data gathered on prices and costs; the latter depend on the frequent non-fulfilment of contracts and agreements, a situation distinctly characterised by increased uncertainty. As a consequence, when companies attempt to develop a sustainable business plan, the objective of reducing uncertainty by controlling risks becomes as complex as it is essential.

More numerous and complex risks have an impact on long-term investment and, therefore, on security of supply. In this regard, it seems that a clarification of government policy and the wholesale-market framework would send satisfactory financial signals to players and investors. The problem does not arise for investors if they are certain of operating in a monopoly situation or sharply competitive market. However, in the present market – where competition is unequal – the application of theoretical models (industrial, strategic and financial) is more complex, despite excellent methods of acquiring data and assessing uncertainties. By reducing uncertainty, a stable and clear regulatory framework should make risk control easier and investment safer; as a result, it should help ensure a sustainable security of supply.

## Conclusions

In rising to the future challenges faced by Europe a debate is now launched on the need for a common European Energy Policy.

The setting up of a common European Energy Policy has in view the following priority areas:

- a common European external policy, to secure of energy supply;
- a common European internal policy, to secure of energy supply
- an increase in the use of clean and indigenous energy resources
- a strategic plan for European clean energy technologies
- European action on energy efficiency
- the completion of single European electricity and natural gas markets, by 2007.

In conclusion, the alleviation of vulnerability of the Europe-29 to energy crisis could be achieved by applying the following policy actions:

- ensuring stronger co-operation between producer and consumer countries, by moving from interdependence to interaction with producer countries;
- keeping European energy markets attractive;
- providing a favourable and predictable regulatory framework to inspire confidence among operators and investors to promote long-term commitments;
- promoting a consistent and flexible approach to domestic energy resources, renewable energy and energy efficiency.

# Part Seven
# Overall Conclusions and Recommendations

## Review of the Threats

The European long-term energy supply is potentially vulnerable due to the following predominant threats:

- Growing dependence on energy imports in a future world that could be dominated by conflict and competition between countries for energy procurement
- Geopolitical instability in the energy producing regions
- Lack of investment in the energy/electricity supply chain, which would support the balance between energy supply and demand
- Recent uncertainties in the reliability of electricity grids, owing to low maintenance in the reserve capacity and minimal cross border interconnection.

Europe is one of the largest energy consuming regions in the world and the energy production of the European countries is insufficient to cover their energy demand. The scarcity of fossil fuel resources and lack of capacity to develop other resources define the vulnerability of Europe to potential energy crises. As a result, the dependency on energy imports is constantly growing and forecast at almost 70% in 2030 if no adequate policy measures are taken in response. The vulnerability can be seen in all economic sectors.

Ensuring the security of energy supply to Europe is a critical issue for all European states excepting Russia and Norway. The growing dependence on imports and lack of investment in the energy sector are of prime concern to policy making and market players, all perceiving the uncertainties and vulnerability linked to future supplies, primarily of hydrocarbons. The bulk of oil and natural gas to Europe comes from countries with geopolitical instability. Environmental challenges deregulation and market forces have introduced new players to the energy security scene. To face all these challenges, the European Commission brought out a new Green Paper in January 2007 recommending more pro-active policy measures, to ensure future supplies and reliable function of the electricity market while pursuing the objectives of long-term sustainability of the European energy market.

Environmental concerns, focusing on the climate change issue, demand the implementation of concrete measures, which could have an unfavourable impact on the use of fossil fuels. Facing this challenge, the flexible balance of the energy mix will remain the backbone of a secure, sustainable and competitive energy market. Given these conditions there will be an undoubted need for the development of new technologies for carbon capture and $CO_2$ sequestration, more advanced nuclear technology and related waste solutions, as well as on renewable energy. Technological innovation is fundamental for reducing vulnerability and successfully confronting a potential energy crisis in Europe.

There is still public reluctance or local opposition to the construction of new capacities of nuclear generators, wind farms and electricity networks. This aspect discourages investment in these particular areas of the energy sector where development guarantees a higher level of security and substantial reduction of GHGs in Europe and provides strong motivation for the timely design and implementation of well- balanced energy supply structures.

Nuclear power is an integral part of the European energy scene, providing more than 30% of electricity, and emerges as a feasible and already available option to address climate change and substantially reduce the future European vulnerability to energy crises. Nuclear power competes strongly in the electricity market, costs continue to decline owing to operational performance and lower fuel cost. Advanced Nuclear technology (Generation 3) is commercially available and generators are under construction in a number of countries. Further technological progress and the R & D undergoing on the closed fuel cycle should make for easier waste management.

Constitutionally, the EU is the only international body with a legal mandate, possessing the power to designate energy policy and monitor their implementation in its 27 member states. The EU has bilateral agreements with Norway and Switzerland, and both countries generally follow the basic directives and objectives of the EU, both in the functioning of the energy market and sustainable policies. The new EU Green Paper should certainly bring improvements and advance the culmination of a single European energy market. However the Green Paper should not be considered as a bible; new challenges and circumstances should encourage regularly revisions and updates.

## Assessing Vulnerability

Energy security could be analysed globally, to ensure adequacy of resources; at regional level, to ensure that interconnections and trade can flourish; at national level, to ensure state security; and finally at consumer level, to ensure satisfaction of consumer demand.

Using the term vulnerability, which has broad implications, only in the context of dependence could limit such analysis. The vulnerability of an energy system is generally perceived as "the degree to which that system is able to cope with selected adverse events". The degree of vulnerability is a combination of different factors; among which is energy intensity, flexibility in modifying the energy mix, quick response and adaptation to energy price increases and the ability to manage disruption of the energy supply.

The WEC Study Group attempted to define the concept of vulnerability (what we understand by vulnerability) and establish a set of quantitative indicators, both at macroeconomic and microeconomic level, that would help policy makers to determine the level of vulnerability of a country or region.

Vulnerability indicators defined at macroeconomic level are: price volatility, exchange rate, rate of energy dependency, rate of energy diversity, import concentration index, rate of energy bill and level of technology performance. Those defined at microeconomic level vary in correlation to the type of energy consumer and of supplier.

It is important to emphasise that while energy vulnerability is linked to energy dependency it is quite distinct. For example, a country could be dependent on imports without being vulnerable if the import portfolio is diverse and suppliers reliable. Vulnerability indicators are not independent; the interaction between some depends on particular issues, considered in part 2.

## Review of Challenges

Important transformations and challenges that currently take place in the European energy sector, in terms of economy and environment, affect energy vulnerability.

**Electricity market:**

Ongoing deregulation of energy markets brings more opportunities to enhance flexibility of the energy supply, transportation and distribution areas. However, the experience since the beginning of liberalisation (1996-2006) showed a lack of interest in investing in power generation and transmission. How could market forces be encouraged to make timely investments in new capacities and infrastructure?

The following key challenges are identified:

- Lack of an adequate regulatory framework to encourage investors
- National borders still influence electricity prices
- Current market is not yet well enough designed to work smoothly
- Administrative procedures for licensing are intensely bureaucratic
- Lack of follow up to the Emission Trading System (ETS) beyond 2012.

**Oil market:**

Since 2003, due to a number of unfavourable circumstances, serious tensions, disturbance and price volatility have occurred. These are brought to light in chapters 4 and 6.

The following key challenges are cited:

- Global oil supply/demand imbalance, leading to volatility in price
- Lack of sufficient investment in infrastructure and upstream
- Lack of sufficient global refinery capacities;
- Insufficient level of co-operation between producers & consumers, at policy level.

**Natural gas market:**

The following key challenges are identified:

- Substantive lack of investment in gas infrastructure and storage
- Price volatility is a risk factor for fuel competition in large-scale power generation
- LNG becomes an attractive alternative to cover progressive demand
- Conflicts between Russia and transit countries may temporarily disturb supply (low risk).

**Coal market:**

Two key challenges, the first is crucial:

- Climate change issue is the prime enemy facing coal use
- Low efficiency in coal-fired power generation, in Central and Eastern Europe.

**Nuclear power:**

The major prevailing challenges are:

- Negative public opinion is still an obstacle to policy action
- Technology solutions to waste management and disposal
- Need to open up new uranium capacities (low priority).

**Renewable energy sources**

Two major challenges:

- RES are still not competitive in the market.
- Administrative burden of obtaining licenses in some countries.

# Considering the aforementioned **threats** and **challenges**, the Study Group made the following recommendations for policy making:

## Enhance the Level of Policy Cooperation in Europe

Setting up and implementing a common EU-energy policy, with the emphasis on security of supply, is highly desirable, as it will undoubtedly provide strong support in reducing the European vulnerability to energy crises and sustain long-term development of European energy market. European countries should speak with one voice when maintaining a policy dialogue with strategic external suppliers.

## More Pragmatism in Policy Implementation

The policy should ease market integration and enhance its attractiveness to investors, (which has not been the case to date), by providing a more transparent, stable and predictable long-term regulatory framework (legislative & fiscal). This would inspire confidence among operators & investors and urge long-term commitments. In addition, but in this context, the borders should be opened to cross-investment (upstream for European consumers, downstream for suppliers). With the latter, it is imperative to **shift the approach**, from interdependence to interaction. Furthermore, the present administrative burden (e.g. for license procurement) should be simplified and timely delivered.

## Enhance the Promotion of Energy Efficiency and a Market for Renewable Energies

Energy efficiency improvements in all areas of the economy should become a priority issue for policy making in Europe.

Energy efficiency regulations and standards should be **mandatory** in all sectors of national economy with **enforcement** in the Central and Eastern European economies, where the potential in making energy savings is still much higher than in Western Europe. The construction norms/standards in households and buildings must be considered and upgraded.

A consistent and less dogmatic approach to renewable energy and energy efficiency is needed to attract investors. The adequacy of issue objectives should be adapted to the reality of energy market, rather than considered from political or environmental positions.

## Mitigate Tensions and Vulnerability Level in Electricity and Gas Markets

In the case of electricity, the EU member states should be required to effectively develop the internal market, thus attracting investment in constructing new generating and transmission capacities. At regional level, there is an urgent need for (1) harmonising cross-border tariffs, and (2) developing methods for defining a common price formation, with the proviso that the price of electricity is the primary signal to investors in a deregulated market. In addition, an emission-trading scheme beyond 2012 is a necessary development to encourage investment in power generation for the future.

In the case of natural gas, to create a surveillance mechanism at regulatory level, with a mandate to control and co-ordinate functions on the construction and access to infrastructure facilities (LNG terminals, pipelines, underground storage), with a view to easing, instead of impeding, development. The Council of European Energy Regulators could integrate such a mechanism. In addition, the EC may consider elaborating a **security supply standard** defining the level of gas volumes demanded by non-interruptible customers under the conditions of a single gas market.

## Encourage Further Diversification of Each National Energy Mix

Given the current circumstances of intensity and commitment to Kyoto Protocol targets, the re-evaluation of **each domestic energy mix** is strongly recommended. The purpose would be to reduce the dependence on imports by any country and expand the supply pattern by promoting the use of domestic energy resources, including renewables. It should take into account economics, technical fundamentals and local circumstances in promoting each energy alternative, supplement policy measures, use additional regulations, especially for renewable options and preserve market rules for fair competition.

## Re-integrate the Nuclear Option into Policy and Public Debate

Nuclear power is a promising alternative for both reducing dependency on imports and fulfilling the commitment of all European countries to the Kyoto Protocol. The EU and neighbouring European countries should seriously consider including the nuclear option in their public debate and energy policies. The European Union should take a firm position about option of nuclear re-integration, a source that already provides a 1/3 of the electricity supply.

## Achieve more Consistent and Targeted Research and Development

Budgets, including that of the EU, allocated for R&D on future technologies should be distributed among energy carriers in proportion to their expected share in the future energy mix and keep a healthier balance between supporting other forms and technologies of low carbon generation (carbon capture, $SO_2$ sequestration, nuclear).

It is important to develop joint public and private sector R&D programmes with the aim of promoting commerce and competition in the market.

## Promote a "Fact-Based" Debate on Energy Issues

A new approach should be established - regular dialogue between all stakeholders involved in energy policymaking, including the public. Municipal acceptance, in Western Europe in particular, still remains a key factor in overcoming resistance to the long-term policy vision. Civil society should be more informed, consulted and associated with policymaking. In this respect, public co-operation must be embraced when debating key issues, making it easier to promote and encourage new investment in the energy sector.

## Encourage the European Countries to Assess their Vulnerability Level by Applying the Indicators Proposed by this Study

The Study Group encourages all the European countries to use the selected vulnerability indicators by this Study. These countries should also attempt to assess their level of vulnerability at macroeconomic and microeconomic level, e.g. on energy dependence, import concentration, energy intensity, the national energy bill, carbon content of primary energy supply, price volatility, exchange rates and on technology. This would be helpful when drawing up a national or regional level energy policy.

# Appendix A

## EU-29 Primary Energy Consumption and Energy Mix Structure

| | Gross Inland Consumption 2004 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mtoe | | | | | | | % | | | | | | |
| | All Fuels | Solid Fuels | Oil | Natural Gas | Nuclear | Renew-ables | Other | Solid Fuels | Oil | Natural Gas | Nuclear | Renew-ables | Other |
| EU-29 | 1860.5 | 329.5 | 699.3 | 441.2 | 267.2 | 130.6 | 3.7 | 17.7 | 37.0 | 23.7 | 14.4 | 7.0 | 0.2 |
| EU-25 | 1747.2 | 311.9 | 650.6 | 417.6 | 254.4 | 109.5 | 3.2 | 17.9 | 37.2 | 23.9 | 14.6 | 6.3 | 0.2 |
| Belgium | 54.8 | 6.1 | 20.1 | 14.6 | 12.2 | 1.2 | 0.7 | 11.1 | 36.6 | 26.6 | 22.3 | 2.1 | 1.4 |
| Czech Rep. | 43.6 | 19.5 | 9.4 | 7.8 | 6.8 | 1.4 | -1.3 | 44.8 | 21.5 | 17.9 | 15.6 | 3.1 | -2.9 |
| Denmark | 20.0 | 4.4 | 8.3 | 4.6 | - | 2.9 | -0.2 | 21.9 | 41.6 | 23.2 | - | 14.6 | -1.2 |
| Germany | 347.7 | 85.8 | 125.4 | 78.7 | 43.1 | 13.8 | 1.0 | 24.7 | 36.0 | 22.6 | 12.4 | 4.0 | 0.3 |
| Estonia | 5.6 | 3.3 | 1.1 | 0.8 | - | 0.6 | -0.2 | 59.1 | 19.1 | 13.7 | - | 10.8 | -2.7 |
| Greece | 30.6 | 9.1 | 17.5 | 2.2 | - | 1.6 | 0.2 | 29.7 | 57.1 | 7.3 | - | 5.1 | 0.8 |
| Spain | 140.2 | 21.1 | 68.9 | 25.2 | 16.4 | 9.0 | -0.3 | 15.0 | 49.1 | 17.9 | 11.7 | 6.4 | -0.2 |
| France | 273.7 | 14.1 | 92.8 | 39.2 | 115.6 | 17.3 | -5.3 | 5.1 | 33.9 | 14.3 | 42.2 | 6.3 | -1.9 |
| Ireland | 15.7 | 2.3 | 9.3 | 3.6 | - | 0.3 | 0.1 | 14.7 | 59.1 | 23.2 | - | 2.1 | 0.9 |
| Italy | 184.8 | 16.6 | 85.0 | 66.0 | - | 12.5 | 4.7 | 9.0 | 46.0 | 35.7 | - | 6.8 | 2.6 |
| Cyprus | 2.5 | 0.0 | 2.4 | - | - | 0.1 | - | 1.5 | 94.6 | - | - | 3.9 | - |
| Latvia | 4.6 | 0.1 | 1.4 | 1.3 | - | 1.6 | 0.2 | 1.5 | 29.6 | 29.0 | - | 35.9 | 4.1 |
| Lithuania | 9.2 | 0.2 | 2.6 | 2.4 | 3.9 | 0.7 | -0.6 | 2.0 | 28.2 | 25.9 | 42.6 | 8.0 | -6.8 |
| Luxemburg | 4.7 | 0.1 | 3.0 | 1.2 | - | 0.1 | 0.3 | 2.0 | 64.6 | 25.6 | - | 1.6 | 6.2 |
| Hungary | 26.2 | 3.4 | 6.3 | 11.7 | 3.1 | 1.0 | 0.7 | 13.2 | 24.1 | 44.7 | 11.7 | 3.7 | 2.6 |
| Malta | 0.9 | - | 0.9 | - | - | - | - | - | 100.0 | - | - | - | - |
| Netherlands | 82.3 | 9.2 | 31.6 | 36.7 | 1.0 | 2.4 | 1.4 | 11.2 | 38.4 | 44.7 | 1.2 | 2.9 | 1.7 |
| Austria | 32.7 | 4.0 | 13.8 | 7.6 | - | 6.8 | 0.6 | 12.1 | 42.2 | 23.3 | - | 20.7 | 1.7 |
| Poland | 92.5 | 54.6 | 22.0 | 11.9 | - | 4.3 | -0.3 | 59.0 | 23.8 | 12.8 | - | 4.7 | -0.3 |
| Portugal | 26.2 | 3.4 | 15.0 | 3.3 | - | 3.9 | 0.6 | 12.9 | 57.5 | 12.6 | - | 14.9 | 2.2 |
| Slovenia | 7.1 | 1.5 | 2.5 | 0.9 | 1.4 | 0.8 | -0.1 | 21.6 | 35.2 | 12.6 | 19.8 | 11.6 | -0.8 |
| Slovakia | 18.6 | 4.5 | 3.6 | 5.5 | 4.4 | 0.7 | -0.1 | 24.3 | 19.4 | 29.5 | 23.6 | 4.0 | -0.7 |
| Finland | 37.7 | 7.5 | 10.9 | 4.0 | 5.9 | 8.8 | 0.6 | 19.9 | 29.0 | 10.5 | 15.5 | 23.3 | 1.7 |
| Sweden | 53.1 | 2.9 | 15.4 | 0.9 | 20.0 | 14.1 | -0.2 | 5.5 | 28.9 | 1.7 | 37.6 | 26.6 | -0.3 |
| UK | 232.1 | 38.3 | 81.5 | 87.4 | 20.6 | 3.7 | 0.6 | 16.5 | 35.1 | 37.6 | 8.9 | 1.6 | 0.3 |
| Bulgaria | 18.9 | 7.2 | 4.3 | 2.5 | 4.3 | 1.0 | -0.5 | 38.4 | 22.7 | 13.2 | 23.0 | 5.2 | -2.5 |
| Romania | 39.6 | 9.3 | 10.3 | 13.9 | 1.4 | 4.6 | 0.0 | 23.4 | 26.1 | 35.2 | 3.6 | 11.7 | 0.0 |
| Norway | 27.6 | 0.9 | 10.6 | 4.4 | 0.0 | 10.7 | 1.0 | 3.3 | 38.3 | 16.1 | 0.0 | 38.7 | 3.6 |
| Switzerland | 27.1 | 0.1 | 12.5 | 2.7 | 7.1 | 4.8 | -0.1 | 0.5 | 46.2 | 10.0 | 26.0 | 17.6 | -0.2 |

Source: EU Energy and Transport in Figures, 2006.

# Appendix B

## EU-29 Final Energy Consumption by Source

| | Final Energy Consumption 2004 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mtoe | | | | | | | % | | | | | |
| | All Fuels | Solid Fuels | Oil | Gas | Electri-city | Derived Heat | Renew-ables | Solid Fuels | Oil | Gas | Electri-city | Derived Heat | Renew-ables |
| EU-29 | 1216.1 | 55.8 | 518.0 | 289.1 | 247.6 | 50.4 | 55.2 | 4.6 | 42.6 | 23.8 | 20.4 | 4.1 | 4.5 |
| EU-25 | 1140.9 | 52.3 | 488.1 | 276.9 | 227.9 | 46.7 | 49.0 | 4.6 | 42.8 | 24.3 | 20.0 | 4.1 | 4.3 |
| Belgium | 37.4 | 2.3 | 16.6 | 10.6 | 6.9 | 0.5 | 0.5 | 6.2 | 44.4 | 28.3 | 18.5 | 1.3 | 1.3 |
| Czech Rep. | 25.8 | 4.3 | 6.7 | 6.6 | 4.6 | 2.7 | 0.8 | 16.6 | 25.9 | 25.8 | 17.9 | 10.5 | 3.2 |
| Denmark | 15.2 | 0.3 | 7.2 | 1.7 | 2.8 | 2.5 | 0.7 | 1.7 | 47.4 | 11.3 | 18.7 | 16.2 | 4.8 |
| Germany | 229.9 | 10.6 | 90.5 | 63.0 | 44.1 | 15.8 | 5.9 | 4.6 | 39.3 | 27.4 | 19.2 | | 2.6 |
| Estonia | 82.7 | 0.1 | 0.9 | 0.2 | 0.5 | 0.5 | 0.5 | 3.1 | 34.0 | 7.6 | 18.4 | 19.0 | 17.9 |
| Greece | 20.2 | 0.6 | 13.9 | 0.5 | 4.3 | 0.0 | 1.0 | 2.8 | 68.5 | 2.3 | 21.1 | 0.2 | 5.1 |
| Spain | 94.3 | 1.9 | 52.1 | 16.8 | 19.8 | - | 3.8 | 2.0 | 55.2 | 17.8 | 21.0 | - | 4.0 |
| France | 157.9 | 4.8 | 74.0 | 33.4 | 35.8 | - | 9.9 | 3.0 | 46.9 | 21.2 | 22.6 | - | 6.3 |
| Ireland | 131.2 | 0.5 | 7.5 | 1.3 | 2.0 | - | 0.2 | 4.3 | 65.4 | 11.5 | 17.2 | - | 1.7 |
| Italy | 1.8 | 4.1 | 59.0 | 40.7 | 25.4 | - | 2.0 | 3.1 | 45.0 | 31.0 | 19.3 | - | 1.5 |
| Cyprus | 3.9 | 0.0 | 1.4 | | 0.3 | - | 0.1 | 2.1 | 75.7 | | 17.0 | - | 5.3 |
| Latvia | 4.3 | 0.1 | 1.2 | 0.5 | 0.5 | 0.6 | 1.1 | 1.5 | 31.3 | 12.7 | 11.9 | 15.4 | 27.2 |
| Lithuania | 4.4 | 0.2 | 1.5 | 0.5 | 0.7 | 0.9 | 0.6 | 4.0 | 35.1 | 11.3 | 15.3 | 20.9 | 13.4 |
| Luxemburg | 17.4 | 0.1 | 3.0 | 0.7 | 0.5 | 0.1 | 0.0 | 2.1 | 68.4 | 15.5 | 12.5 | 1.2 | 0.4 |
| Hungary | 0.5 | 0.7 | 4.5 | 7.5 | 2.7 | 1.2 | 0.7 | 4.1 | 25.9 | 43.4 | 15.7 | 6.9 | 4.0 |
| Malta | 52.5 | - | 0.3 | - | 0.2 | - | - | - | 66.1 | - | 33.9 | | |
| Netherlands | 25.6 | 1.6 | 17.4 | 21.7 | 8.9 | 2.6 | 0.4 | 3.0 | 33.2 | 41.3 | 16.9 | 4.9 | 0.8 |
| Austria | 56.9 | 0.5 | 11.4 | 4.9 | 4.8 | 1.5 | 2.5 | 2.1 | 44.6 | 19.0 | 18.7 | 5.7 | 9.9 |
| Poland | 20.1 | 11.3 | 17.3 | 8.3 | 8.6 | 7.5 | 3.9 | 19.8 | 30.4 | 14.6 | 15.1 | 13.2 | 6.8 |
| Portugal | 4.8 | 0.1 | 12.2 | 1.3 | 3.8 | 0.3 | 2.5 | 0.4 | 60.4 | 6.4 | 19.1 | 1.3 | 12.4 |
| Slovenia | 10.0 | 0.1 | 2.3 | 0.7 | 1.1 | 0.2 | 0.4 | 1.6 | 48.6 | 13.9 | 22.6 | 4.3 | 9.0 |
| Slovakia | 26.5 | 1.5 | 2.0 | 3.1 | 2.1 | 1.0 | 0.3 | 14.5 | 20.3 | 31.3 | 20.6 | 10.2 | 3.1 |
| Finland | 34.0 | 1.0 | 8.2 | 1.3 | 7.1 | 3.6 | 5.3 | 3.6 | 31.1 | 4.8 | 26.9 | 13.5 | 20.1 |
| Sweden | 152.0 | 1.2 | 11.6 | 0.7 | 11.2 | 4.1 | 5.1 | 3.6 | 34.2 | 2.2 | 33.0 | 12.0 | 15.0 |
| UK | 9.0 | 4.7 | 65.2 | 51.0 | 29.2 | 1.3 | 0.7 | 3.1 | 42.9 | 33.5 | 19.2 | 0.8 | 0.5 |
| Bulgaria | 26.1 | 1.0 | 3.4 | 0.9 | 2.1 | 0.9 | 0.7 | 11.2 | 37.4 | 9.9 | 23.7 | 9.9 | 7.9 |
| Romania | 18.6 | 1.5 | 7.4 | 8.5 | 3.3 | 2.3 | 3.1 | 5.7 | 28.3 | 32.6 | 12.8 | 8.6 | 12.0 |
| Norway | 21.4 | 0.8 | 6.8 | 0.2 | 9.4 | 0.2 | 1.1 | 4.5 | 36.6 | 1.3 | 50.7 | 1.1 | 5.8 |
| Switzerland | 1.8 | 0.1 | 12.3 | 2.5 | 4.8 | 0.4 | 1.3 | 0.6 | 57.4 | 11.6 | 22.5 | 1.7 | 6.2 |

Source: EU Energy and Transport in Figures, 2006.

# Appendix C

## EU-29 Final Energy Consumption by Consumer Sector

Appendix C

| | Gross Inland Consumption 2004 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mtoe | | | | | | % | | | | |
| | All Sectors | Industry | Households, Commerce | House-holds | Services | Trans-port | Industry | Households, Commerce | House-holds | Services | Transport |
| EU-29 | 1216.1 | 344.0 | 502.4 | 319.7 | - | 369.7 | 28.3 | 41.3 | 26.3 | - | 30.4 |
| EU-25 | 1140.9 | 318.9 | 471.7 | 299.7 | 172.1 | 350.3 | 27.9 | 41.3 | 26.3 | 15.1 | 30.7 |
| Belgium | 37.4 | 12.4 | 14.8 | 10.0 | 4.8 | 10.2 | 33.3 | 39.5 | 26.8 | 12.7 | 27.3 |
| Czech Republic | 25.8 | 9.8 | 9.8 | 5.8 | 3.9 | 6.2 | 38.2 | 37.9 | 22.7 | - | 23.9 |
| Denmark | 15.2 | 2.9 | 7.1 | 4.3 | 2.8 | 5.1 | 19.3 | 46.9 | 28.1 | 18.8 | 33.9 |
| Germany | 229.9 | 58.4 | 109.0 | 77.0 | 31.9 | 62.6 | 25.4 | 47.4 | 33.5 | 13.9 | 27.3 |
| Estonia | 2.7 | 0.6 | 1.7 | 1.2 | 0.5 | 0.5 | 22.7 | 60.3 | 42.4 | - | 17.0 |
| Greece | 20.3 | 4.0 | 8.2 | 5.4 | 2.9 | 8.0 | 20.0 | 40.7 | 26.5 | 14.2 | 39.3 |
| Spain | 94.3 | 30.7 | 25.3 | 14.4 | 10.9 | 38.4 | 32.5 | 26.8 | 15.2 | 11.6 | 40.7 |
| France | 157.9 | 35.9 | 71.9 | 41.9 | 30.0 | 50.1 | 22.7 | 45.5 | 26.5 | 19.0 | 31.8 |
| Ireland | 11.5 | 2.1 | 4.8 | 2.9 | 1.9 | 4.6 | 18.5 | 41.6 | 24.8 | 16.8 | 39.9 |
| Italy | 131.2 | 41.2 | 46.0 | 30.1 | 16.0 | 43.9 | 31.4 | 35.1 | 22.9 | 12.2 | 33.5 |
| Cyprus | 1.8 | 0.5 | 0.4 | 0.3 | 0.2 | 0.9 | 29.4 | 24.1 | 14.8 | - | 46.4 |
| Latvia | 3.9 | 0.7 | 2.2 | 1.4 | 0.7 | 1.0 | 19.2 | 56.1 | 36.8 | - | 24.8 |
| Lithuania | 4.3 | 0.9 | 2.0 | 1.4 | 0.7 | 1.3 | 21.9 | 47.3 | 32.0 | - | 30.8 |
| Luxemburg | 4.4 | 1.0 | 0.8 | 0.6 | 0.1 | 2.6 | 22.6 | 17.4 | 14.4 | 3.0 | 60.0 |
| Hungary | 17.4 | 3.4 | 10.1 | 6.0 | 4.1 | 3.9 | 19.6 | 58.2 | 34.5 | - | 22.2 |
| Malta | 0.5 | 0.0 | 0.1 | 0.1 | 0.1 | 0.3 | 10.4 | 31.2 | 19.4 | - | 58.4 |
| Netherlands | 52.5 | 14.8 | 22.6 | 10.4 | 12.2 | 15.0 | 28.2 | 43.1 | 19.9 | 23.2 | 28.7 |
| Austria | 25.6 | 7.6 | 10.2 | 6.8 | 3.4 | 7.7 | 29.9 | 40.0 | 26.7 | 13.3 | 30.1 |
| Poland | 56.9 | 17.7 | 27.9 | 17.4 | 10.5 | 11.3 | 31.2 | 49.0 | 30.6 | - | 19.9 |
| Portugal | 20.1 | 7.2 | 5.6 | 3.0 | 2.6 | 7.3 | 35.8 | 28.0 | 15.1 | 12.9 | 36.2 |
| Slovenia | 4.8 | 1.5 | 1.9 | 1.2 | 0.6 | 1.4 | 32.0 | 39.2 | 25.8 | - | 28.8 |
| Slovakia | 10.0 | 4.2 | 4.3 | 2.7 | 1.6 | 1.6 | 41.5 | 42.7 | 26.6 | - | 15.8 |
| Finland | 26.5 | 13.2 | 8.6 | 5.0 | 3.6 | 4.7 | 49.7 | 35.5 | 18.8 | 13.7 | 17.9 |
| Sweden | 34.0 | 13.2 | 12.4 | 7.1 | 5.4 | 8.2 | 39.0 | 36.8 | 21.0 | 15.8 | 24.2 |
| United Kingdom | 152.0 | 34.6 | 64.0 | 43.3 | 20.6 | 53.5 | 22.7 | 42.1 | 28.5 | 13.6 | 35.2 |
| Bulgaria | 9.0 | 3.6 | 3.1 | 2.1 | - | 2.4 | 39.7 | 34.1 | 23.3 | - | 26.2 |
| Romania | 26.1 | 10.7 | 10.2 | 8.0 | - | 5.2 | 41.1 | 39.1 | 30.5 | - | 19.8 |
| Norway | 18.6 | 6.7 | 7.1 | 3.9 | - | 4.9 | 35.8 | 38.1 | 20.8 | - | 26.1 |
| Switzerland | 21.4 | 4.1 | 10.3 | 6.1 | - | 7.0 | 19.4 | 48.0 | 18.3 | - | 32.5 |

Source: EU Energy and Transport Figures, 2006

# Appendix D

## Committee Membership

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Mr. Slav Slavov (Regional Coordinator for Europe)
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# Appendix E

## Terms and Abbreviations

**BCM** – Billion cubic metre

**CCN** – EU candidate countries + Norway and Switzerland

**CEEC** – Central and East European countries

**CHP** Combined heat and power generation

**$CO_2$** – Carbon dioxide

**DTI** – Department of Trade and Industry

**DEFRA** – Department for Environment, Food an Rural Affairs

**DETR** – Department for Environment, Transport and the Regions

**DGE** – Department General of Energy

**DGET** – Department General for Energy and Transport

**ETSO** – European Transmission Service Operator

**EU** – European Union

**EU-15** – European Union before the enlargement of May 2004

**EU-25** – Enlarged European Union

**EU-29** – EU-25 + Bulgaria, Norway, Romania, Switzerland

**EURELECTRIC** – The Union of Electricity Industry

**FSU** – Former Soviet Union

**GDP** – Gross domestic product

**GW** – Gigawatt

**GWh** – Gigawatt-hours

**IEA** – International Energy Agency

**ISPS** – International Ship and Part Facility Security

**LNG** – Liquid Natural Gas

**Mtoe** – Million toe

**MW** – Megawatt

**MWh** – Megawatt-hours

**NMS** – New Member States

**NPP** – Nuclear Power Plant

**NPV** – Net Present Value

**OECD** – Organization for Economic Co-operation and Development

**OPEC** – Organization of Petroleum Exporting Countries

**RD&D** – Research, Development & Dissemination

**R&D** – Research & Development

**RES** – Renewable Energy System

**tce** – Tonne of coal equivalent

**toe** – Tonne of oil equivalent

**TPES** – Total primary energy supply

**TPP** – Thermal Power Plant

**TSO** – Transmission Service Operators

**TWh** – Terawatt-hours

**UCTE** – Union for the Co-ordination of Transmission of Electricity

**UNDP** – United Nations Development Programme

**UNDESA** – United Nations Department of Economic and Social Affairs

**WEC** – World Energy Council

**WHO** – World Health Organization

# Appendix F

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