

Long-Term Energy Security Risks for Europe: A Sector-Specific Approach

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Abstract

The aim of the paper is to identify and evaluate existing and potential EU energy supply risks on the basis of a sector-specific approach. Moving away from common generalisations on security of energy supply as well as from those studies that focus only on one sector, it brings together all types of fuel and analyses the risks related to each of them. The result is a comprehensive picture of the energy security challenges faced by the EU in the long-term. The paper can be seen as a tool to avoid overlapping, incoherence and contradictions in the process of assessing security of supply and aims to formulate a consistent and more unified European energy policy.

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The SECURE project started in 2008 and is aimed at building a comprehensive framework for measuring security of energy supply in the EU. Assessing the risks related to geopolitics, price formation and the economic and technical design of energy markets inside and

outside the EU, the SECURE project focuses on both qualitative and quantitative analyses, adopting a global as well as a sectoral approach. The tools, models and policy recommendations provided by this project will enable policy-makers to formulate energy security policies, taking into account the related costs, benefits and risks.

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Executive Summary

This paper aims to identify and evaluate existing and potential EU energy supply risks on the basis of a sector-specific approach. Moving away from common generalisations on security of energy supply as well as from those studies that focus only on one sector, the paper brings together all types of fuel and analyses the risks related to each of them. The outcome is a comprehensive picture of the energy security challenges faced by the EU in the long-term. In fact, the idea is to build a map from which policy-makers can identify policy options to address sector-specific challenges. The paper can be seen as a tool to avoid overlapping, incoherence and contradictions in the process of assessing security of supply, in order to formulate a consistent and more unified European energy policy.

After a brief overview of the concept of security of supply – both from an economic and a political point of view – the paper proposes a classification of security of supply risks, including geopolitical, geological, economic, technical and environmental risks. Then, recognising the existence of fuel-specific diversities in EU energy trends and policies, the paper calls for a sector-specific approach to analyse Europe's security of supply challenges. Accordingly, the main body of the work focuses on sector-specific supply risks and long-term policies for the major energy sources: oil, gas, coal, nuclear energy and renewable energy sources (RES). The second part of the paper addresses cross-cutting issues – energy efficiency, electricity, Europe's external energy policy and climate change – and analyses their contribution to the security of energy supply in the European Union. The work is accurately embedded in the past, present and planned policy context of the European Union and takes into account the interconnection between energy security and climate change.

The findings of the paper are summarised in Table 1 (p. 47). Although the security of energy supply in the EU faces four major categories of risk, not every fuel has to cope with all four of them. The combination of risks affecting EU energy supply, their possible causes and impacts, as well as their duration and future probability is different from sector to sector. The table shows that generalisations on the concept of security of supply may be misleading, given the fact that there are different risks for different energy sources.

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Introduction

1. The concept of security of supply

A discussion on security of supply requires a common understanding of the concept. The existence of different interpretations and approaches makes its definition difficult and somewhat elusive. The literature is divided between those who interpret energy security from an economic perspective and those who stress its political and strategic side. The former prefer to challenge the concept of energy security by considering it as nothing but a myth (Noël, 2008). Indeed, the majority of economists consider the expression meaningless, since they believe that energy matters are subject to market rules only, leaving political and hard power factors aside. The idea here is to let markets work, calling for government intervention only where markets fail. In line with this view, neither the world nor the EU are currently facing severe energy security challenges to be dealt with in a strengthened international framework, by heavy government intervention or even by military means. Instead, “the world economy does face a mid-term risk of liquid fuel scarcity and short-term risk of oil supply distortion, but there is nothing we are ill-equipped to deal with. [...] Similarly, higher prices are not an energy security problem but a solution” (Noël, 2008).

A contrary view is held by foreign policy analysts who are convinced that the increasing nationalisation of energy resources and the politicisation of energy management by resource-rich countries have made energy security – as in the 1980s – a matter of national security (Yergin, 2000). According to them, the market alone is not able to deal with the mounting and multi-faceted challenges that energy-consuming countries have to face in a globalised world. Energy security therefore requires international cooperation, government intervention and military control. Neither of these two interpretations can be dismissed, but neither can capture the whole picture of security of supply. In fact, the economic and the so-called political interpretation are two sides of the same coin; they complement each other and both are necessary to explain the challenges as well as the solutions to dealing with the security of energy supply in Europe (Checchi, 2008).

The complementarity of the two dimensions becomes clear when we come to the definition of energy security or security of supply. Although there is no common interpretation, it is possible to identify a number of features that are always included, namely physical availability and prices (see Box 1). Given that commodity prices affect economic growth, wealth and industrial competitiveness, energy must be available at a ‘reasonable’ price – not at any price. By definition, if prices were allowed to rise without limit, there would always be a sufficiently high price at which demand would equate supply – but in this case it would be naïve to say that the security of supply was guaranteed. To what extent it is acceptable to let prices vary to restrict

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demand and allocate scarce supplies is a question that can only be settled politically by governments or international cartels (such as OPEC). But security of supply also implies an ‘uninterrupted availability’ of resources, which depends on geological and economic dynamics as well as government intervention (especially on the demand side) and some political compromises. In addition to prices and the uninterrupted availability of resources, security of supply is characterised by other features that are resource-specific. These will be analysed in the following chapter (see Chapter 2).

Box 1. Definitions of security of supply

Political View

“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 environmental 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” (European Commission, 2000, p. 2). However, the Commission later noted that the risk of supply failure associated with increasing dependency on imported hydrocarbons is growing (European Commission, 2007).

“[Energy security is] the continuous availability of energy in varied forms, in sufficient quantities and at affordable prices” (United Nations Development Programme – UNDP, 2001).

Economic View

“A condition in which a nation and all, or most, of its citizens and businesses have access to sufficient energy resources at reasonable prices for the foreseeable future free from serious risk of major disruption of services” (Barton, Redgewell, Ronnel & Zillman, 2004).

“[Energy security is] the concept of maintaining stable supply of energy at a reasonable price in order to avoid the macroeconomic dislocations associated with unexpected disruptions in supply or increase in price (Bohi & Toman, 1996).

“Free markets are the consumers’ first line of defence” (Noël, 2008).

The literature is further divided between those who see the security of supply as exclusively related to energy and those who like to couple it with the environmental dimension. Energy experts generally prefer to keep energy and climate change issues separate, especially when it comes to policy implications (see Hartley & Medlock, 2008). Accordingly, different approaches are adopted to study the two topics, different solutions are required, and different policies are suggested. Climate change experts also tend not to deal with questions of energy demand and supply. However, with energy and climate change being strictly interlinked, it would be nonsense to assess their risks and consequences separately. We therefore call for an integrated approach of energy and climate change. Indeed, security of supply is essentially a strategy to reduce or hedge risks that derive from energy use, production and imports. All security-of-supply approaches are aimed at ‘insuring’ against supply risks with an emphasis on cost-effectiveness and the shared responsibility of governments, firms and consumers.

2. Supply Risk Analysis

Defining energy security is also complicated by the variety of views of what is at stake: to some it means protecting against politically-induced supply disruptions or technically-induced supply problems, to others it is facing the challenge of terrorism or dealing with price shocks, while to many it means addressing the issue of global warming (Monaghan, 2005, p. 2). There is no consensus among economists, energy experts and politicians on the correct hierarchy of energy

challenges for Europe in the near to long-term future. In line with the current debate on energy security of supply in Europe, we identify the following types of risk:

- **Geological risks** refer to the possible exhaustion of an energy source. Oil and gas reserves in the EU are decreasing (BP, 2007) and over 90% of world hydrocarbon reserves are controlled by state-owned companies in the Middle East and Eurasia. Not only are oil and gas difficult to access for European companies, but total hydrocarbon reserves and resources remain unknown. In addition, the increasing pace of world energy consumption is a source of concern for the future availability of resources: between 1973 and 2005 world energy consumption doubled and by 2030 a further 55% increase has been predicted, mainly because of developing countries' rapid economic growth (International Energy Agency – IEA, 2007).
- **Technical risks** include system failure owing to weather, lack of capital investment or the generally poor conditions of the energy system. They are of particular concern for electricity generated from renewables, coal and nuclear generation. The nine-hour electric blackout that occurred in Italy on September 2003 and the power interruptions of November 2006 that originated in Germany by the tripping of several high-voltage lines and affected 15 million European households, showed the possible consequences of technical problems affecting the electricity sector (UCTE, 2004 and 2007).
- **Economic risks** mainly cover erratic fluctuations in the price of energy products on markets. Price variations can be due to actual or anticipated imbalances between supply and demand, but they can also result from speculative movements and market power abuse. On the one hand, the rise in fuel prices creates monetary and trade imbalances between energy producing and consuming countries, especially harming the economy of the latter. On the other hand, decreasing prices of energy sources tends to diminish capacity-enhancing investment in energy producing countries, creating new bottlenecks to oil and gas supply. In addition, economic risks may include regulatory risks. Government-regulated policies in energy-producing countries may underplay the level of future investments, causing related effects on production and prices (e.g. Riley, 2006)
- **Geopolitical risks** concern potential government decisions to suspend deliveries because of deliberate policies, war, civil strife and terrorism. Energy industries in most supplier countries are subject to extensive government interference, and do not necessarily function in a competitive market framework. This adds to the fears that energy will increasingly be used as a political weapon. In addition, security of supply is threatened by political instability of exporting regions where civil wars, local conflicts and terrorism have often been the cause of temporary damage to energy facilities and infrastructures. Although the concept of geopolitical risk generally refers to the oil and gas sector, cross-border trade of renewables-generated electricity could also raise similar concerns.
- **Environmental risks** describe the potential damage from accidents (oil spills or nuclear accidents), or emissions such as greenhouse gas emissions. It is generally assumed that industrial countries will need to reduce emissions by 60-80% or more by 2050. Given that within the EU 80% of all emissions are related to fossil fuel burning in the energy, transport, household and industrial sectors, energy policy will increasingly be constrained by climate change objectives. While near-zero carbon energy or possibly fusion will ultimately be essential to meet the climate change challenge, the present focus is on how to reduce GHG emissions from fossil fuels, which continue to dominate the EU's energy mix. The principal obstacle facing the EU is the absence of a comprehensive global climate-change agreement that would provide the necessary certainties for investors (Behrens & Egenhofer, 2008).

It is important to note that the time scale of different risks differs considerably from fractions of a second to hundreds of years (International Energy Agency, 1995; Stern, 2006; Mandil, 2008). In the short term, the concern is with the disruptive impacts of a price shock or an unanticipated cut in supply. The latter is generally associated with supply shortages due to accidents, extreme weather conditions, terrorist attacks or technical failures of grids. Such risks are sometimes referred to in the context of ‘operational security’ or ‘systems security’. In the long term, the concern is more with the availability of sufficient energy supply that allows stable and sustainable economic development. Here the emphasis is on geological depletion, adequacy of investments in generation capacity, transport infrastructure and grids, as well as the quality of systems’ management, including pricing mechanisms and mitigating market power.

Another necessary distinction concerning risks refers to the fact that the EU is confronted with both external and internal energy security risks. All the elements linked to energy imports dependence belong to external risks, including geopolitical issues, international transit, upstream technical issues in non EU countries, etc., while uncertainties related to European energy demand, infrastructure, as well as energy policy orientations and institutional developments refer to internal energy insecurity. Accordingly, market risks in the framework of liberalisation, either due to bottlenecks, market power or regulation, have to be addressed, as well as their potential impact on import development. The distinctions between internal and external insecurity are fundamental as far as tools available to the EC and to European governments are concerned. Dealing with external issues involves developing diplomacy and relying on the European energy companies present in international markets.

3. EU Energy Trends¹

Barely half of the energy consumed in Europe is produced within the region while the other half needs to be imported.² Accounting for almost 37% of total energy consumption, oil remains the dominant fuel followed by natural gas, coal, nuclear energy and renewable sources (European Commission, Statistical Pocketbook 2007-2008). Together the UK and Denmark supply just a quarter of the oil consumed in the EU while the rest is imported from Russia (30% of all oil imports), the Middle East (20%), Norway (16%), North Africa (12%), and other regions (23%) (European Commission, 2008a).

For environmental and economic reasons, natural gas has become more popular over the last decade, mainly at the expense of coal. Natural gas currently accounts for one quarter of total EU energy consumption and its consumption is predicted to grow further (IEA, 2007). With 1.3% of world natural gas reserves – mostly in the North Sea – and a general depletion of the fields, slightly over one third of natural gas consumed in Europe is produced domestically (BP Statistics, 2007). The remainder needs to be imported from Russia (45% of all natural gas imports), from Norway (24%), from Algeria (21%), and some 11% from Nigeria, Libya, Egypt, Qatar and Oman (European Commission, 2008a).

Accounting for just 8.5% of primary energy consumption, renewable energy sources play a modest role in the EU, but much more potential could be exploited. The most developed forms of renewable are biomass, hydropower – especially in the Nordic, Alpine and Iberian Mountains – and, to a lesser extent, wind power (especially in Germany and Spain), geothermal (in Italy) and solar power (European Commission, 2008a).

¹ All data refers to the EU 27.

² However, the Norwegian share of oil and gas supply to the EU is misleadingly treated as imports here. In fact, Norway belongs to the European Economic Area and should not be considered as an external supplier to the EU.

Conventional thermal accounts for most of electricity production (57.7%), nuclear ranks second (18%), and renewables for 24.1%. However, the mix of energy production is quite different from country to country: electricity from conventional thermal dominates in Germany, Italy, and the UK; nuclear power accounts for almost 80% of electricity production in France and for half of national consumption in Germany, Spain, and the UK, while countries such as Italy, Portugal, Denmark have banned nuclear generation. Renewables have been growing especially in Austria, Germany, Sweden, Latvia, Romania and Denmark (European Commission, 2008a).

It has been estimated that by 2030 energy consumption in the EU will increase by 15% whereas production will stagnate, causing a further increase in oil and natural gas imports (up to 70%) (European Commission, 2006b).

4. General policy context and current developments

Given the increasing risks related to the security of energy supplies and climate change, the European Union has recently committed itself to taking action in these new areas of concern. The policy approach of European institutions has evolved: it moved from prioritising energy security concerns to a progressive integration of energy and climate change.

Features and challenges of Europe's security of energy supply were first addressed by the European Commission in the 2000 *Green Paper* on "Security of Energy Supply" (European Commission, 2000). Given a preliminary analysis on facts and figures about energy, the document brought up three main energy concerns for Europe: high dependence on energy imports; limited influence of the EU on the supply side; and difficulties in meeting the requirements of the Kyoto Protocol. In line with this first document, on 8 March 2006, the European Commission issued a second *Green Paper* on "A European Strategy for Sustainable, Competitive and Secure Energy" (European Commission, 2006a). The latter put forward suggestions and options for shaping EU's future energy policy in six priority areas:

- the completion of the internal European electricity and gas markets;
- solidarity among member states;
- a sustainable, efficient and diverse energy mix;
- an integrated approach to tackling climate change;
- a strategic energy technology plan;
- a common European external energy policy.

Following the publication of the second Green Paper the European Commission tabled a major energy policy package on 10 January 2007, entitled "Energy Policy for Europe" (EPE), which was accompanied by a number of sectoral policies to implement the overall strategy. The EPE contained a chapter dedicated explicitly to increasing security of supply, which calls on a "spirit of solidarity" between member states, especially in the event of an energy supply crisis. A similar notion has been included in the Lisbon Treaty.

After discussions in the EU Energy and Environment Councils, the EU heads of state and governments by and large endorsed the European Commission's strategy presented three months earlier at their European Council meeting of 8 and 9 March 2007 (European Council, 2007), including:

- 1) A binding absolute emissions reduction commitment of 30% by 2020 compared to 1990

conditional on a global agreement,³ and a “firm independent commitment” to achieve at least a 20% reduction by 2020. At the same time, the EU advocated that industrialised countries reduce their emissions collectively by 60% to 80% by 2050 compared to 1990. The European Parliament in its resolution has insisted that the EU should unilaterally commit to 30%.

- 2) A 20% reduction of primary energy consumption by 2020 compared to projections;
- 3) A binding target of 20% of renewable energy in total energy consumption by 2020;
- 4) A binding minimum target of 10% biofuels of all transport fuels by 2020;
- 5) The development of a European Strategic Energy Technology Plan;
- 6) An endorsement of the European Commission’s carbon capture and sequestration policy.

In the follow-up to the spring 2007 Council, the European Commission has tabled various proposals to implement the European Council decisions. A Strategic Energy Technology Plan was published in November 2007, focusing on specific technologies that may help to achieve the 2020 commitments. On 23 January 2008, the Commission presented a whole package of proposals, containing an update of the EU emissions trading system (ETS), binding national targets for the reduction of greenhouse gas (GHG) emissions outside the EU ETS until 2020, binding national targets for increasing the share of renewable energy sources in final energy consumption in 2020, proposals on biofuels including environmental sustainability criteria,⁴ new rules to stimulate CCS, as well as new state aid rules. The final version of the energy and climate change package was agreed by the EU leaders on 11-12 December 2008 and it was then endorsed by the Parliament on 17 December 2008. Following pressure by Germany, Poland and Italy, the agreement contains numerous derogations aimed at reducing the costs for heavy industry, but the final agreement was crucial for reaching the “20-20-20” targets by 2020.

The last step in the development of Europe’s energy policy was the Commission’s Second Strategic Energy Review published, as a first draft, on 13 November 2008. The focus of the document is supply security and fossil fuels. In the related EU Energy Security and Action Plan, the Commission addressed five points that chart the policy priorities for the next Commission, due to take office in September 2009. These are:

- Infrastructure needs and the diversification of energy supplies
- External energy relations
- Oil and gas stocks and crisis responses mechanisms
- Energy efficiency
- Making the best use of the EU’s indigenous energy resources.

This new energy package should be regarded as complementary to the “20 20 by 2020” targets and will guide discussions about energy policy at the EU level in the coming months.

³ Provided that other developed countries commit themselves to “comparable” reductions and economically more advanced countries to contributing “adequately” according to responsibility and capabilities.

⁴ Included in the proposal on renewable energy resources.

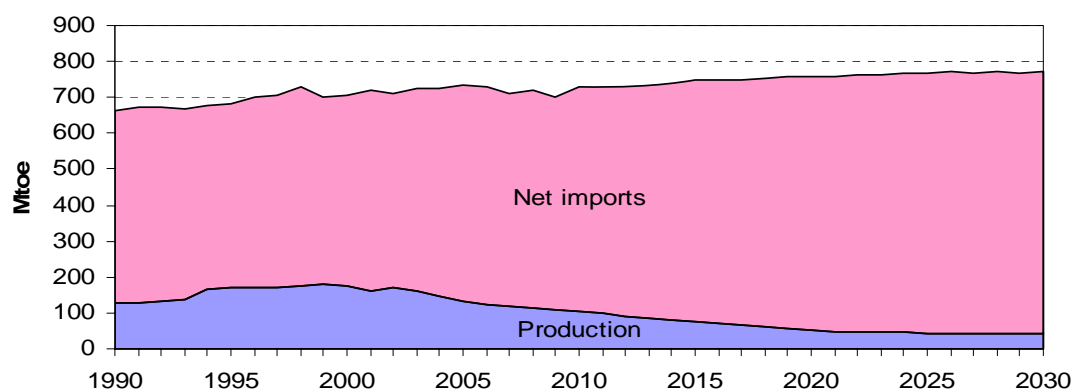
Part I. Specific Supply Risks for the Major Energy Sources

1. Oil

Oil is an energy source of critical importance for the European Union. Its relevance is especially related to transport, followed by the industrial sector. Oil use for power generation has declined since 1990 thanks to fuel switching to natural gas and, to a lesser extent, to renewables. This trend is expected to continue: oil will be used as a fuel only in niche markets but it will continue to dominate the transport sector. The overall EU transport demand is indeed projected to increase by 18% by 2020 and the European target of replacing 10% of transport fuel use with renewables energy sources – even if it is reached – is expected to only moderately reduce the European dependence on oil with incontrovertible negative impact on climate change (IEA, 2008).

EU-27 oil demand (crude oil and oil products) increased from 665 million tons of oil equivalent in 1990 to 731 Mtoe in 2006 (see Figure 1). Notwithstanding this relatively small increase, the gap between internal demand and supply is widening. Today, domestic oil production in the EU is less than in 1990 and only covers 14% of EU consumption. The rest of the oil demand is met by imports. A third of crude oil imports in the EU come from Russia, followed by Norway (15%), Saudi Arabia (9%), Libya (8%) and Iran (5%) (IEA, 2008) (see Figure 2). Although oil imports from Norway are not a source of concern since the country belongs to the European Economic Area, the other suppliers are sometimes perceived as a potential source of insecurity for Europe's energy supply. Import dependence is not necessarily risky if a relatively well diversified source of supply origins exists, but some EU members, such as Slovakia, Poland, Hungary, Lithuania, are almost completely dependent on Russia for oil imports.⁵

Figure 1. EU-27 oil production, consumption and net imports⁶



Source: Eurostat for 1990-2006, EC (2008) for 2006-2030.

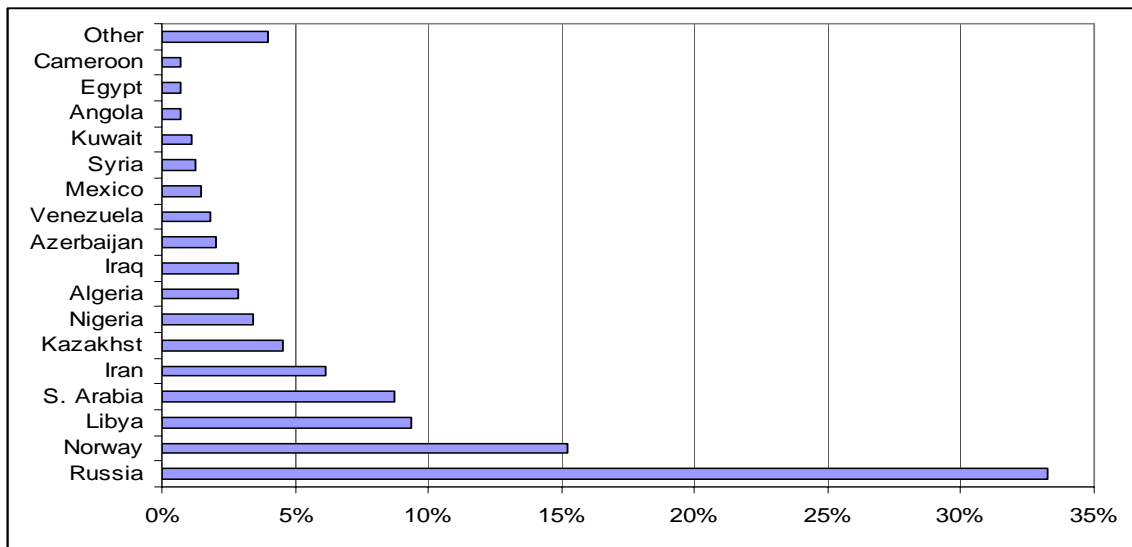
While small discoveries continue to be made in a number of EU countries, it is unlikely that the rate of import dependence will decrease in the near future. By 2030, oil production in the EU is

⁵ This paragraph is mainly based on the contribution of Sohbet Karbuz from OME.

⁶ In the graph, Norwegian's supplies are considered as net imports. Taking into account that Norway is part of the European Economic Area, the picture looks slightly different: Enlarged EU 'domestic production' is in fact 15% higher than stated here.

expected to be only one-third of today's level. Yet, according to the latest EC estimates⁷ the demand in the EU-27 is expected to reach some 770 Mtoe by 2030.⁸ As a result, net oil import requirements of the EU will increase by 20% in the next two and half decades, reaching 730 Mtoe in 2030 (or almost 95% of domestic consumption), compared to 608 Mtoe in 2006. Russia will remain the biggest supplier of oil to the EU, although only a slight increase in its exports is expected. Libya and Saudi Arabia will both increase their export share to Europe. Norway, on the other hand, will become less important by 2030 due to the depletion of its oil reserves, which already peaked in 2001. By 2030, OME expects Norwegian oil exports to be only 10% of these of today. Also, EU member states will receive less crude oil in the future from the Americas, mainly because of increasing oil needs in the US, whose demand will preferably be met by imports from other countries in the American continent. This means that Europe will become more dependent on Russia, the Caspian region, Africa and the Middle East for oil imports.⁹

Figure 2. EU-27 imports of crude oil in 2006 (intra-EU-27 trade excluded)



Source: Calculated from Eurostat data.

This expected increase in oil imports is at the centre of Europe's energy policy debate. Because of the existence of a number of oil suppliers around the world and the global nature of the oil market, the real concern for Europe is not increasing oil import dependence *per se*, but the risks related to it: the vulnerabilities of transporting oil, the possible rivalry over oil resources around the world, and the oil price.

1.1 Oil transport risks

Over 85% of crude oil imports to the EU are transported by sea while only 14% are transported by pipelines. Pipeline imports come from Russia through the Druzhba North and South pipelines, and from Norway through Norpipe (to the UK). As a consequence of falling

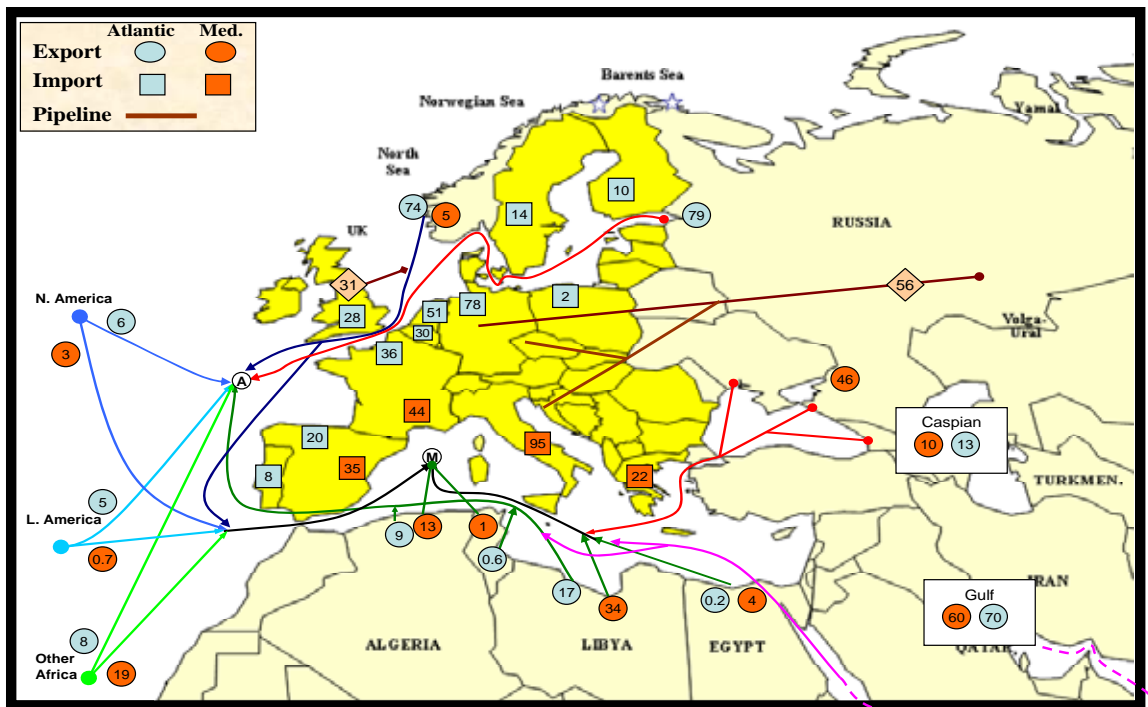
⁷ "European Energy and Transport Trends to 2030 – Update 2007", Directorate General for Energy and Transport, European Commission. April 2008.

⁸ However, EU projections do not yet include the effects of planned and soon to be adopted climate change measures such as stringent emissions standards for cars.

⁹ This paragraph is mainly based on the contribution of Sohbet Karbuz from OME.

Norwegian crude oil production and exports, the share of Europe's pipeline imports is expected to decrease to 11%. However, pipeline oil imports from the Former Soviet Union region will increase, adding to the security of supply risk for two reasons. The first reason is related to the capacity constraints of the Druzhba pipeline. Its transport capacities are fully exploited and they will need to be nearly doubled to meet Europe's import needs. The second risk is linked to Russia's possible supply interruptions to the states of the Former Soviet Union. If supply cuts to Western countries are not a credible threat due to their relatively diversified supply sources, some central European countries with a quasi-total dependence on Russian oil exports have some reason to be fearful. In particular, land-locked countries with a high dependency on Russian oil exports, such as Hungary, Slovakia and the Czech Republic, are vulnerable to technical supply interruptions or to Russia's use of energy as a tool of political pressure. In this context, however, existing IEA and EU stock policies are an important assurance tool and minimise the possible geopolitical threats from Russia.

Figure 3. Major EU crude oil import routes, 2005 (in million tonnes)



Source: OME (Observatoire Méditerranéen de l'Energie).

But the majority of Europe's oil imports is shipped by tankers (see Figure 3). Nearly 60% of seaborne crude oil imports to Europe go to the North of Europe (of which Rotterdam is the most important) while over 40% go to the Mediterranean ports of the EU. According to OME estimates, in 2030, more than half of EU crude oil imports will be delivered to the Atlantic ports of the EU, while only 35% will go to its Mediterranean ports. Atlantic ports will gain importance in share mainly because of two factors. On one hand, the increase in demand of northern EU countries (especially from the UK and other countries relying on decreasing Norwegian crude) will push northern countries of the EU to rely more and more on oil from the Middle East and Africa. On the other hand, the foreseen decrease in demand, especially in Italy,

will limit the demand of Mediterranean countries. However, most of the import volumes to Atlantic ports will have to transit through the Mediterranean.¹⁰

Although shipping oil has the flexibility advantage of allowing both exporters and importers to re-direct their exports/imports, this means of transport is vulnerable to the so-called 'chokepoints', namely the narrow sea-lanes through which the oil tanks have to transit. The 106 million tons of crude oil shipped every year from the Middle East to Europe (including Turkey), have to pass through different chokepoints: the Bosphorus linking the Black Sea to the Mediterranean Sea, the Bab el-Mandab Strait from the Arabian Sea to the Red Sea, and the Suez Canal together with the Sumed pipeline connecting the Red Sea to the Mediterranean Sea. Shipping accidents, and some pirate attacks, could seriously impede transport on these routes, with significant impact on oil supply and prices (Willenborg, Tönjes & Perlot, 2004).¹¹

Yet the risks related to oil transport – either by pipelines or tankers – are limited compared to the geological challenges that the oil sector is currently facing.

1.2 Increasing competition for global resources: is an oil crunch possible?

Europe's security of oil supply mainly depends on the future equilibrium between global demand and supply for oil and the related competition for available resources. Today, the world demands 86 million barrels of oil per day – i.e. 1000 barrels a second – and, according to the IEA, EIA and OPEC, oil demand is expected to rise by 35% until 2030. Yet about 42% of this increase will come from China and India and, to a lesser extent, from transition economies and oil producing countries where the persistence of government subsidies does not provide

¹⁰ Some of this information is based on the contribution of Sohbet Karbuz from OME.

¹¹ The Bosphorus Strait represents one of the most important supply and environmental vulnerabilities for Europe, especially for Southern countries. The Strait is less than 1km wide at its narrowest point and has several blind turns that make its waters difficult to navigate. With 5,500 oil tankers transiting the Strait every year, the threat of accidents is real (Willenborg, Tönjes & Perlot, 2004). The Black Sea has always been the largest outlet for Russian oil exports but the volume of oil passing through it increased further since the collapse of the Soviet Union, adding to the accident record of the Strait. There are fears that the projected increase in Caspian Sea exports might exceed the ability of the Turkish Straits to accommodate the tanker traffic. However, the risk could be mitigated as some of the planned projects bypassing the Strait should be realised soon, such as the BTC oil pipeline, which opened in 2006 (EIA, World Oil Transit Chokepoints). Some of these projects include: the connection between the Romanian port of Constantia and the Adriatic ports of Omisalj and Trieste; the oil pipeline project from Constantia or from the Bulgarian port of Bourgas, either through Macedonia to the Albanian port of Vlora, or to the Greek port at Alexandroupolis; the reversal of the Odessa-Brody oil pipeline; the Samsun-Ceyhan oil pipeline; and a shorter oil pipeline from the Turkish port of Kiyikoy to Ibrikkaba or Saros. All these projects would help to decongest the Bosphorus but none of them are currently among the priorities of the EU (Nies, 2008).

The other key chokepoint for Europe's oil imports is the Bab el-Mandab Strait. The closure of this passage – through which 3 million barrels are channelled every day – would force tankers from the Persian Gulf to navigate around the southern tip of Africa instead of passing through the Suez Canal. This would add greatly to transit time and cost, shrinking spare tanker capacity. The fact that security remains a major concern in the Strait was proven by the terrorist attack on the French-flagged tanker Limburg in October 2002 (World Oil Transit Chokepoints). Close to the Bab el-Mandab Strait is the Suez Canal and the Sumed pipeline, which are very important for Europe's oil imports from Saudi Arabia. A closure of the Suez Canal or the Sumed pipeline would cause oil tankers to navigate around Africa's southern tip, making the route much longer and forcing a reduction in tanker capacity with an overall effect on oil import prices (Willenborg, Tönjes & Perlot, 2004).

incentives to contain energy demand.¹² More specifically, the annual increase in oil demand is expected to be 3.6% in China, 3.9% in India, 1.9% in the Middle East, 2.2% in Africa and 1.6% in Latin America, but only 0.1% in Europe. Accordingly, by 2030, the number of vehicles on the world's roads will double (up to 2.1 billion) but Europe's share of the increase in world transport oil demand will only be 3% of the total (IEA, 2008). The global increase in oil demand would therefore require an additional production of more than 1 million barrels of oil per day each year up to 2030. Would the oil industry be able to provide this level of production in the near future, thereby allowing Europe to meet its energy demand?

A key concern for the oil sector today is indeed the diminishing inventory of oil. About half of world production comes from 116 giant fields, each producing more than 100 thousand barrels per day. Yet the majority of them are 50 years old and their resources are depleting (e.g. Ghawar in Saudi Arabia and Burgan in Kuwait). The consequent loss in production is partly (1/4) offset by newly discovered oil fields whose size is nevertheless decreasing. The data shows that there is still plenty of oil in the ground but the problem is how to recover it. Today's average global recovery rate is only about 35%, which means that 65% of the world's discovered oil is left in the ground. Although new technologies and exploration techniques may be able to increase the recovery rates and make unconventional oil (such as tar sands, extra heavy oil and oil shale) become conventional, the era of 'easy oil' seems to be over.

This is what the peak oil debate is about. On the one hand, there are the pessimists who argue that unconventional resources will be able to postpone the oil peak until no later than 2015. Then, they foresee oil prices to skyrocket causing economic issues, social and environmental collapse, massive dislocation and a dying civilisation.¹³ On the other hand, there are the optimists who believe that unconventional oil sources would be able to offset the decline in conventional oil sources meeting the future increase in oil demand; to them, the oil peak will not be visible before 2030 (Karbuz, 2007).¹⁴ Assuming that a peak is inevitable, it is difficult to tell which view is correct because of different methodologies, data, definitions and assumptions

¹² Between 1999 and 2007, Middle East domestic oil consumption grew on average 3.9% per year, while OECD growth rate was only 0.4% (Stevens, 2008). Domestic oil demand in Middle Eastern countries is expected to more than double by 2030, mainly due to high population and income growth. This is especially the case in Saudi Arabia, which will remain the biggest oil consumer in the region and, in 2030, despite its production growth, will have an oil export potential not much higher than that of today. In Russia, although weak demographic developments will help reduce the growth of oil consumption in the future, the high level of energy intensity is also expected to contribute to a relatively high level of oil consumption. Moreover, in most of the African countries, demand is expected to more than double but, due to the increased use of gas in power generation and in residential sectors, as well as government policies to free more oil for exports, export potential over the 2004-2030 period will mirror production. This will not prevent some African countries – such as Egypt – from becoming net importers as soon as 2010. Although some of these areas seem distant and therefore irrelevant for Europe's security of oil supply, they are closer than one might imagine: regardless of where they are located, rising domestic consumption in major oil producing countries seriously constrains their ability to export to international markets, putting pressure on oil volumes and prices (Stevens, 2008).

¹³ The most relevant representative of this group is the International Association of the Study of Peak Oil and Gas (ASPO).

¹⁴ The main supporters of this view are the US Energy Information Agency, the International Energy Agency and Cambridge Energy Research Associates. These two views are also divided on whether the decline in global oil production will be preceded by a peak or a plateau. The optimists generally think that before a peak the world will experience an 'undulating' plateau. The pessimists are divided between those who talk about a 'pumping plateau' and those who expect a sharp decline after the peak.

used (Mabro, 2006), but both foresee a future – sooner or later – of a world without oil.¹⁵ Yet peak oil may become irrelevant the moment the world engages in aggressive climate change policies.

Oil companies are struggling to replace their reserves, not only for geological reasons but also for pecuniary and political constraints. Because of spreading ‘resource nationalism’ in oil producing countries (such as Venezuela, Kazakhstan, Russia, etc.), IOCs are increasingly facing strong competition with national companies. The latter are claiming their rights, especially on easy-access reserves, pushing IOCs towards remote and geologically complex areas (Karbusz, 2007).

1.3 The impact of oil prices

The oil price has recently decreased towards \$40 per barrel. Before oil prices plummeted in October 2008, the latter had been the 7th consecutive year of crude oil price increase: the barrel passed \$100 at the end of 2007 and reached its peak in summer 2008 (\$147). The growth of oil prices of the last years has mainly been caused by a narrowing gap between supply capacity and demand for oil. As mentioned above, booming economies – such as China, India and Middle Eastern countries – are the driving force behind high global demand for oil and the relative increase in oil prices. On the supply side, the market was tight, the investment was low and the technical and geological hardships were numerous. Other factors, such as the weak dollar, financial speculations on oil driven by large trader banks and hedge funds, rising expectations of a possible oil-peak, political tensions in the Middle East, and unexpected weather conditions also played a role in pushing oil prices up. However, the current oil price slowdown shows that the impact of some of these factors is temporary rather than structural. Negative expectations for the future economic growth and energy demand growth have been the main driver behind the oil price collapse.

Jan-Hein Jesse and Coby van der Linde (2008) argue that, in the long-term, oil prices are expected to be high for two main reasons. First, “there is no credible cushion of spare capacity in the core OPEC countries: [...] although spare capacity has improved since 2004, it is still fragile, uncertain and not perceived as adequate”. As a consequence, when unexpected events occur (e.g. hurricanes in the Gulf of Mexico, terrorist attacks on oil pipeline in oil-producing countries in the Middle East or Africa), there can hardly be a response in volume, which has to be compensated with an equivalent upward pressure in the price of oil. This trend is reinforced by the conviction that global oil consumption will continue to increase putting supply under pressure. Moreover, the two authors explain that the demand-supply tension is aggravated by the problem of under-investment in the upstream sector, especially in those countries – such as Russia and the OPEC states – where access to international oil companies is becoming more and more limited. Having no alternative but to invest in remote and difficult areas, international oil companies are contributing to drive up the costs of the marginal oil barrel, creating further pressure on its price (Jesse & van der Linde, 2008).

To others, the extreme oil price situation of 2008 was nothing but a speculative bubble. R.S. Eckaus (2008) from MIT University, argues – for example – that “hedge funds have been very active in the oil market and their activity, along with other speculators, has raised the volume of oil transactions far above the volume warranted by ordinary commercial transactions” causing a prolonged increase in oil prices. According to Eckaus (2008), only a “strong dose of reality”

¹⁵ Mabro (2006) identifies three different sets of problems. First, the definition of important concepts such as crude oil, production, reserves and resources is not always the same. Second, estimates of proven reserves may be understated or overstated depending on who delivers them, e.g. oil companies or OPEC. Third, some use recoverable reserves to make their estimations, others use proven reserves.

could break the bubble. Some may indeed argue that the ongoing financial crisis triggered the burst of the bubble leading to a strong decrease in oil price prices. However, strong criticisms of the “speculation theory” exist in literature.

Whichever view on oil price mechanisms is correct, it does not change the fact that oil price volatility can have a negative impact on the welfare of energy-importing countries, including Europe. Generally speaking, an increase in oil prices affects the price of many other energy carriers, especially, and most directly natural gas. A higher than expected increase in oil prices leads to increased costs of production of all other goods requiring energy for production and transport. The outcome is additional inflation (“imported inflation”) largely regarded by economists as harmful to the overall economy (Willenborg, Tonjes & Perlot, 2004). On the other hand, a decrease in oil prices is generally a symptom of a global economic slowdown, and mainly affects energy producing countries by reducing their revenues. With profits reduced, their incentives to invest in the energy sector decrease. Also, with low oil prices, a long-term fuel substitution becomes less likely and the economic incentive to move towards a low-carbon economy decreases. Under these circumstances, the security of energy supply can in fact worsen in the long-run.

1.4 Possible fuel substitution

Since oil is mainly used for transport, the Council decision to increase the share of renewable energy in transport to 10% by 2020 may have some impact on improving the security of European oil supplies. By decreasing the amount of fuel subject to the risks of transport, import and scarcity, biofuels and other renewables may indeed benefit the security of fuel supply. Moreover, the increased use of renewables could potentially contribute to a reduction of EU greenhouse gas emissions, 27% of which are produced by the transport sector.

However, biofuels seem to have a number of drawbacks. First, their production could accelerate the destruction of natural habitats causing the alteration of the ecosystem’s equilibrium. Deforestation and the release of carbon sinks in the atmosphere are only two of the problems related to biofuels production. Second, although they have the potential to reduce greenhouse gas emissions (up to 3% according to the OECD), not all biofuel options benefit the global climate. On the contrary, some of these options lead to increased greenhouse gas emissions compared to their conventional alternatives. Third, from a European security of supply point of view, the role of biofuels is disputed: the EU would need to import about 50% of its biofuels demand without gaining very much in terms of self-sufficiency (see also Behrens, 2008). Also, as biofuels production is strictly related to the food sector, its price may vary according to changes in the commodity sector and vice-versa (Jesse & van der Linde, 2008).

Other alternatives to oil are second generation biofuels, gas-to-liquids, coal-to-liquids and electricity to fuel up plug-in hybrid electric vehicles. These technologies are still at various stages of research and development and, for the time being, they remain too costly to be able to make a relevant impact on the transport sector before 2020 and may be unsustainable due to the large carbon content (Jesse & van der Linde, 2008). In conclusion, the EU should think about building a framework to encourage investment in some of the most promising new technologies, which all together may be able to improve fuel security of supply and the impact of the transport sector on climate change. On top of this, a social effort to educate European consumers to a less oil-based life-style may accelerate the transition towards oil substitutes.

2. Natural Gas

Gas and oil reserves often occur together and are concentrated in similar countries. They also share some economic characteristics such as relatively high fixed upstream costs and physical transportation constraints to reach the market. However, gas has its own features. First, it is

mostly transported by pipeline unless it has to cross oceans or run over long distances (in this case LNG is preferred). The pipeline physical link creates a two-way dependence, or interdependence, which is the essence of the security of supply/security of demand issue for natural gas. Second, gas markets are regional rather than global as in the case of oil (increasing LNG trade may change the *status quo*). The regional nature of gas supply matter: depending on where the sources of supply are located and where demand is concentrated, dependency is different. Finally, gas is the fuel of choice for electricity generation and it has several potential substitutes, instead, oil is mainly used for transport and it cannot be replaced anytime soon (Helm, 2007). Given these differences, it can be argued that the concept of security of supply and the related risks for natural gas differ significantly to the case of oil.

The IEA defines the security of gas supply as “the capability to manage, for a given time, external market influences which cannot be balanced by the market itself”. In the short term, “security of gas supply covers the adequacy of supply and capacity to avoid unforeseen interruptions of customers” under rare and extreme events. In the long term, “it includes the capacity to mobilise investment to develop supply and infrastructure as well as the insurance to ensure reliable supply” (IEA, 2004).

Gas security challenge in the EU has an external and an internal dimension (IEA, 2004). The first is linked to increasing import dependence from external suppliers. It includes three different risks: investment and facility risks, exporters’ reliability risk and transit risks. The internal dimension of gas security of supply is linked to the development of the internal EU market and the liberalisation of gas sector. The risks attached to this second dimension are concerned with under-investment in the internal gas market – both in the short- and in the long-run.

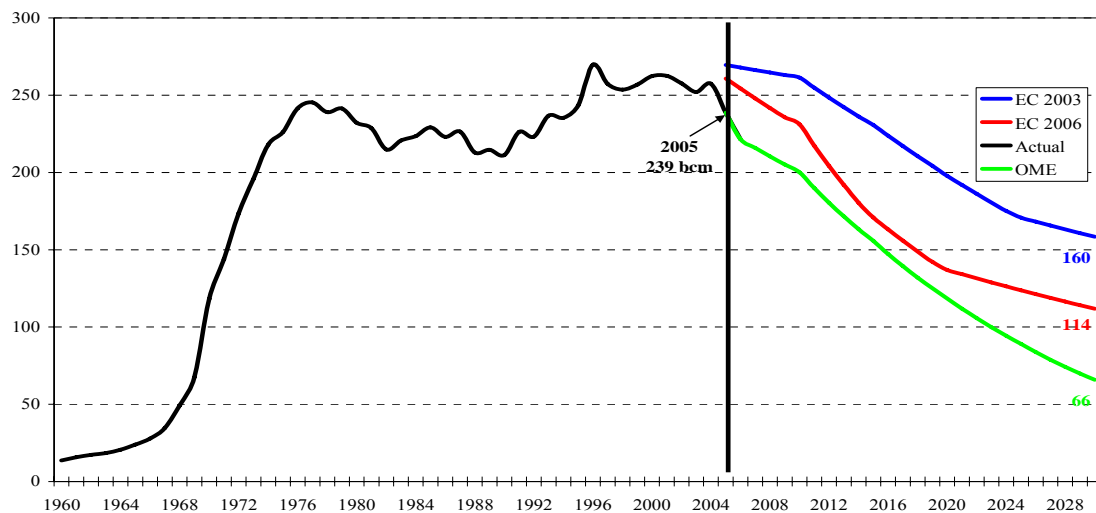
2.1 Rising demand, declining production and increasing import dependence

An important factor in Europe’s natural gas supply is the clear trend towards declining domestic gas production and resource discovery vis-à-vis increasing demand for gas. From 1990 to 2005, EU gas consumption rose by 50% and a further increase in demand is expected in the next twenty years or so (IEA, 2008). In the DG TREN reference scenario¹⁶ published in 2006, for example, the EU natural gas demand was forecasted to grow by 24% (from 537 bcm to 666 bcm) between 2005 and 2030, while in 2008, DG TREN reduced the expected demand growth to 16%. These trends will mainly be driven by an increased use of natural gas in the power sector, but also by the rising use for space heating and in the industrial and commercial sectors. Yet major uncertainties about future EU gas demand exist mainly because of inadequate knowledge about future gas prices and their impact on demand: power generation is very sensitive to gas price increases compared to those of its alternatives like coal, fuel oil and nuclear. Uncertainties about government policies also matter. How they will affect the development of new technologies (such as Carbon Capture and Storage), the increase of renewables share in electricity production and the development of European Emission Trading Scheme will strongly influence Europe’s future natural gas demand (Tonjes & de Jong, 2007). Finally, demand for gas will also depend on the degree of commitment to fulfil environmental and climate change related targets such as those set by the Kyoto Protocol and the EU Emission Trading Scheme. To what extent these factors will affect EU gas demand is a matter of debate, but there is no doubt that natural gas consumption will continue to exceed Europe’s indigenous production and that import dependence will increase.

¹⁶ European Commission – Directorate-General for Energy and Transport, “European Energy and Transport, Trends to 2030 – Update 2005”, May 2006.

EU domestic gas production reached its peak in 1996 entering a period of ‘pumping plateau’ and long-term decline exacerbated by the progressive exhaustion of off-shore fields in the North Sea (see Figure 1). The UK potential has largely been explored and, although some fields have been put on-stream in the past ten years, a future decline in production seems irreversible. Accordingly, the UK has ceased to be a net gas exporter and is now an importer of gas. The Department of Trade and Industry has projected that by 2020 the UK may import 80% of its natural gas needs. The Dutch government has announced a cap of 425 bcm over the period 2006-2015 on production from the Groningen field to compensate for declines in small fields production. Yet it seems that, after 2010, Groningen will no longer be able to make up for the decline of small fields. Apart from Norway, most countries in the rest of Europe will experience a gradual decline in gas reserves. Natural gas production in Norway has increased by 60% in the first half of this decade and is expected to continue to grow substantially up to 2010; thereafter it will probably reach a steady phase (IEA, 2006 and 2004). Overall, OME expects Europe’s production rate of decline to be rather slow until 2010 due to some new fields coming on-stream, mainly in the UK. However, the EU’s natural gas production in 2030 will be less than 30% of today’s production. Even if demand remained at its 2005 level, the EU would need over 100 bcm of additional external gas supply just to compensate for the loss of production.¹⁷

Figure 1. EU gas production outlooks to 2030 (in bcm)



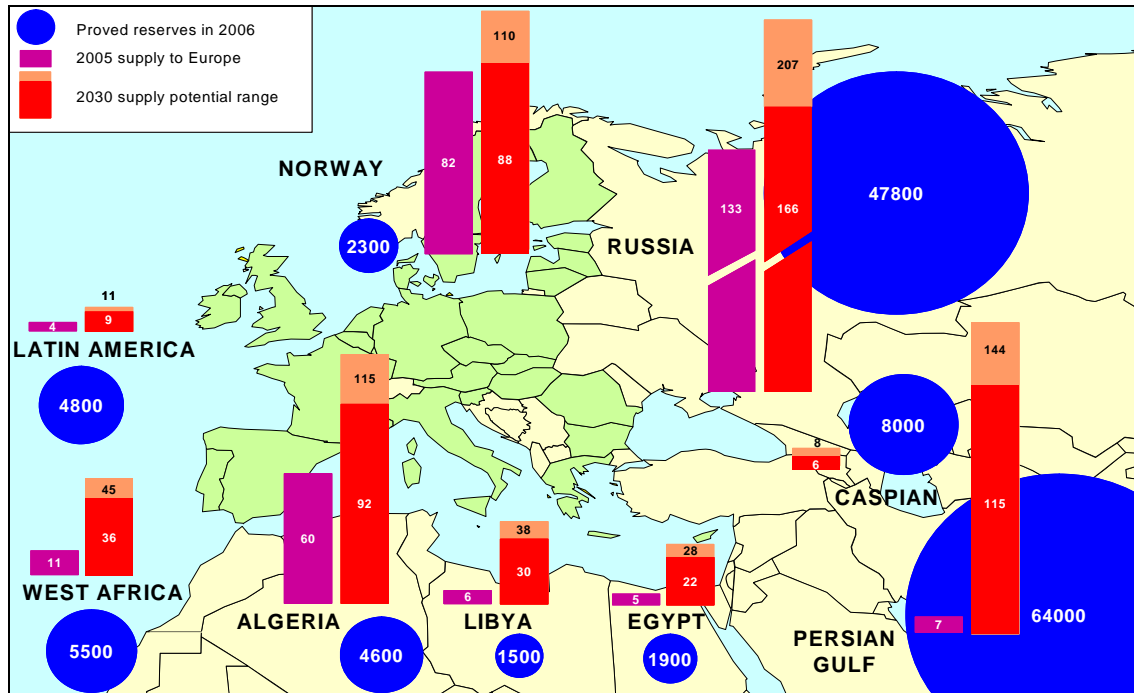
Sources: DG TREN (2003, 2006) and OME (2007).

Therefore, in the absence of new gas field discoveries in Europe, EU’s import dependence is expected to rise. Over the period from 1990 to 2006, natural gas imports to the EU-27 already doubled, exceeding 300 bcm. By 2030 imports are expected to increase to 625 bcm, that is 65% of EU demand (IEA, 2004). The bulk of OECD European imports are projected to come from its two main current suppliers – Russia (151 bcm) and Algeria (60 bcm) – but the number of suppliers will probably go up allowing for further diversification. According to the IEA, Russia – which owns 27% of world’s reserves – will remain the largest exporter for Europe and, in 2030, it will export around 200 bcm to OECD Europe; while Algeria’s export capacities will increase to 115 bcm/yr. Other African countries will also increase their exports to Europe (Libya, mostly by pipeline, Egypt and Nigeria by LNG) both by pipeline and LNG (see Figure 2). Yet the biggest increase is believed to be from the region with the largest reserves (36% of

¹⁷ This paragraph is mainly based on the contribution of Sohbet Karbuz from OME.

the world total),¹⁸ the Middle East. Here exports will mostly develop in the form of LNG, while pipelines from Iran and possibly Iraq could also play an increasingly important role (IEA, 2004). Other regions that are seen by the EU as suppliers of potentially increasing importance are Central Asia and the Caspian region, but their resource share is less than 5% of the world's total and could therefore provide only limited relief to Europe's increasing gas needs. In sum, EU's potential main suppliers have significant reserves that will enable them to increase production and meet Europe's gas demand, at least until 2030.

Figure 2. Reserves and main suppliers' export potential to the EU (in bcm)



Note: Uncertainty range for 2030 is +/- 20%.

Sources: OME, Oil and Gas Journal, CEDIGAZ and Norwegian Petroleum Directorate.

2.2 The external dimension of security of gas supplies

The economic and geopolitical risks attached to energy production and export activities in regions outside Europe are often perceived as a source of increasing vulnerability for the EU. As noted by Stern (2002), there are three main risks associated with Europe's gas import dependence: investment and facility risks, exporters' reliability risks and transit risks. Those associated with facility dependence can be technical or financial in nature, while source dependence and transit dependence refer to political risks associated with government decisions of producing and transit countries.

2.2.1 Investment and facility risks

As gas imports grow, massive investments in the Middle East, Africa and the CIS are required. WEO 2003 projects that the total investment necessary to meet growing European gas demand up to 2030 would be \$333 billion for Russia, \$160 billion for other transition economies, \$280 billion for the Middle East and \$226 billion for Africa, respectively (IEA, 2004). Despite energy

¹⁸ Qatar and Iran account for the majority, each about 15%.

revenues being abundantly available in gas producing countries, a certain reluctance to reinvest in the energy sector is quite common. Gazprom's production, for example, depends on ageing and inefficient facilities built during the Cold War and its ability to manage and develop its gas reserves is limited. Yet this does not prevent the company from investing its gas revenues in other commercial or financial businesses – such as telecommunications. The evidence so far is not encouraging: the IEA reports that Russia's three major gas fields (Urengoy, Yamburg and Medvezhye) are declining at a combined rate of 20 bcm per year; similarly, the Zapolyarnoye field – which came on-stream in 2001 – has already peaked due to a lack of investment (IEA, 2006).

Foreign investment could be a solution but even in this regard the picture looks daunting. In order to attract foreign investment, competitive and predictable legal, fiscal and regulatory terms are needed but in non-OECD countries the sovereign risks of investment remain high. More important is the will of gas-producing countries to limit foreign influence in their gas industries. Russia, for example, does not allow foreign companies to operate on its territory unless they are in a partnership with Russian companies. Yet, as the Sakhalin II deal with Shell and the BP-TNK Kovykta gas field case showed, also this option seems to no longer appeal the Kremlin (Helm, 2007). But Russia is not the only country where joint-ventures seem to have become unwelcome. Similar restrictions have recently been adopted in Algeria through the introduction of new unfavourable tax conditions for foreign companies investing in the country. However, national oil companies are slowly realising that they have neither the technological know-how nor the capital to bring most of their resources on-stream. This may open new perspectives for technological cooperation between NOCs and IOCs, meaning that the days of IOCs predominance are over, but not the days of investment per se (Noël, 2007).

As gas imports from external suppliers rise rapidly and cross-border gas trade becomes increasingly important, the need for investing in international gas pipelines increases. However, cross-border gas trade implies substantial start-up and maintenance costs, which can only be recouped in the long-term. This raises the risk of under-investment in interconnectors: European gas supplies are vulnerable to potential accidents at key transmission and import facilities, some of which are remote from European territory and therefore far from its control. The Yamal-Nenets pipeline corridor – which carries 90% of Russian gas production – and the Trans-Mediterranean gas pipeline connecting Algeria to Italy are good examples of facilities that cannot be completely monitored by Europe and rely on gas exporting countries' willingness to keep them in a good shape. The problem is that Europe's security of gas supply could be temporarily affected in the event of a technical accident affecting the gas infrastructure due to poor maintenance (Stern, 2002).

As European production decreases, future dependence on import points or pipelines from more remote areas will increase. Only diversification of routes, import points and interconnection grids could help to mitigate these and related risks. Accordingly, a number of multi-billion pipeline projects leading to Europe have been proposed and considered (see Figure 3). Among them, it is important to recall the Nord Stream gas pipeline connecting Russia with Germany via the Baltic Sea, the Nabucco gas pipeline from the Middle East and Caspian regions, the South Caucasus pipeline from Azerbaijan, the Turkey-Greece-Italy interconnection, the two new lines (Medgaz and Galsi) connecting Algeria with Spain and Sardinia (IEA, 2004 and 2006) as well as the South Stream from Russia to Europe via the Black Sea.

Figure 3. Import pipelines to Europe, projects and reinforcements, 2008



Source: Eurogas and OME.

Nabucco (N)

2.2.2 Exporters' reliability risks

In the EU, the main source of concern and debate associated with the projected increase of gas imports from Russia, the Middle East and Africa is related to the political reliability of these countries: nationalistic policies or possible internal instability are perceived as major energy security threats. Part of this European sensitivity is the result of a new assertiveness on the part of energy-producing countries, which stemmed from the post-2003 increase in hydrocarbon prices. Because of resource nationalism, international oil and gas companies and OECD governments have faced reduced access to resources and increased requests by host governments for substantial shares of rents from joint activities (Stern, 2006). The main fear is that gas and oil producers, together with their national companies, will increasingly link their export policies to political considerations using Europe's dependence as a tool of political pressure. Should this be the case, natural gas would be the tool of choice for producers because, being pipeline-bound to a greater extent than oil, it allows deliveries to be suspended to target countries pushing them towards specific political behaviour. In addition, European concern for exporters' reliability is justified by the unpredictability of interruption to supplies caused by internal political turmoil. The risk of terrorism, riots and political downturn in countries governed by undemocratic regimes is indeed an issue.

For European policy-makers the main source of concern is Russia. As the recent war in Georgia has shown, Russia does not seem to have abandoned its ambition of maintaining its influence on CIS countries nor its desire to regain a relevant position within the international system. Hydrocarbon resources seem to have become the preferred tools for pursuing these objectives, especially natural gas, which represents the biggest chunk of Russia's exports. Various episodes have contributed to rising doubts about Russia as a reliable supplier and commercial partner. The gas supply cuts (1993, 1994, 1995, 2005/2006, 2007 and 2009) to Ukraine illustrate this

point. In particular, the December 2005 crisis was officially triggered by a price dispute (Stern, 2006),¹⁹ but its coincidence with the political victory of the pro-Western candidate Viktor Yushenko has raised doubts about the purely commercial nature of Gazprom's price demand (Baran & Tuohy, 2006). The January 2009 gas crisis between Russia and Ukraine, although apparently economically rather than politically driven, is adding to the negative perception of Russia's reliability as a gas supplier. Russia's 'pipeline politics' is also a matter of concern, especially in the context of opposing gas pipeline projects bypassing its territory. It has indeed favoured the South Stream gas pipeline and the extension of the Blue Stream at the expense of the Nabucco project. Moreover, Gazprom has jealously preserved its monopoly over natural gas transiting from Central Asia, namely Turkmenistan and Uzbekistan, to Europe.

However, the interdependence between Russia and Europe should not be underestimated as a deterrent for Russia to use the energy weapon. The latter is in fact very much dependent on its gas exports to European countries, while the latter rely on Russia only for 6.5% of their total primary energy supply (Noël, 2008a). For Russia, gas exports to Europe (52% for western Europe and 20% for Eastern Europe) account for 3/4 of Gazprom's total export revenues (Heinrich, 2006; Stern, 2005). Accordingly, Russia has never voluntarily interrupted its supply to European customers but it has done so to CIS countries, which only accounts for 5% of Gazprom's export revenues. In addition, the degree of interdependence between Moscow and Europe varies from country to country. On average, Eastern Europe imports 60% of its total gas consumption from Russia (73% in Czech Republic, 66% in Hungary, 58% in Poland and 97% in the Slovak Republic). This amounts to 87% of all Eastern European gas imports. Western European countries, on the other hand, import only 18% of total consumption from Russia (amounting to 28% of all gas imports to Western Europe) (Stern, 2005).

The other important exporter, Algeria, has shown relative political stability during the mid-2000s, notwithstanding its internal upheavals and conflicts that are akin to a civil war (Stern, 2006). But the consequences of resource nationalism of the early 80s have not been forgotten. The extent of reliability of other emerging gas-producing states in North Africa – such as Libya and Egypt – may be difficult to predict. As for West Africa, it is worth mentioning Nigeria, the most important LNG producing country where petroleum-related unrest increased dramatically in 2006 (Stern, 2006). Finally, the Middle East's political instability raises questions about whether gas producers in the region will be able to turn into reliable exporters to meet Europe's future gas needs. Iran's regular confrontations with the West on various issues – especially nuclear issues – does not send out positive signals. Notwithstanding new investments in Iraq, the very unstable political situation of the country and the continuous risk of Islamic-extremist terrorism makes it a highly insecure supplier. Qatar is also supposed to become a major LNG exporter but internal political strains should not be underestimated when it comes to gas exports (Stern, 2006).

It has also been mentioned, Europe is facing the possible formation of a gas exporters' cartel in control of supplies and prices. Since the Gas Exporting Countries Forum (GECF) was launched in 2001, major producers such as Algeria, Qatar, and Russia have on various occasions signalled their support for it. In part, this was a reaction to Europe's decision to liberalise energy markets, thereby increasing competition and putting long-term contracts at stake. But the GECF is also related to Russia's ambition to increase its bargaining power towards European customers.²⁰

¹⁹ In 2005, Ukraine was paying \$50 per 1000 m³ of gas while Gazprom wanted to increase the price up to \$230.

²⁰ Although it formally denies pursuing a cartelisation plan, Russia continues to search for forms of cooperation with other producing countries: the 2007 agreement between Sonatrach and Gazprom and the 'big troika' formed in early November 2008 together with Iran and Qatar are good examples.

During the last GECF summit (23 December 2008), the member states agreed on a charter to give a more formal structure to the organisation. However, the institutional basis for a European gas cartel is at present relatively weak (Finon, 2007). First, gas trade is mainly based on long-term contracts making cartelisation of gas markets very difficult, if not impossible. Only a further increase of on-the-spot contracts, possibly related to LNG trade, could favour cartelisation. Second, to be effective, a gas cartel should include the other two major gas exporters to Europe – the Netherlands and Norway – but it is difficult to imagine that these two European countries would comply to a cartel. Third, unlike oil, natural gas has a number of substitutes (coal, renewable and oil) that also influence gas prices, making producers' control over prices limited. Finally, the nature of natural gas should not be underestimated as a limit: holding significant spare capacity will be much more costly and complicated for natural gas than it is for oil, as the necessary transport infrastructure in the form of pipelines of LNG are very capital-intensive (Tönjes & de Jong, 2007; Stern, 2002; McCracker, 2007).

2.2.3 *Transit risks*

Europe's natural gas imports are mostly (89%) delivered by pipelines that run across, at least, one transit country before reaching the EU border. This adds to the import risks. Trade negotiations between several countries are indeed complex and costly, especially if politically unstable countries are on the route or if their relationships with the exporter are tense. If any one of these conditions is fulfilled, the risk of supply interruption increases.

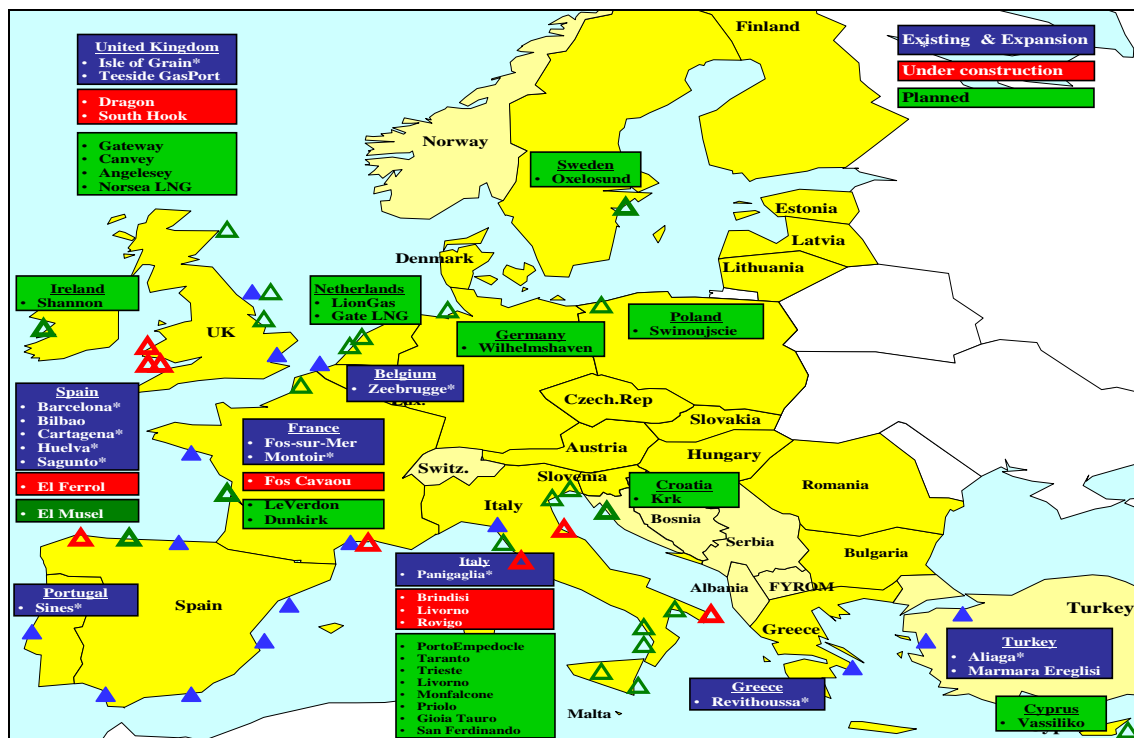
Despite internal political problems (the Algeria-Morocco dispute over the Western Sahara) and certain disagreements over transit fees, the flow of gas from Algeria to Europe has never been disrupted. But the main concern for transit is related to Russia's gas export. Most of its pipeline system was built during the Soviet period when there were no borders within the Eastern block. When the Cold War ended, the Soviet pipeline system turned into an inter-state system raising several issues: lack of transparency over the conditions under which access is granted to export capacity; lack of clearly-established criteria for the setting of transit tariffs; rising gas debts in Former Soviet Republics. Around 90% of Russian gas exports to Europe pass through Ukraine or Belarus before reaching the EU border. As Russia's relationships with other Former Soviet Republics remain tense this settlement represents a threat for European security of supply. The 2004 gas dispute between Russia and Belarus, the 2006 and 2009 Russia-Ukraine dispute over gas prices as well as a number of similar episodes during the 90s demonstrated Europe's vulnerability to events occurring in Eastern European transit countries. More important, if the reported consequences of these crises were limited to a few days, the 2009 dispute lasted about two weeks.

As the EU's borders enlarge, the transit risk decreases but being at the end of a transnational pipeline will always entail a certain amount of uncertainty for European importers. In addition, Russia's monopolisation of gas transit from Central Asia and the Caspian amplify Europe's concerns. Hence, several projects aimed at a diversification of routes and bypassing transit countries have been implemented or are currently underway, e.g. the Nabucco project. Thanks to technological improvements allowing longer undersea pipelines at increased depth under acceptable economic conditions, some international gas transportation projects directly connect the country of gas origin to the European gas market. This is the case for the Galsi and Medgaz gas pipeline from Algeria to Spain and Sardinia.

Once some of the LNG projects planned and under construction in Europe become operational (see Figure 4), transit risks could be eased. In Italy, for example, there are four proposals for the construction of LNG terminals and two of them – at Rovigo and Brindisi – have already been authorised. Spain has two LNG regasifiers under construction: at Sagunto and El Ferrol. France has authorised the construction of For-sur-Mer 2, while the UK has a couple of projects

at Milford (IEA, 2004). By eliminating the physical connectivity of pipelines, LNG is expected to limit and diversify security of supply risks, especially with respect to Russia (Helm, 2007). Far from being the panacea of Europe's security of supply, LNG has its own uncertainties and drawbacks. First, it still represents a small part of the gas market and it currently accounts for barely 11% of Europe's gas supply. However, a number of new LNG projects are in the construction and planning stages, notably in the UK, Spain and Italy. As OME's gas infrastructures database foresees, by 2030, in the EU-27 total regasification terminal capacity will triple reaching over 380 bcm/yr.²¹ Second, LNG facilities are highly capital-intensive: for a 4.5 mtpa project in the Middle East, liquefaction facilities may cost between \$900 and \$1200 million and regasification facilities based in Europe between \$300 and \$400 million; shipping costs for 5 ships from the Middle East to Europe are around \$850-950 million (Clingendael, 2003). As a consequence, exporters are not keeping up with increasing facilities in importing countries, leading to some regasification terminals standing idle. Third, LNG is susceptible to physical – both technical and political in nature – threats as much as pipelines. Finally, the EU is expected to face fierce competition from other importing countries such as the US (Larsson, 2007).

Figure 4. LNG gasification terminals in Europe: existing plants and projects



Source: OME.

2.3 Internal security of supply

While Europe's increasing import dependence from non-OECD regions raises external concerns about the security of supply, the completion of the internal market and the liberalisation process add some internal concerns. The implementation of Directive 98/30/EC gave the first input for the reorganisation of the gas sector and, in particular, towards the opening of several activities

²¹ This information was provided by the contribution of Sohbet Karbuz from OME.

to the competition rules in Continental Europe. The liberalisation process has been accelerated with the implementation of the second Directive 2003/55/EC,²² Regulation 1775/2005/EC²³ and Directive 2004/67/EC. In the context of the Third Liberalisation Package (European Commission, 2007c), in 2007, the Commission drafted a new directive proposal to improve access of competitors to the transmission network and ensure the effective separation between the operation of gas transmission network from supply and generation activities. As a first option, the so-called *full ownership unbundling*, the Commission proposed to break up big companies by forcing them to sell their transmission networks. As an alternative, the Commission proposed a system of *independent system operators* (ISOs), which would allow vertically integrated firms to keep their transmission infrastructure, but to hand over management of pipeline and storage assets to ISOs.²⁴ This last option was accompanied by a supporting regulatory framework: the Third Liberalisation Package called for more power and independence for national regulators, for the creation of an EU regulator together with an agency for the cooperation of energy regulators and system operators as well as for increased market transparency. Due to political pressure by Germany and France, a ‘third way’ option – the so-called *regulating unbundling* – was then put forward in June 2008: companies would retain full network ownership and control, while operations would be managed by an *independent transmission operator* (ITO) that would ensure fair network access and push for investments (Riley, 2008). This proposal was then approved by a majority of MEPs as a possible alternative to full ownership unbundling; the ISO option was rejected.

The idea behind the creation of the EU single market for natural gas is that it should bring economic efficiency due to higher competition and, allowing customers to choose their supplier, should push operators to reduce costs and propose improved quality of services. However, moving from centralised to de-centralised decision-making and from volume-signals to price-signals, unless the market is ‘perfect’, could in reality lead to less efficiency in the allocation of gas in the system. In this case competition may reduce the quality of the system management.²⁵ The opening of the gas sector indeed raises the question of whether the market itself will be able to guarantee the security of supply. The main concern regards the ability of the market to deliver timely signals and competitive incentives for investment to guarantee secure and reliable gas supply all the way to the final consumer. As we explain below, this applies both to the short- and the long-term security of supply.

2.3.1 Short-term security: coping with low-probability events

An important challenge for the security of gas supply is to meet the demand not only under regular circumstances, but also when a supply disruption or an unexpected event – such as extreme weather conditions or a technical accident – occurs. A failure to deliver gas on a cold winter day would indeed have serious consequences for most of the households and, to a lesser extent, for industry – unless they have the possibility to switch to other sources. To ensure a

²² The latter is divided in two sections, one on third-part access for transportation (Article 18) and one on new infrastructure (Article 22). In addition, the directive mandates access to storage and ancillary services (Article 19) leaving the choice between negotiated or regulated access to member states.

²³ It sets non-discriminatory rules for access conditions to natural gas transmission system taking into account the specificities of national and regional markets with a view to assuring the proper functioning of the internal market.

²⁴ To avoid a sell out of strategic assets to third countries, the Commission included a clause which would force foreign companies to comply with the same unbundling regulations at home before buying EU assets. This clause is commonly referred to as the “Gazprom clause”, as it intends to limit acquisitions by Gazprom and thus a unilateral increase of the Russian sphere of influence into the European market.

²⁵ Some of these ideas reflect the views of OME’s contribution by Sohbet Karbuz.

high degree of supply reliability to the customers during low-probability events, there are a number of traditional insurance instruments. The most important are the diversification of supply sources and routes, the interconnection of national grids, long-term contracts, flexibility instruments (supply flexibility, interruptible contract, etc) and storage facilities (IEA, 2004). In the past, the gas industry has had a very good record in covering low-probability/high-impact events because companies used to provide these instruments, passing their costs on to customers. Yet there is a risk that the liberalisation of the European gas market will undermine some of these instruments, thereby contributing to the insecurity of supply.

First of all, in open markets, the possibility to get extra-supply by buying gas in spot markets is increased, while counting on long-term contracts decreases. So far, the latter have played a very important role in Europe, as everywhere else: committing sellers and buyers to trade gas for a long period under specific conditions, long-term contracts allow the risks associated with large gas projects to be divided between producers and importers. In particular, they put the price risk on the seller, and the risk related to marketing the gas on the buyer. More important, they have been regarded up to now as necessary requirements for financing and investment in new long-distance transport infrastructure. In light of this, it can be said that security of supply would seriously be threatened if long-term contracts were to disappear.²⁶ Yet, liberalisation emphasises short-term trading without necessarily eliminating long-term deals. Certainly, liberalisation implies shortening contracts from 15-25 to 8-15 years and the shift of take-or-pay obligations from 80-90% to 50-60% and a flexible level of price indexation level (Stern, 2002). But long-term and spot contracts will probably co-exist in the new European gas market because the two are complementary: the first allow the financing of large new gas supply sources, but the second allow short and medium-term balancing of supply and demand and therefore offer more efficient use of existing infrastructure and better flexibility and security (IEA, 2004).²⁷ The recent signing of long-term contracts between some European countries (e.g. Italy) and Russia confirms this observation.

In order to cope with short-term security of supplies, gas storage and availability of spare capacity are also important. At the moment, Europe is relatively well-endowed with gas storage facilities. At the end of 2004, OECD Europe had 103 underground gas storage facilities with a working volume of 64.7 bcm, or the equivalent of 48 days of average consumption. Three countries dominate the European storage scene: Germany (30% of capacity), Italy (20% of capacity) and France (17% of capacity). Storage at LNG import terminals also plays a role in Europe, particularly in Belgium and Spain. Overall, there are 14 LNG import regasification terminals in Europe with a capacity of 75 bcm per year and a storage capacity of 1.4 bcm (2% of European storage capacity) (IEA, 2006). By 2030, WEIO 2003 projects a further investment of around \$23 billion for enlargements of existing facilities and the construction of new underground storage. However, as low-probability/high-impact events occur very rarely, the incentive of market players to invest in insurance is projected to be low in the future because of scarce incentives within a liberalised environment.

²⁶ Indeed, in the second directive and in the Directive on security of gas supply, the European Commission has recognised the importance of long-term contracts for security of supply and the financing of major new gas supply projects.

²⁷ For a further discussion on the survival of long-term contacts in liberalised energy markets see Coop (2006).

2.3.2 Long-term security: dealing with timing signals for investment in transmission and distribution

In general terms, the long-term reliability of supply depends on timing and sufficient investment in production and transportation facilities. For the specific case of internal security of supply, the concern is especially over investment in transmission and distribution facilities.

With gas market reforms and the unbundling of transportation and supply functions, incentives for investment decisions on infrastructure may decrease. In the past, in most countries, governments delegated responsibility for security of supply to one single actor, namely a monopoly state-owned company that was responsible for reliability of gas supply across the whole gas market. In open markets, the responsibility for transmission security is shared: the unbundling of gas companies implies unbundling the responsibility along the whole gas chain – from the production site to the burner tip (IEA, 2004; Eurogas, 2006). Under these conditions, the risk is that new competitors will be tempted to ‘free-ride’ on the security provided by the incumbent suppliers and the ‘heat of competition’ may push operators to play down security and prioritise cost-cutting (Luciani, 2004).

The propensity to invest seems to decline in liberalised markets, especially because of increased risks for operators. Competition has introduced a new risk of market share loss for retailers as well as uncertainty over regulation development. Unbundling threatens the past stable relations between complementary operators reducing the possibility of cooperation. More specifically, the changes in the rules of the game due to liberalisation have had two consequences on companies’ strategies. The first is horizontal integration: incumbents are merging in order to restore part of their past market power and, hence, protect themselves against new downstream market risks. These mergers are also a way of improving the bargaining power of importers in their negotiations with exporters. The second is vertical integration: importers try to accede to production and exporters try to develop on downstream markets. Germany is a good case in point for both cases: EON and Ruhgas have merged (horizontal integration), while EON and RWE has progressively acquired small municipalities (vertical integration) (Jacobsen, Frstrup & Munksgaard, 2005). This is a way of reducing the uncertainty introduced by the unbundling of the gas chain.²⁸

Looking at past years, it seems that competition development has not led to a significant increase in infrastructure investment. For the time being, the European gas grid seems sufficient to cover Europe’s transmission needs. However, almost all gas connections between European countries are fully used and many peripheral parts of the national networks are entirely dependent on a single feeder-line, which makes them vulnerable to disruption. The projected increase in gas imports will add further capacity risks to the European grid requiring, among other things, a substantial enlargement of the network and therefore massive investment. Accordingly, the WEIO 2003 projects that, by 2030, the gas sector would need \$110 billion for transmission and \$108 billion for distribution (IEA, 2004). Given the scarce incentives to invest, reaching these targets may be difficult, unless gas operators will get higher rates of return and more flexibility in project development. The central point is indeed whether investment into networks is attractive for them: operators need a predictable, reliable and transparent framework in order to commit for a given project. The role of regulators – both at national and at EU level – then becomes crucial to the extent that they are responsible for providing attractive incentives.

²⁸ See the contribution by Sohbet Karbuz, OME.

3. Coal

On the global scale, coal is currently the fastest-growing fossil energy carrier and continues to be the second most important fossil fuel, slowly closing the gap with oil. In the reference scenario of its World Energy Outlook, the IEA (2007) predicts a 73% increase in the global demand for coal between 2005 and 2030. Over the next 10 years, China alone will install more power-generation capacity based on coal than Europe's entire current stock. Steam coal will continue to play a dominant role in world coal production with a projected 79% in 2030 (up from 73% in 2005). The share of coking coal and especially brown coal and peat, on the other hand, will remain comparatively small.

In Europe, however, primary coal demand has decreased considerably since the 1980s, largely due to the switch from coal- to gas-fired power production in Western Europe and economic transition in the East. While demand is expected to remain roughly constant between 2005 and 2030 (IEA, 2007), the volume of coal produced domestically within the EU-27 will continue to decrease. As a result, the EU will become ever more dependent on imports. Domestic coal production is forecasted to fall to 37% of consumption by 2030, down from 61% in 2005 (IEA, 2008). In 2005, the main suppliers of coal to the EU-27 were South Africa with a share of 23% of total imports, followed by Russia (21%), Australia (12%), Colombia (11%), USA (7%) and Indonesia (6%) (European Commission, 2008e).

These figures suggest that coal imports are far more regionally diversified than natural gas imports, for example, and most exporting countries qualify as stable democracies that largely respect the same market and political rules as the EU. In addition, the coal market is a truly global, open and well-functioning one, not dominated by a single supplier such as OPEC. At the same time, there are still considerable global proven coal reserves, which – at the current global rate of production – may be sufficient for another 133 years (BP, 2008). Finally, coal is relatively safe to transport and store. It can be transported quickly by ship and rail, without the need for expensive long-run infrastructure and related security issues. All these factors contribute to the assessment that European import dependency does not pose an elevated risk to its uninterrupted supply of coal in the long-run. However, there may be some risks in the short-run.

The global coal market's just-in-time supply chains remain vulnerable to temporary supply disruptions. This has been confirmed in early 2008, when disruptions in three of the five major exporting countries led to record global coal prices. Australia's coal mines were hit by heavy rains and floods and continued port congestion resulted in delays and cancellations of coal deliveries. China, on the other hand, experienced heavy snowstorms in early 2008, which reduced output and rail transport capacities, causing the country to temporarily stop all coal exports (EIA, 2008). South Africa also experienced problems, not due to *force majeure* but rather due to power shortages/outages as a consequence of years of underinvestment in its energy sector. Heavily dependent on coal itself, the resulting reductions in coal supply directly affected coal export operations. In the long-run, however, such supply disruptions are expected to be overcome and the total volume of coal traded on the global market will continue to increase.

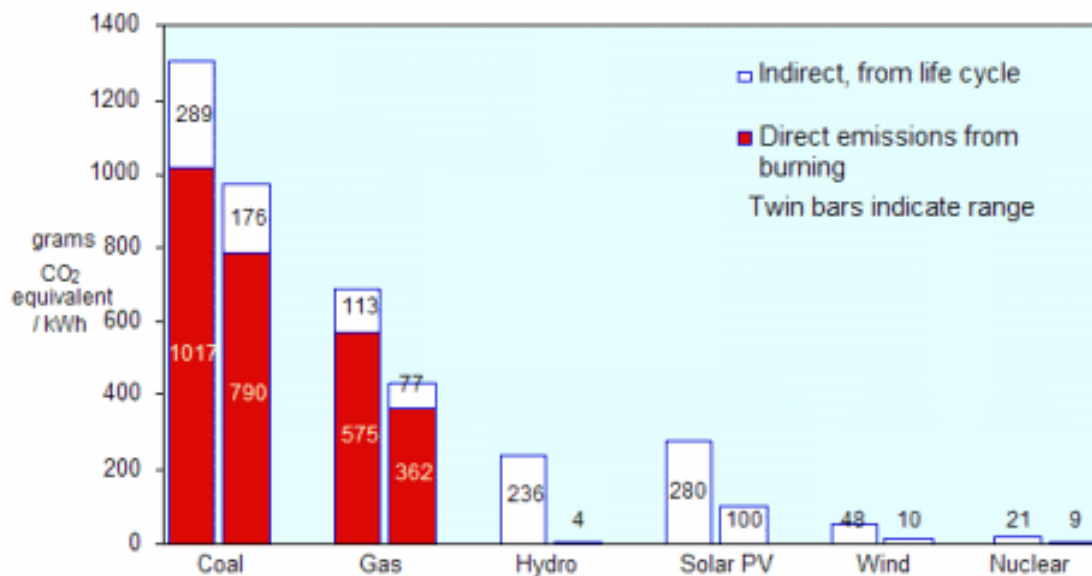
Another short-term risk for European coal supplies may stem from changing global demand structures. While China is still the world's largest coal producer, its consumption is increasing rapidly. In 1990, China's coal consumption was still at 534 Mtoe. By 2005, it had already doubled to 1094 Mtoe, and by 2030, it is expected to double again to 2399 Mtoe (IEA, 2007). According to MIT (2007), China's expansion in coal-fired power plants compares to the equivalent of two 500 megawatt plants per week, "and a capacity comparable to the entire UK power grid each year". As a result, China has recently turned into a net coal importer. The global surge in demand for coal, however, is faced with short-term supply constraints and

disruptions resulting in skyrocketing coal prices over the last year. Europe has been directly affected by this increase with the export price for one metric tonne of South African coal tripling from \$50 in May 2007 to \$143 in June 2008 (IMF, 2008) resulting in upward pressures on European electricity prices. More recently, prices have started to go down again.

More important, there are environmental risks associated with the extraction and combustion of coal. Coal mining, especially surface mining, is still responsible for large amounts of soil erosion, dust, noise and water pollution and impacts on local biodiversity. Another risk associated with underground coal mining is the subsequent subsidence of mines, i.e. the lowering of the ground above (former) coal mines. Examples of Germany and Poland illustrate this point. In addition, coal mining releases large amounts of methane (the same is true for abandoned mines, unless flooded), a greenhouse gas. Many of these effects can be kept to a minimum with modern mine management methods. For example, the amount of dust can be reduced with water sprinkler systems, acid mine drainage can be treated actively or passively, and methane can be collected and used for electrical generation or industrial chemical processes. Similarly, detailed rehabilitation and reclamation plans need to be developed to reintegrate formerly mined land into surrounding ecosystems (see also WCI, 2008). With decreasing coal mining activity in Europe, it can be argued that many of the aforementioned environmental consequences of mining pose only a limited direct threat to Europe in the future. However, they need to be taken into consideration reflecting the long-run responsibilities associated with European coal consumption.

On the global scale, a far greater long-run risk is climate change. As shown in Figure 1, the use of coal in electricity production causes far more greenhouse gas emissions than the use of any other energy carrier. To put this into perspective, with 28% coal is the second largest source of electricity generation in the EU-27, just behind nuclear (30%). In some countries, this share is considerably higher, such as in Poland (91%), Estonia (91%), the Czech Republic (59%) and Greece (59%) (European Commission, 2008e). In view of Europe's ambitious energy and climate change targets, clean coal technologies must be developed quickly, otherwise coal cannot continue to play a major role in Europe's energy mix.

Figure 1. Greenhouse gas emissions from electricity production



Source: IAEA 2000

In its climate change communication of 10 January 2007, the European Commission (2007d) clarified that global greenhouse gas emissions must decrease by 50% until 2050, with decreases in developed countries of about 60-80%. This is necessary to keep the average global temperature rise below 2 degrees Celsius, an increase above which climate change is said to become unmanageable. The current energy mix of the EU-27, however, is largely characterised by carbon-intensive fossil fuels which made up 79% of Gross Inland Consumption in 2005 (European Commission, 2008e). Given the carbon intensity of the European energy mix and the possibility of a ‘renaissance’ of coal on security of supply grounds, Europe can only achieve such ambitious greenhouse gas reduction targets if it develops carbon capture and storage (CCS) focused on coal-fired power production, but also on emissions from other fossil based forms of power production and emissions from industry.²⁹ Under current technological conditions, CCS processes can capture around 85% of the CO₂ emitted but these processes reduce thermal efficiency of plants by 8-12% (IEA, 2008) increasing the need for coal inputs.

Recent papers presented by the European Commission (2008e; 2008d) identify the possibility for sustainable energy production from fossils and provided a legal framework for CCS technology. The intention of the European Commission is to have 10-12 CCS demonstration projects ready by 2015 and to have the technology ready for wide-scale commercial application in 10-15 years. To get there, however, investments of about €1 billion will be required until 2020 to bring CCS to commercial deployment (European Commission, 2008e). Among the issues that need to be addressed until CCS can become commercially viable are (a) financial issues in terms of carbon pricing that will make CCS more competitive, (b) legal and regulatory issues, including the allocation of liabilities and risk-management procedures, (c) technical issues related to the isolation of reservoirs and the potential long-term leakage of CO₂, and (d) public awareness and acceptability.

The success of the CCS technology will largely depend on the speed of adopting EU legislation and of providing a secure legal framework, and on the success of the EU-ETS and the price of CO₂. To improve liability and reduce costs of CCS technologies, it is important in the short to medium term to develop appropriate demonstration projects, in which currently used CCS technologies are adapted for use in large-scale power plants and improved through research and development. The Commission notes that over 20 demonstration projects have been identified by European industry in recent months. To achieve wide-scale deployment of this technology, the EU will need to accelerate domestic research and will also need to get involved in international research cooperation, for example with China. After all, CCS is not just an opportunity for the EU to continue benefiting from the advantages of coal but also to clean China’s power sector and related technology export possibilities.

4. Nuclear

Nuclear energy is currently the largest single source of low-carbon electricity in the EU. In 2007, it accounted for 14% of the EU total energy supply and provided 31% of the electricity generated. Overall, there are some 146 power plants located in Europe, run in fifteen member states (IEA, 2008). Currently there is a divide among the EU member states regarding nuclear energy. Several countries such as France, Finland, the UK, Italy and some Eastern European member states (e.g. Bulgaria and Slovak Republic) want to increase the number of nuclear power plants in their home country while several other member states such as Germany, Spain, Belgium, the Netherlands and Sweden have committed to a complete phase-out of nuclear

²⁹ CCS refers to a three-step process in which CO₂ is captured at source, compressed and transported, and finally injected and stored in deep saline formations, depleted oil/gas fields, or unmineable coal seams. In addition, the captured CO₂ may be used for enhanced oil and gas recovery.

power. In addition, countries like Ireland and Austria remain sceptical of the technology and refuse to produce nuclear energy within their borders. However, due to factors such as the rising price of oil, increasing energy demand, and the requirements of Kyoto emission reduction targets, the governments in some of the countries that have agreed to phase-out nuclear power are reconsidering the role of nuclear energy.

Those in favour argue that nuclear energy could contribute to the increase of Europe's security of energy supply and to the attainment of the EU's climate objectives. First, this stated support comes from the increasing competitiveness of electricity generation from nuclear over time. This is due to declining fuel (including enrichment), operating and maintenance costs, while the plant concerned has been paid for (World Nuclear Association, 2008). A 2005 OECD comparative study shows that at a 5% discount rate nuclear generation is expected to become cheaper than coal or gas generation. More specifically, nuclear is comfortably cheaper than coal in seven out of ten countries, and cheaper than gas in all but one. At a 10% discount rate nuclear ranged 3-5 cents/kWh (except Japan: near 7 cents, and the Netherlands), and capital becomes 70% of power cost, instead of the 50% with a 5% discount rate. Here, nuclear is again cheaper than coal in eight out of twelve countries, and cheaper than gas in all but two (see Tables 1 and 2). In addition, although uranium prices have been increasing in the last few years (\$1787 per kg in 2007), and the trend may continue (up to \$2286 per kg according to the World Nuclear Organisation, 2008), the repercussions on the price of electricity from nuclear generation are limited.

Table 1. Electricity generating cost projections for 2010 (5% discount rate)

	nuclear	coal	gas
Finland	2.76	3.64	-
France	2.54	3.33	3.92
Germany	2.86	3.52	4.90
Switzerland	2.88	-	4.36
Netherlands	3.58	-	6.04
Czech Republic	2.30	2.94	4.97
Slovakia	3.13	4.78	5.59
Romania	3.06	4.55	-
Japan	4.80	4.95	5.21
Korea	2.34	2.16	4.65
USA	3.01	2.71	4.67
Canada	2.60	3.11	4.00

Source: IEA, 2005.

Table 2. Electricity generating cost projections for 2010 (10% discount rate)

	nuclear	coal	gas
Finland	4.22	4.45	-
France	3.93	4.42	4.30
Germany	4.21	4.09	5.00
Switzerland	4.38	-	4.65
Netherlands	5.32	-	6.26
Czech Republic	3.17	3.71	5.46
Slovakia	4.55	5.52	5.83
Romania	4.93	5.15	-
Japan	6.86	6.91	6.38
Korea	3.38	2.71	4.94
USA	4.65	3.65	4.90
Canada	3.71	4.12	4.36

Source: IEA, 2005.

Second, the indigenous nature of nuclear power production reassures member states against risks related to import dependency. It is not surprising that the most supportive of nuclear power are Central and Eastern European countries with the highest dependency on Russia's gas imports. Uranium also has to be imported, but its availability in reliable countries such as Canada and Australia (45% of EU uranium requirements) does not usually raise import-dependency concerns. To some, the availability of uranium is not a concern and its actual level – 14.4 million tons – would allow a four-fold increase in nuclear generation (Bouttes, Leban & Trochet, 2006). However, some studies state that, unless investments into closed fuel-cycle reactor designs are undertaken, uranium may become a risky factor for nuclear power generation (Edenhofer, Luderer, Flachsland & Fussel, 2008). Also, Besides Canada and Australia, the major producers of uranium are countries such as Turkmenistan and Russia, which have not always been considered reliable trading partners.

The third reason for nuclear support is related to the fact that, together with renewable energy sources, nuclear energy is one of the least carbon-intensive sources of energy. This argument is often used by proponents of nuclear energy in relation to achieving climate change objectives at current levels of energy consumption.³⁰

Despite the recent declarations of intent of many European countries to undertake new nuclear projects (e.g. 2 in Bulgaria and Slovakia, 1 in France, Finland, Lithuania and Poland), some scepticism exists about the ability to achieve a real boost to nuclear power generation in Europe. Without massive investment to replace ageing facilities and build new plants, Europe's nuclear generating capacity is in fact expected to shrink rather than grow. Accordingly, the IEA forecasts that electricity generation from nuclear power will decrease from 31% to 21% by 2020 (IEA, 2008). This expected trend is due to a number of risks that investors have to face when operating in the nuclear sector. More specifically, the main reasons for the possible stagnation and decline of nuclear power generation are costs, safety, perception, waste and proliferation (MIT, 2003).

Costs. Although the operating costs of running a nuclear power plant are relatively low (and for short periods of time could also be negative), capital investment, operation and maintenance costs highly reduce the financial attractiveness of nuclear projects. The start-up costs of a nuclear plant (66% of the total costs) are the biggest challenge for investors. Building a new nuclear plant in Europe is estimated to cost roughly € 2 to 3 billion and the initial capital costs will not start its pay-back any time before 15-20 years (Nuttall & Taylor, 2008).³¹ In addition, decommissioning and waste management requirements mean that financial assets must be made available for 50 to 100 years after the shutdown of the reactor (European Commission, 2006c).

Safety. Relying on nuclear generation means paying continuous attention to the safety of nuclear infrastructure, which are vulnerable to technical accidents, human error and terrorist attacks. This is also true for other generation technologies and large scale technology projects. But additional safety measures will most likely make nuclear plants expensive. Modern reactor designs have very much limited the risk of major accidents and until now the safety and reliability record of EU nuclear power plants is excellent. However, what happened in Chernobyl (1986), the Three Miles Islands (1979), Tokai-mura (1999) and Forsmark (2006) has left a perception that nuclear power plants can fail causing long-term and even irreversible damage. The importance of nuclear safety for European countries was recognised for the first time in 1958 in the Euratom Treaty, but since then Europe has never been able to introduce a

³⁰ Institute Thomas More (2008) suggests figures in the range of 2.5-5.7 grams per KWh vis-à-vis 105-366 grams for the production of electricity from thermal sources and 2.5-76 grams from renewables.

³¹ However, following the so-called 'fleet approach' of building a large number of reactors with similar design may save between 10% and 40% of the costs of the first plant (EU Commission, 2006).

common approach on nuclear safety standards (and radioactive waste). Common decisions such as Euratom loans for ageing nuclear plants (e.g. in 2000 Bulgaria and in 2004 to Romania) have been implemented. Yet the attempt to create a common approach failed in 2004 when the Commission proposed a “nuclear package”.³² More recently (2007), a Nuclear Forum and a high-level group on nuclear safety (and radioactive waste) have been put forward but this will hardly change the perception of nuclear power (IEA, 2008; European Commission, 2006c).

Perception. Public opinion and the perception of nuclear power is fundamental to the future development of European nuclear policy because public opposition further increases the risks of undertaking a nuclear project. The 2007 Eurobarometer reported indeed that 53% of European citizens still consider nuclear energy as a problem rather than a solution for their security of supply.

Waste. In the EU, some 40 000 m³ of radioactive waste is generated every year. Most of this waste is low-level and short-lived and it is generally stored in surface or near-facilities spaces. For high-level and long-lived waste a solution has generally not yet been found (Finland is the exception) not for technical reasons but mainly because people are reluctant to have nuclear waste in their backyards (European Commission, 2006c).³³ Research projects to find additional techniques for dealing with radioactive waste are underway but the glaring absence of a clear-cut solution raises environmental and health issues that have influence when it comes to considering new nuclear projects.

Proliferation. Although the proliferation of nuclear weapons is a major global problem, all European countries take a robust approach in their measures to prevent proliferation. Removing highly enriched uranium and separating plutonium from civil nuclear activities in one of the EU-12 countries cannot raise concerns about proliferation, however (Nuttall, 2007). In principle, the same is true for the new European member states but some scepticism may still exist about their long-term reliability. The export of nuclear technologies to third countries may raise concerns about the proliferation of nuclear weapons in the future however.

Notwithstanding all these issues and the resulting economic disincentives for investing in new nuclear power plants, many governments continue to directly subsidise nuclear technologies. This is especially true in the United States, where nuclear energy is supported by means of government incentives such as production tax credits and state portfolio standards, including incremental nuclear power capacity (Nuttall & Taylor, 2008). In the EU, nuclear research and development continues to receive substantial amounts of public funding (e.g. through the FP7), but nuclear sectors may benefit most from the establishment of a stable and well-functioning EU Emissions Trading Scheme (ETS), which will decrease the price of nuclear energy (and other low-carbon technologies) relative to more greenhouse gas intensive alternatives. Similarly, it

³² More specifically, the package included the proposal for a directive on the safety of nuclear installation that suggested: common safety standards and monitoring mechanisms based on the internationally recognised principles of the International Atomic Agency and the Western European Nuclear Regulator's Associations; the requirement for all member states to have an independent safety authority; a peer review system to inspect the inspectors community rules for the construction, management and use of decommissioning funds to ensure the availability of funds to carry out decommissioning operations. In the same package, a directive on radioactive waste was also proposed to focus on: priority to geological burial of waste as the safest method of disposal; obligations for all member states to adopt national programmes by 2018 for the disposal of radioactive waste; and more support and more funding for research on waste management.

³³ The recognised possible solutions are basically two: deep disposal in stable rock formation or near-surface storages.

may be expected that high prices of oil and gas may benefit the nuclear industry in the long-run (Nuttall & Taylor, 2008).

5. Renewable Energy Sources in Electricity and Heat

Since 1997, renewable energies have increased their contribution to gross inland consumption in the EU-25 by 55%. This is mainly due to the rise of new renewable energy such as wind, biomass or solar. Accounting for 66% of the total renewable electricity (2005), hydropower is the most important renewable source in electricity generation in Europe. Yet other sources have started to play a role. Wind energy, in particular, has made good progress moving from 8.000 GWh in 1997 to almost 70.000 GWh in 2005 registering – since 2000 – an increase of some 150%. Accordingly, in 2005, 56% of world wind capacity was installed in Germany and Spain with the UK, Portugal and Italy also making a small but evident improvement. Biomass electricity has also risen at a growth rate of 13% in 2003 up to 23% in 2005. Installed photovoltaic solar energy has also been growing at an annual rate of 70% in the EU (especially in Germany), but its contribution to electricity generation currently accounts for only 0.3% of the total generation from renewables (European Commission, 2007a and 2007b).

Although the power sector has registered the most significant growth in renewables, the most important end-use is taking place in heat (57% vis-à-vis 43%) (IEA, 2008). Unlike the electricity sector, renewables for heat have not improved very much in recent years because they do not have a network that they can access, but depend on the creation of new infrastructures and networks and the development of technologies (IEA, 2008). Biomass use – especially wood heating – make the most of Europe's renewable heat consumption. Countries – such as Italy, Sweden, Hungary, France and Germany – are the major producers of geothermal heat in Europe. Solar thermal energy has taken off in Germany, Greece, Austria and Cyprus. This points to evident differences in the use of renewable energies among European countries, both for electricity and heating (European Commission, 2007a and 2007b).

Notwithstanding their increasing penetration in the European energy markets, renewable energies only constitute 8.5% of EU total primary energy consumption. This level seems to be below the European Commission's expectation to reach, by 2010, a 12% share of renewables in total EU energy consumption. Similarly, the target set by the Directive 2001/77/EC to reach 21% share of renewables in electricity consumption by 2010 will not be met: Europe is expected to achieve a figure of only 19% by then (European Commission, 2007b). As a consequence of missed targets and growing concern over security of supply and climate change, the Commission has decided to adopt a firmer stand over renewables. In January 2007, it launched a long-term Renewable Energy Roadmap including a binding target of 20% renewable energy share in total energy consumption by 2020 (and a binding minimum target of 10% for biofuels in transport, which was later reformulated into a 10% target for renewable energy sources in transport).³⁴ The European Council of March 2007 approved these proposals and, on 23 January 2008, the European Commission put forward differentiated targets for each EU member state, based on their per capita GDP. On December 13th, the European Parliament approved the new Directive to promote the use of energy from renewable sources, agreeing that each member state will have to produce at least 5.5% of its energy from renewables, plus a country-specific quota.

The attention given by the Commission to renewable energy sources is not only aimed at combating climate change and reducing CO₂ emissions in the EU but is also part of a strategy to increase the economic competitiveness of the EU and to reassure Europe's security of supply. As regards the latter, renewable energies have at least three main types of potential:

³⁴ The biofuels target will not be dealt with here since it has been addressed in the oil chapter.

Reduced import dependency on fossil fuels. Since renewables are produced indigenously, increasing their share in the EU energy mix can help to reduce the dependence on imported fossil fuels – such as natural gas – from unstable geopolitical regions.³⁵ As a side effect, competition with major energy consuming countries over depleting oil and gas sources is reduced. In addition, the local and de-centralised nature of renewable production minimise the risks related to transport disruption as well as cross-border transmission losses. Small hydro applications and small wind turbines for self-production tend, for example, to be widely dispersed and not to involve major security risks in terms of exposure to sabotage (IEA, 2007a).

Structural and technical advantages. First, scarcity is not a concern for many renewable sources. Some of them indeed have an unlimited potential: solar and geothermal sources are virtually inexhaustible, especially in Southern European countries such as Italy, Spain, Portugal and Greece. Moreover, having the advantage of being storable, biomass can add to the security of supply by providing spare-capacity for either electricity or heat production. Second, renewable energy technologies are flexible in scale and type of use. Hydropower, for example, has a very fast response time generation and is therefore able to meet unexpected fluctuation in demand or help to compensate for the loss of other sources. Moreover, hydropower as well as biomass can be stored and be ready to offset other variable power production systems (IEA, 2007a).

Reduced energy price risks and energy price volatility. The problem of security of supply is also reflected in the fossil-fuel price risk, notably for natural gas and oil. Electricity or heat supplied using renewable energy is less prone to fuel fluctuations than in the case of fossil fuel plants. Also, using more renewable inputs at the expense of natural gas puts downward pressure on natural gas prices. As distinct from generating portfolios in which gas-based electricity generation is assuming an increasingly dominant role, portfolios with a substantially rising share of renewable electricity (RES-E) will see their long-term portfolio price risk fall. More specifically, increasing the share of renewables in the EU electricity mix in a cost-effective way will help to reduce: the (average EU) portfolio (electricity) price at the same year-to-year portfolio (price) risk; or the portfolio risk at the same portfolio price; or the portfolio price and year-to-year portfolio price risk. In other words, it will help move the EU's electricity mix closer to the efficient frontier of electricity mixes (Egenhofer & Jansen, 2006).

Improved energy prospects for rural and isolated regions. Electricity supply in rural and isolated regions might be improved cost-effectively by on-grid and distributed generation options based on renewables. These options imply the deployment of more local labour, including labour in the supplying industry (Jansen, Gialoglou & Egenhofer, 2005).

However, the contribution of renewables to EU security of supply may have to be reconsidered when taking into account certain specific structural characteristics of renewable inputs. Increasing the share of renewables in the EU portfolio means focussing on wind energy, biomass and photovoltaic, which can have a number of drawbacks. Wind is intermittent because turbines do not operate when wind speed is either low or too high since there are damage risks for the turbines. Solar photovoltaic is subject to seasonal variation from winter to summer as well as to daily variation from diurnal to nocturnal. In addition, PV is not dispatchable, meaning its output cannot be controlled and scheduled to respond to the variable consumer demand for electricity (IEA, 2007a).³⁶ The possible lack of continuity in electricity generation from wind and solar energy requires a backup capacity from more flexible sources. This could ideally be provided by other renewables such as large hydro but, more realistically, the difference would

³⁵ This view also reflects FEEM's contribution by Daniele Benintendi.

³⁶ See FEEM's contribution, Daniele Benintendi.

be met by fossil fuels such as natural gas or coal. Natural gas however increases import dependency further while coal has high CO₂ emissions. Back-up capacity increases the cost of renewables.

Table 1. Import dependency in the EU-25 in the 'high renewable' case

	2000	2010	2020	2030
<i>Solid fuels</i>	30.8%	43.2%	51.1%	50.2%
<i>Liquid fuels</i>	76.4%	83.3%	92.3%	93.3%
<i>Natural gas</i>	49.6%	61.4%	79.7%	83.6%
TOTAL	47.2%	52.1%	58.2%	57.8%

Source: adapted from PRIMES.

The nexus between renewables and reduced fossil fuels import dependency should in fact not be overstated. As the Commission's study on future *Scenarios on Energy Efficiency and Renewables* reports, assuming that the share of renewables in electricity generation increases to 23.5% in 2010 (see Table 1), 39.4% in 2020 and 45.6% in 2030, import dependency in 2010 would moderately be reduced to 52%, reaching 58% in both 2020 and 2030 instead of 55%, 64% and 65% in the Baseline scenarios (European Commission, 2006e). In other words, doubling the share of renewables in electricity generation by 2030 would reduce import dependency by about 6-7%. Similar conclusions were reached by an assessment of EU energy policy analysis published by the Energy Research Centre of the Netherlands (Groenenberg, Ferioli, van den Heuvel, Manders, Slingerland & Wetzelaer, 2008). This means that renewables would decrease import dependency but would not be able to reverse the import dependency trend alone.

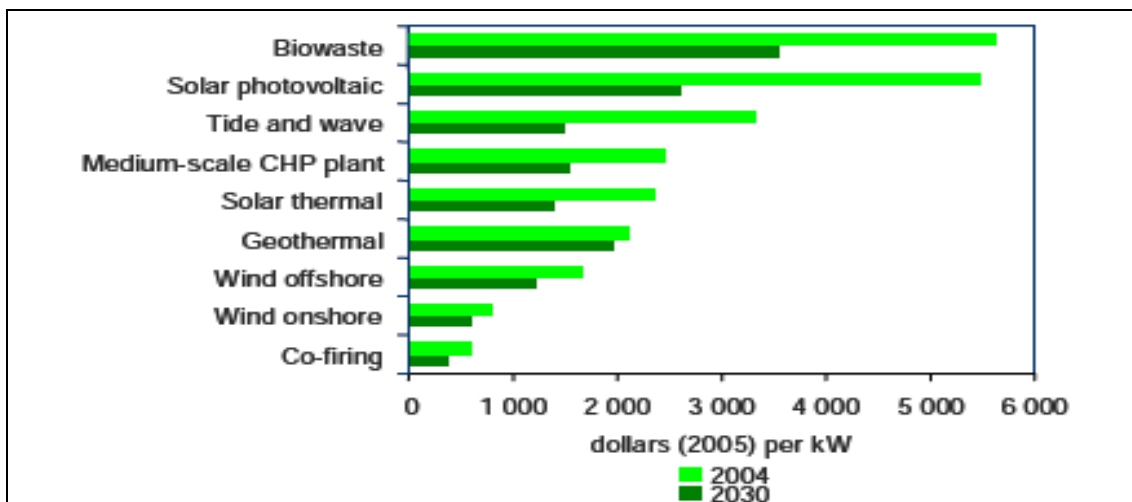
Moreover, it should be taken into account that in the long-run, some renewable inputs may become tradable across countries raising import dependence risks. In this regard, biomass is the most eligible source. Its physical characteristics, namely storability and transportability, allow a parallel between security of supply risks of biomass and traditional energy sources, both in terms of physical availability and prices. For biomass, competition risks are worsened by the fact that biomass is used not only for energy uses – such as electricity, heat and transport – but also for food, fibre and chemical production. In turn, this leads to price volatility of biomass inputs. Another import dependency concern is related to solar energy and the on-going discussion to build a large-scale grid to import solar electricity (by concentrating solar power) produced in North Africa and the Middle East. On the one hand, the project would allow Europe to diversify its energy portfolio by augmenting the share of a clean energy sources but, on the other hand, imports of solar power from these regions would further increase Europe's dependence from unstable regions. On balance, how much Europe would gain, or possibly lose, in terms of energy security is a matter of discussion.

The relatively recent nature of most of renewables-based technologies does not make them very competitive from an economic point of view.³⁷ Only the generation of hydropower electricity has had the time to amortise its costs, which have gone down to \$0.03 per kW, for large hydropower, and \$0.2 kW for small hydropower (IEA, 2006a). Instead, solar PV electricity is produced at a cost of \$0.35/\$0.45 kW (IEA, 2006a), while capital costs for solar thermal are about \$2500 per kW, and \$5500 per kW for solar photovoltaic (see Figure 1 and Table 2; IEA, 2007a). The average price for large, modern wind farms is about \$1000 per kW and off-shore

³⁷ Costs are not the only obstacle to the further penetration of new renewables-based technologies, concerns about public acceptability are indeed another barrier. Public resistance has for example emerged against the installation of off-shore wind turbines in Italy as they are considered aesthetically damaging.

wind installation can cost between 35% and 100% more (IEA, 2007a). In the long term, learning-by-doing effects and economies of scale are expected to drive down capital and production costs of renewables-based technologies, making them more competitive. The IEA (2006a) expects that renewables (except wind) will experience a 15-19% cost reduction for each doubling of capacity. This is what has happened over time: in the 1960s, for example, a solar PV module cost about \$100 000 per kW, today the price is between \$2000 and \$3000 per kW (IEA, 2006a). Similarly, in 2020, capital costs for solar photovoltaic are expected to drop by half, while capital-costs for off-shore wind will be one third cheaper (see Figure 1). However, these technologies are not expected to become ready for mass deployment before 2030 (IEA, 2006a). In order to make these technologies economically viable, considerable public support is necessary, at the level of both investment incentives and changing consumer behaviour. In order to have a successful deployment, a set of coherent and coordinated policy actions is required in the whole chain of activities concerning a specific technology.

Figure 1. Capital costs for renewables-based technologies, 2004 and 2030



Source: IEA 2007a.

Table 2. Costs of electricity generation technologies in OECD countries, 2005 and 2030

Technologies based on:	Investment costs (USD per kW), 2005	Investment costs (USD per kW), 2030	Typical electricity generation costs ¹⁸ , 2005 (USD per MWh)	Typical electricity generation costs, 2030 (USD per MWh)
Large hydro	1,500 – 5,500	1,500 – 5,500	30 – 120	30 – 115
Small hydro <10 MW	1,800 – 6,800	1000 – 3000 ¹⁷	60 – 150	50
Wind onshore	900 – 1,100	800 – 900	30 – 80 ¹⁹	30 – 70
Wind offshore	1,500 – 2,500	1,500 – 1,900	70 – 220	60 – 180
Geothermal	1,700 – 5,700	1,000 – 2,000	30 – 90	30 – 80
Solar PV	5,000 – 8,000 ¹⁸	1,200 – 1,800	180 – 540	70 – 325
Solar thermal	2,000 – 2,300	1,700 – 1,900	105 – 230	90 – 190
Biomass	1,000 – 2,500	400 – 1200	30 – 100	30 – 100
Ocean (current, tidal, wave)			55 – 160	
Coal	1,000 – 1,200	1,000 – 1,250 ¹⁹	20 – 60	35 – 40
Coal with CCS ²⁰	1,850 – 2,100	1,400 – 2,100 ¹²	40 – 90	45 – 60
Natural gas	450 – 600	400 – 500	40 – 60	35 – 45
Nuclear	2,000 – 2,500	1,500 – 3,000	25 – 75	47 – 62 ²¹

Source: IEA 2007a.

Part II. Cross-Cutting Issues

1. Electricity

Security of electricity supply refers to “the ability of an electricity system to supply final customers with electricity” (European Parliament and the Council, Directive 2005/89/EC). More specifically, there are two necessary components of electricity security of supply: operational network security and demand-supply balance, namely adequate generating capacity. At both levels, the key challenge is reaching adequate and timely investment. As in other sectors of the economy, the market should be able to provide investment adequacy through price movements. Yet due to the specific characteristics of the electricity sector, price signals are rarely strong enough to stimulate a correct level of investment.³⁸ Also, in newly liberalised electricity markets, regulatory uncertainties add to the risk of under-investment: companies that are supposed to make investments in the power sector are prevented from doing so if they perceive strong uncertainties over their returns (IEA, 2002).

Operational network security means the continuous operation of both the transmission and the distribution networks. Transmission System Operators (TSOs) are responsible for the safe and efficient operation of the transmission grids. More specifically, their tasks include balancing the market, facilitating spot exchanges and developing the transmission grids. In this context, TSOs face a number of challenges linked to the security of electricity supply. First, increasing international trade for electricity and rising demand from third countries to be interconnected to the EU grid has augmented pressures on grids triggering the risk of congestion. For example, Italy has congested links with France, Switzerland and Austria, while the Netherlands has congested connections with Germany and Belgium (IEA, 2002). Second, TSOs face the problem of lack of public acceptance of network construction. In most of Europe, notably in densely populated areas it is virtually impossible to build new overhead lines. As a consequence, TSOs have to install underground cables, which are more expensive by a factor of 10 to 30 in extreme cases. The risk originating from insufficient grid capacity is significant. The costs of unserved energy are estimated to be between 3-20 euro per KW and for short-term interruptions of under 15 minutes between 1-100 euro per KW; the damage easily runs into billions of euro. Third, TSOs also have to face the problem that there are different time horizons between the planning of new generation (e.g. three years for combined cycle gas turbines) and network assets, typically 5-10 years (Egenhofer & Legge, 2001).

Imbalances between demand and supply can also cause major disturbances in the electrical system, such as general or local interruptions of the flux of electricity to both household and industry. Such events are usually the result of scarce reserve generation capacity, which is necessary to face peak demand, maintenance and outage needs (European Commission, 2003). In the monopolised market structure, capacity shortages were never a problem. The system was inherently producing overcapacity in the knowledge that costs could easily be passed on to consumers. Additional safety margins were possible ‘just in case’ since they did not entail a business risk. In many countries regional or local monopolies considered it prestigious to own

³⁸ First, demand for electricity is highly inelastic. This is caused by the fact that there is no available alternative for most applications of electricity and price information rarely reaches consumers in time to adjust their behaviour. Moreover, electricity consumption is usually measured over long periods so consumers have no incentive to shift their consumption from peak hours to off-peak hours. Second, the supply of electricity is only partially characterised by a gradually increasing marginal-cost function. When all available generation units are producing electricity, no marginal increase is possible in the short term. As a result, the marginal-cost curve ends with a perfectly price-inelastic section. Third, electricity is a strong time-limited product: it cannot be stored, other than in pumped-hydro facilities (de Vries & Hakvoort, 2004).

generation capacity. In addition, under the vertically integrated structure, prices were regulated and used to be very stable: they were set to cover total costs and hence enable the utility to finance investment (Roques, Newberry & Nuttall, 2005). In competitive markets the situation has reversed. Investment decisions for generation capacity are based on calculations of profitability. Particularly if peak demand is seldom reached, which by definition is the case for the marginal KWh, incentives to build reserve capacity are low. Also, in liberalised electricity markets, the risk of price volatility has increased.

Peak-load capacity is not a problem at the EU aggregate level. However, due to the fragmentation of the internal electricity market and a lack of cross-border trade or even unused cross-border interconnection capacity, the aggregate figure is largely irrelevant. Relevant reference points are regional trading areas where the spare capacity to deal with peak loads differ considerably. Theoretically, shortages of generation capacity could be offset via trade. However, interconnection capacity is generally insufficient and where it is sizeable such as in the case of France and Italy, it is linked to regular imports or exports, i.e. not available for dealing with peak-load problems. In addition there might be internal bottlenecks that can restrict cross-border flows in a wider region.

Under certain conditions, competitive markets can lead to an erosion of reserve capacity. In principle, though, concentration should be detrimental to security of supply. Especially where generation is oligopolistic or monopolistic – which is the case for most member state markets – there are strong incentives to keep reserve capacity small. Further liberalisation to speed up import competition to challenge the dominant generators should reduce this risk. Market liberalisation also gives large customers the possibility of offering frequency response and standing reserve services, as well as demand-side management; these all contribute to reinforcing the integrity of supply at times of peak demand.

Yet the process of liberalisation of the European electricity market is far from complete. This is why the so-called Third Energy Liberalisation Package has been proposed. Central to this Package is the separation between electricity (and gas) transmission networks and supply from generation activities. The Commission initially proposed two options: *full ownership unbundling* and *independent system operator* (ISO). The first option – strongly preferred by the Commission – forbids companies involved in transmission to get involved, at the same time, in energy generation or supply. The second option allows production and supply companies to keep their network assets but their management would have to be left to an independent company to be designated by national governments (the ISO). Following the opposition of eight member states, led by Germany and France, a ‘Third Way’ option – the so-called *regulating unbundling* – was proposed in June 2008. Although successful in the case of natural gas, the “Third Way”, as well as the ISO option has been rejected by the Parliament, preferring full ownership unbundling as the only option for electricity.

2. Energy Efficiency

Following the EC Green Paper of 2000, energy efficiency has become a cornerstone of the European Commission’s energy policy. The 2005 Green Paper on Energy Efficiency recognised that actions on the demand side are as crucial as supply-side initiatives to pursue the three EU energy policy objectives: competitiveness, security of supply and environmental protection (European Commission, 2005). Accordingly, energy efficiency has become one of the three pillars of the Energy Policy for Europe Action Plan (2007-2009) as well as a crucial tool to achieve the Commission’s 20-20 by 2020 policy targets. At the heart of the EU energy efficiency initiatives lies the Energy Efficiency Action Plan (EEAP) presented by the European

Commission in October 2006 (European Commission, 2006d).³⁹ The objective of the plan is to control and reduce energy demand in order to save 20% (1.5% or 390 Mtoe per year) of annual energy consumption of primary energy by 2020. According to the Commission Action Plan on Energy Efficiency, the largest cost-effective saving potential is in the household and in the tertiary sectors – 27% and 30%, respectively. For manufacturing industry, the overall potential is estimated to be around 25%, while for transport the figure is 26%. In an effort to address the economic potential of unrealised energy savings, the Commission proposed to member states to adopt an overall national indicative energy savings target of 9% by 2016. This target, which translates into savings of at least 1% of energy each year (starting from 2008), will be reached thanks to energy services and other energy efficiency improvement measures. The directive on the promotion of end-use efficiency and energy services requires member states to submit National Energy Efficiency Action Plans (NEEAP) to the Commission, describing the measures that are aimed at achieving this target. In its first assessment of the NEEAPs the Commission came to a rather negative conclusion, criticising the fact that the Action Plans follow a business-as-usual approach and that the more progressive few lack concrete definitions of the new measures and how they should be implemented (European Commission, 2008c).

Notwithstanding the Commission's attention to energy efficiency, it will most likely improve less than expected, for a number of reasons. First of all, while the 2020 targets for the reduction of CO₂ emissions and the increase in renewable energy production are binding, the energy efficiency target is not. The Commission was in fact in favour of making it legally binding, but member states were opposed to this option. They were concerned that the financial burden of saving energy would have been unevenly biased towards them. Since energy efficiency was already subject to a number of other directives, the Commission agreed to make the related target non-binding. According to the IEA, since the directives aimed at promoting energy saving do not always capture the full energy efficiency potential, the non-binding nature of the energy efficiency target raises concerns about whether it will eventually be met (IEA, 2008). Moreover, the strategy of ameliorating Europe's security of supply through better energy efficiency needs qualification. Energy efficiency achieved by reducing demand increases the flexibility of the whole energy chain and thereby provides an additional margin for security. Put another way, if the flexibility needed to cope with supply failure is a proportion of overall energy demand, then the cost of providing a constant level of security of supply decreases if the overall energy demand is reduced (Egenhofer & Legge, 2001). Other than that, there is not much evidence to show that increased energy efficiency enhances Europe's security of supply.

In particular, as a strategy to increase the security of supply, energy efficiency is generally related to its presumed ability to reduce import dependency. Yet there are two doubts in this regard. First, it is not clear whether import dependency can be considered as a risk *per se*. As argued before (see chapter on oil and gas), this does not have to be the case if there is a sufficient level of diversification of sources, no supplier is dominant and prices are affordable. Secondly, one may wonder if a correlation between energy efficiency, on the one hand, and energy imports on the other hand, holds good. Past energy trends and future projections do not in fact lead to this conclusion. The IEA (2008) reports that Europe's energy efficiency has consistently improved over time: from 1200 Mtoe of Negajoules (i.e. avoided energy consumption through energy saving) in 1970, to 2000 Mtoe in 1990, to 2800 Mtoe in 2005. However, this improvement has not translated into a parallel downward trend for Europe's total primary energy imports: Europe's import dependence has increased from 42% in 1990 to 52%

³⁹ The Energy Efficiency Action Plan focuses on the following priority areas: dynamic energy performance requirements for products, buildings and services; energy transformation; transport; financing, economic incentives and energy pricing; energy-efficient and energy-saving behaviour of energy consumers; international partnerships.

in 2005 (EIA, 2008). Accordingly, a Commission's study on future *Scenarios on Energy Efficiency and Renewables* reports that, even assuming the full application of the existing EU directives on energy efficiency, in 2030, Europe's import dependency will be higher than in 2000, i.e. 65.5% vis-à-vis 47.2% (see Table 1). In fact, the difference between the 2030 Baseline scenario in which energy efficiency measures are not implemented, and the 'energy efficient case' is very slim: in the former import dependence is 65.5%, in the latter 64.9% (European Commission, 2006e).

Table 1. Import dependency in the EU-25 in the 'energy efficiency' case

	2000	2010	2020	2030
<i>Solid fuels</i>	30.8%	45.3%	50.1%	54.2%
<i>Liquid fuels</i>	76.4%	83.4%	92.2%	93.1%
<i>Natural gas</i>	49.6%	61.9%	78.8%	82%
TOTAL	47.2%	54.5%	63.1%	65.5%

Source: adapted from PRIMES.

The absence of any apparent correlation between energy efficiency, on the one hand and energy imports and security of supply, on the other hand, has different – although complementary – explanations. The progressive exhaustion of Europe's indigenous resources – especially oil and gas – is one. Secondly, there is the so-called 'rebound effect'. Improvements in energy efficiency make energy services (e.g. heat or mobility) cheaper, encouraging their further use. This can result in an overall increase in energy consumption, despite the initial demand reduction. The rebound effect is very difficult to measure and it can have different impacts depending on the sector but, generally speaking, its impact has so far been underestimated. In industrialised countries, for any increase in energy efficiency there is a rebound effect of at least 10% (up to over 50%). This means that the actual reduction in energy consumption is equal to a certain percentage of the expected energy saving (UK Energy Research Centre, 2007).

Furthermore, the strong projected growth of energy demand in developing and transition countries is expected to level-off any possible energy efficiency improvement in the EU, both from a security of supply and a CO₂ emissions perspective (Egenhofer & Legge, 2001). While Europe's total energy consumption is expected to increase by 0.7% between 2005 and 2030, the biggest emerging consumer country in the world, namely China, will register a growth of 3% (IEA, 2007). This means that if the EU was able to save 20% of energy consumption, China alone would make up for more than Europe's improvements. In other words, Europe's efforts to reduce greenhouse gases will be neutralised by China's record. This point is underlined when taking into account the projected demand growth of other emerging economies – such as India – and transition economies. A parallel adoption of energy efficiency measures in third countries and a proper implementation of the latter is thus of most importance.⁴⁰ For this reason, a proactive cooperation between the EU and key third countries is necessary. The International Framework agreement on Energy Efficiency could be a first step in this direction. The proposal, initially suggested in the European Commission paper "An Energy Policy for Europe" on 10 January 2007 (European Commission, 2007), was endorsed by the European Council on 8 March 2007 (European Council, 2007). The EC's proposal was then noted in the G8 communiqué of Heiligendamm in June 2007; legislators from the G8 and G8+5 supported the need for a global energy efficiency agreement when they met in Berlin in June 2007. The idea is

⁴⁰ In China, for example, the real problem is the implementation of the energy efficiency measures. The Chinese Law on Energy Conservation set a target to increase energy efficiency by 20% between 2005 and 2010, but the current performance is far from achieving this objective.

to develop a multilateral partnership for energy efficiency involving, at first, member countries of the OECD with a possible future enlargement to other partners. The agreement could include various issue-areas of cooperation such as regulatory cooperation, information exchange on energy-saving strategies, methods of measurement and research cooperation on energy efficiency technologies. The next crucial step for the development of an International Framework agreement on Energy Efficiency will be at the Copenhagen summit in December 2009 (Kosugi, 2008).

3. Europe's External Energy Policy

One of the recurring themes of the EU integrated climate and energy package is the alleged need for Europe to speak with one voice with major energy producers, transit and consumer countries as well as when an energy crisis occurs. So far progress in this direction has been modest but the EU plans to take further action in 2009.

In March 2006, the Green Paper (European Commission, 2006a) identified a “coherent external energy policy” as one of the six EU energy policy pillars and the Strategic EU Energy Review was supposed to serve as the basis for establishing a common EU vision. In June 2006, the European Council adopted a legal framework for the external energy policy. According to the joint paper by the European Commission and the High Representative, the latter should be “coherent (backed up by all Union policies, the member states and industry), strategic (fully recognising the geo-political dimensions of energy-related security issues) and focused (geared towards initiatives where Union-level action can have a clear impact in furthering its interests). It must also be consistent with the EU’s broader foreign policy objectives such as conflict prevention and resolution, non-proliferation and promoting human rights.” In order to fulfil these objectives, the EU created a network of energy correspondents consisting of representatives by member states and the General Secretariats of both the Commission and the Council, an early-warning system and the European Energy Supply Observatory (Commission/SG/HR, 2006). The 2007 and 2008 Spring European Councils focused on speeding-up the development of a common approach to external energy policy, but concrete measures were limited to improving the existing dialogues and partnerships with energy consumer, producer and transit countries. The Second Strategic Energy Review published in November 2008 is supposed to give a new boost to the external dimension of Europe’s energy policy. Accordingly, the Security and Solidarity Action Plan focuses, among other issues, on crisis response mechanisms and external energy relations (European Commission, 2008f). The point is to develop a new generation of ‘energy interdependence’ provisions with producer countries outside Europe and to update the current EU emergency strategic oil stocks legislation as well as the security of gas supply directive. Yet the most promising point is the Commission’s commitment to identify concrete mechanisms necessary for ensuring transparency between member states and the EU.

Unless the Second Strategic Energy Review introduces concrete changes, “speaking with one voice” in foreign energy matters will remain a mere ambition. EU member states keeps on pursuing their national interests; diverging on how to integrate their energy foreign policy objectives (Mandil, 2008; Geden, Marcelis & Maurer, 2006). A good case in point is the Nord Stream gas pipeline project that has divided Germany and Poland. The first, together with Russia, is the main promoter of the project, while the second has strongly opposed its realisation mainly for historical and political reasons. Similarly, the rigid and cold approach that eastern European members would like to adopt towards Russia often clashes with the more friendly and economic attitude that countries such as Italy, France and Germany prefer to endorse. Foreign policy divergences among member states still play a key role in impeding the creation of a European external approach in energy matters and unless a further convergence of objectives occurs, a common approach in energy matters will be hard to achieve. In addition, a credible EU

foreign energy policy is not credible unless the EU has a functioning common market for electricity and gas. The EU voice can be heard only if it comes from a united and coherent bloc endowed with a true common and integrated energy market and a functioning cross-border exchange system. Once these objectives are met, Europe will be able to enhance its bargaining power in international and bilateral negotiations with energy consuming, producing and transit countries. In the absence of a common energy market, European member states have an incentive to conclude bilateral deals rather than looking for multilateral agreements with third countries and any effort to pursue common security of supply objectives is inevitably understated (unpublished Behrens & Egenhofer, 2008).

The ineffectiveness of the common EU external energy policy is also related to the ‘market governance’ approach so far adopted towards third countries. As Richard Youngs (2007) explains, there is a tendency in the EU to look at the common external energy policy as a mere extension of the *acquis communautaire* (Youngs, 2007). As the Green Paper says, the idea is to achieve energy security “by the EU extending its own energy market to include its neighbours within a common regulatory area with shared trade, transit and environmental rules”. Accordingly, the EU has tried to develop an inter-connected energy market with its periphery using EU regulatory norms which have been put forward by different energy treaties and agreements. Although this approach may work for those countries with an interest in joining the EU or being integrated within it, the majority of non-EU countries do not appreciate this ‘top-down’ approach. In fact, resistance has strengthened in many, if not most, of EU energy suppliers to the export of EU energy-pertinent norms. This is the case in the Arabian Peninsula. The EU-GCC free trade area talks have been running for 18 years without conclusion: the EU proposed a Memorandum of Understanding on energy cooperation, the GCC states rejected the idea, insisting that a free trade agreement was the precursor to deepening other areas of cooperation. Even after Saudi Arabia’s entry into the WTO at the end of 2005, the GCC remains far from accepting EU-style market and governance norms. Gulf states blame the EU for trying to export its own model of regional integration, without recognising that intra-regional dynamics are quite different within the GCC. Even in the EU’s immediate periphery the reach of internal market-governance norms sometimes looks distinctly limited. Algeria, for example, has rejected the whole framework of governance norms incorporated into the Neighbourhood Action Plan offered to it. Similar trends can be witnessed across the Caspian and Central Asia: in negotiations for its ENP action plan, Azerbaijan only accepted a non-specific and diluted commitment on joining the WTO seeing market liberalisation as unnecessary; Kazakhstan has resisted EU regulatory and market norms while it has no prospect of a place in the ENP. More important is Russia’s resistance to the EU’s efforts to spread its norms and standards (Youngs, 2007). The refusal to ratify the Energy Charter Treaty and the related Transit Protocol is the best-known example of Russia’s reluctance towards EU’s norms. A second case in point is Gazprom’s opposition to comply with European liberalisation standards when it concludes commercial deals in the EU.

Some scholars suggest “a far more political approach” to frame Europe’s external energy policy (Youngs, 2007; Baran, 2007) recommending a European external energy strategy deeply incorporated into the CFSP framework. Although deeper integration between the market and geopolitics may be advisable to provide a more coherent and effective external energy policy, someone may wonder how this could be done in practice. First of all, given the low level of Europe’s coordination in the realm of foreign policy and the related incompleteness of the CFSP, it is hard to believe that a common external approach on energy could stem from the CFSP framework. Secondly, one may wonder what ‘less market’ and ‘more politics’ in energy policy actually means. Being attentive to foreign policy objectives while seeking to secure energy supplies, is extremely difficult in a world where over 90% of fossil fuels are located in unstable and non-democratic countries. Yet any discussion on the approach the EU should adopt

to deal with outside countries should come after the resolution of internal disagreements, especially those related to the completion of internal market. The success of the EU in developing the carbon market and running the world's largest GHG allowance system in the form of the EU ETS should be the example to follow in the energy sector.

4. Climate Change

According to the Intergovernmental Panel on Climate Change (IPCC), there is persuasive evidence that most of the temperature rise that has occurred over the last 50 years is attributable to human activity (IPCC, 2007a). As GHG concentrations continue to increase, the potential impact of GHG emissions on people and ecosystems may prove to be significant. In their contribution to the Fourth Assessment Report in 2007, Working Group 1 (IPCC, 2007b), of the IPCC highlights the unprecedented level of observed climate change. For the next two decades, it projects a rise of about 0.2°C per decade across a range of emission scenarios. And even with the concentrations of all GHGs and aerosols being kept constant at year 2000 levels, a rise of about 0.1°C per decade could be anticipated. The same body finds that this is likely to trigger serious consequences for humanity and other forms of life. Ramifications include a rise in sea levels, thus endangering coastal areas and small islands, as well as provoking a greater frequency of extreme weather events, impacts on agricultural production and higher incidences of the spread of disease, damage to infrastructure or migration. Without global action on climate change, this trend is expected to continue.

The principal source of global GHG emissions is CO₂, on which this chapter concentrates. Roughly speaking, about 60% of total GHG emissions come from the use of fossil fuels and 20% from land-use changes, e.g. deforestation. The rest is attributed to GHGs other than CO₂.

According to the reference scenario of the IEA (2008), emissions may increase by almost 60% between 2005 and 2030, thus putting additional pressure on the global climate and life on earth. Limiting global warming to 2°C above pre-industrial levels – a level below which the EU believes that irreversible ecological damage may still be avoided – will require cuts in global emissions of 50% by 2050 relative to 1990 levels (European Commission, 2007e). There is a growing consensus that GHG emissions will need to be reduced globally by around 50% by 2050. This would translate into reductions for industrialised countries by 80-95% by the same period. Industrial countries will need to take the lead due to their historic responsibility of having emitted most of the current GHG emissions stock that is responsible for climate change. However, emissions reductions by developed countries alone will not be sufficient because emissions from developing countries are projected to surpass those of developed countries by 2020. At the latest by then, fast-growing developing countries will need to start reducing their emissions in absolute terms.

Given that energy accounts for about 80% of all greenhouse gas emissions in the EU, climate change policy based on such reduction targets will require profound changes in European energy systems. Climate change thus plays an ever increasing role in energy policy and the value of considering interactions between global warming and energy security is increasingly recognised.

Keeping within the 2°C boundary will require stabilisation of greenhouse gas concentrations in the atmosphere at around 450 parts per million (ppm of CO₂e), up from an estimated 280 ppm before the industrial revolution and roughly 380 ppm in 2005. For the energy sector, this means peaking CO₂ emissions in 2012 and a reduction thereafter (IEA, 2007). In relation to the reference scenario, some 19 Gt of CO₂ emissions will need to be abated by the year 2030. More efficient use of energy in industry and buildings (incl. electricity) could account for almost 40% of the envisaged reductions in CO₂ emissions. Carbon capture and storage in power generation and industry (21%), renewables (19%) and nuclear energy (16%) are also projected to

contribute substantially to CO₂ abatement. While oil, gas and coal will remain the three most important global energy sources in 2030, demand will need to stay roughly at the levels of 2005.

Climate change policy may at the same time be beneficial to security of supply. Areas of common interest are for example better efficiency, renewables, nuclear and generally a new innovation drive (Groenenberg et al., 2008). However many of these benefits are not always straightforward. Renewables are often intermittent, thus causing additional, albeit different security of supply problems. Energy efficiency reduces import dependency. Thus, a security of supply benefit requires that import dependency is a problem. This is not automatically the case, as we have seen. Nuclear has its own security of supply risks (see nuclear chapter). Only technology development seems to be univocally beneficial to security of supply.

Paradoxically, there is a risk however that current climate change policy discourages rather than encourages urgently needed investment. To an extent this is a result of international indecision regarding a global climate change agreement, which in turn reduces predictability. However, some of the design options and implementation by member states of the EU emissions trading scheme (EU ETS) – the EU's flagship policy on climate change – have made the situation worse: they include short-term allocation periods and allocation methodologies, notably including new entrants and closure rules. A second, less prominent but more fundamental aspect on investment is related directly to the ETS itself. Cap-and-trade schemes or carbon market instruments are not capable of providing sufficient incentives to develop and bring to the market new breakthrough technologies, i.e. make R&D profitable on a massive scale. Price signals need to be much higher and more credible in the long-term to generate a significant amount of private resources for R&D (e.g. Egenhofer, 2007). This will require a portfolio of policy measures including R&D, deployment of promising technologies and policies to overcome market failures. The EU's energy and climate package can be read as an attempt at such a portfolio of measures.

In addition to mitigating greenhouse gas emissions, the European energy sector will also need to adapt to changing climatic conditions – both on the supply and the demand side. The intensity of required adaptation will depend on future GHG emissions and will be different across member states depending on their geographical location, present climate and future changes. Southern countries will most likely be faced with less demand for heating but substantially increased demand for air conditioning. They may also experience losses in hydropower and problems with cooling of thermal power plants. Northern countries will equally experience less demand for heating and may gain potential for electricity production from hydropower. At the same time, they may have to adapt to more storms and heavy precipitation. In both regions, electricity supply disruptions due to storms, floods and heat waves may increase the need for more decentralised electricity generation, in order to avoid negative impacts on electricity users (see also Eskeland et al., 2008).

Finally, there are the systems effects of climate change policy. In the EU they include insufficient fuel switching capacity or the fact that gas contracts continue to be indexed to oil prices. The latter had the effect that the higher oil prices increased, the more expensive gas became, meaning that the EU burned more coal and emitted more GHG emissions. These are just a few interactions between climate change/climate change policy and security of supply. To date, these interactions have not yet been assessed, although work is beginning gradually (e.g. Behrens, forthcoming).

Concluding Remarks

The concept of security of supply has different interpretations and approaches, making its definition elusive. The literature is divided between those who interpret energy security from an economic point of view and those who stress its political and strategic side. However, the economic and so-called political interpretation are two sides of the same coin and both are necessary to explain the challenges as well as the solutions to dealing with security of energy supply in the EU. Similarly, those who see energy security as a distinct issue from environmental considerations do not appreciate the strong link between these two domains. Given the relevance of all these approaches in determining the actual picture of Europe's security of supply, this paper has taken into account both the political-economic link and the energy and climate change nexus. Five major factors have been identified as risks to EU security of energy supply: geological, technical, economic, geopolitical and environmental risks. Yet, their combination, their possible causes and impacts, as well as their duration and future probability, differs from sector to sector (see Table 1). Accordingly, the paper has adopted a resource-specific approach to analyse and evaluate existing and potential EU energy and climate change risks.

The widening gap between Europe's demand for oil and its domestic production is a source of concern since it implies increasing import dependence on the Middle East, Russia, the Caspian region and Africa. Far from being a concern per se, increasing oil import dependence makes Europe vulnerable to three main risks: oil transport risks, increasing competition for global resources and the impact of oil price volatility. Considering the existing systems of emergency response and the planned infrastructure to facilitate sea-lane transport, the first risk represents only a minor challenge for the EU. The increasing competition for global oil resources, which is caused by the imbalance between world oil demand and supply as well as increasing extraction difficulties, could become irrelevant if Europe is able to engage in an aggressive climate change policy. As the recent change in oil price levels has shown, oil price volatility can worsen the world economic situation but its impact is perceived only in the short-term. Notwithstanding these risks, oil is expected to remain of critical importance for Europe, especially for the transport sector. Increasing the share of renewable energy in transport to 10% by 2020 may in principle improve Europe's security of supply but the overall impact of the greater use of biofuels in transport is uncertain due to its numerous drawbacks. A further technological boost in developing second generation biofuels is therefore necessary, and a strong European framework to encourage new investments is its bottom line.

Given the fact that natural gas and oil share some economic characteristics but are different in nature, the concept of security of supply for natural gas is significantly at odds with the one used for oil. The security of gas supplies in the EU has a set of external risks related to increasing import dependence from external suppliers, including investment and facility risks, exporters' reliability risk and transit risks. These challenges require further diplomatic efforts, both at the EU and national levels. The EU then has to face a major inward challenge, which is mainly related to the development of the internal market for gas and the related liberalisation process: the problem of under-investment in natural gas infrastructures. Contrary to what is generally believed, there is a risk that the propensity to commit to new projects will decline rather than increase if the liberalisation process is not completed efficiently. To avoid this, energy operators need a predictable, reliable and transparent regulatory framework; something only the EU can provide.

Unlike oil and gas, coal does not seem to pose serious security of supply threats to the EU. Although most of the coal used within the EU is imported and its share is expected to increase in the future, coal imports are quite diversified, come from relatively stable countries, and its transport is relatively safe. This implies no long-term security threats for European consumers,

only short-term vulnerability to temporary supply disruptions caused by ‘force majeure’ or temporary demand-supply imbalances. What the EU has to be concerned about are the environmental challenges caused by coal combustion. In order to achieve Europe’s ambitious climate change targets, clean coal technologies must therefore be developed for coal to continue to be extensively used. The EU should therefore encourage massive investment in CCS technologies as well as further research and cooperation in this field. The planned CCS demonstration projects are indeed a good start.

The indigenous nature of nuclear energy, its strong contribution to Europe’s security of supply and its low-carbon content have again directed attention on this controversial energy source. Yet, given its numerous drawbacks – high costs as well as safety, perception, waste and proliferation risks – producing electricity from nuclear energy remains a divisive issue among European countries. The future development of nuclear energy in the EU will depend on the price of substitute fuels, as well as on the evolution of the EU Emission Trading Scheme. If the latter became more stable and well-functioning, the costs of nuclear energy relative to those of greenhouse gas intensive alternatives would decrease.

Although the contribution of renewable sources to EU total energy consumption is currently lagging behind the indicative target of 12% by 2010, the European Commission is strengthening its efforts to encourage the use and production of alternative energies. Their main benefits lie in reducing greenhouse gas emissions and air pollution, but renewables are also believed to contribute to security of supply due to their domestic (often regional) availability. However, security of supply benefits are not so clear for two reasons. First, some renewable energy sources are intermittent (e.g. wind, small hydro, solar PV) and may thus cause supply disruptions if they are not linked to more reliable renewables (such as large hydro or bioenergy) or to backup capacity provided by fossil fuels. Second, the potential of renewables to reduce fossil fuel imports is limited and only constitutes a security of supply benefit if import dependence is regarded as a problem – which is not the case for all fossil fuels. Another issue is the high cost of developing renewable-based technologies. In order to improve the future economic viability of these technologies, investment incentives as well as new stimulus for changing consumers’ behaviour will have to be provided both by the EU and the member states.

Natural gas, coal, nuclear and renewable energies all contribute to determining the security of supply of electricity. The latter has two components: operational network security and adequate generating capacity. At both levels, the key challenge is reaching adequate and timely investment. Yet the peculiar role of electricity prices, the difficulties encountered by transmission system operators to maintain safe and efficient transmission grids, and the incompleteness of the internal market do not always provide adequate incentives to investment. Moving forward in the liberalisation process is the precondition to overcome the challenges posed by a system in transition.

Energy efficiency has also become a cornerstone of the European Commission energy policy. The latter recognises actions on the demand side as crucial as supply-side initiatives to pursue, among others, energy security objectives. Yet the non-binding nature of the energy efficiency targets set for 2020 downplay its already limited potential to increase Europe’s security of supply. It is indeed misleading to believe that improving energy efficiency would substantially contribute Europe’s energy self-sufficiency: even assuming the full application of the existing EU directives on energy efficiency, in 2030, Europe’ import dependency will anyway be higher than today. Moreover, the beneficial impact of EU energy efficiency measures on CO₂ emissions underplay the negative effects of projected energy demand growth in developing countries where energy efficiency standards remain modest.

Speaking with one voice in foreign energy matters may be a first step to increasing Europe’s energy security but so far this remains a mere ambition. EU member states keep on pursuing

their national interests, diverging on how to integrate their energy foreign policy objectives. In addition, a credible EU foreign energy policy is not credible unless the EU has a functioning common market for electricity and gas. And the ‘market governance’ approach so far adopted by the EU is regarded with suspicion by non-European countries. Would a more political approach make foreign European energy policy more effective? This does not seem to be the case.

Also, given that energy accounts for about 80% of all greenhouse gas emissions in the EU, climate change policy will require profound changes to European energy systems. Climate change thus plays an ever-increasing role in energy policy and the value of considering interactions between global warming and energy security is increasingly recognised, especially in areas such as better efficiency, renewables, nuclear and technological innovation. As well as mitigating greenhouse gas emissions, the European energy sector will also need to adapt to changing climatic conditions – both on the supply and the demand side. To date, these interactions have not yet been assessed and more work needs to be done in this direction.

The energy and climate change risks affecting the EU, their possible causes and impacts, as well as their duration and future probability are summarised in Table 1, which has also been devised to reflect the resource-specific approach of this paper.

Table 1. Classification of security of supply risks in the EU

Type of risk	Events	Price rise		Probability in Duration		Fuel affected					
		Intl.	Domestic	20 years		Oil	Gas	Coal	Nuclear	RES	Elec.
<i>Geological risks</i>											
Resource depletion/shortage	Lack of investment; extraction difficulties; unsustainable global demand; political constraints	Yes	Yes	Low	Decades, permanent	x	x	x	(x)	–	–
<i>Geopolitical risks</i>											
Voluntary output reduction	Quotas on production (by OPEC cartel; by a possible gas cartel); supply cut-off	Yes	Yes	Low-medium	Months, days	x	x	–	(x)	(x)	–
Involuntary output reduction	Civil unrest; political turmoil; war; terrorism	Yes	Yes	Low-medium	Variable	x	x	–	–	–	–
Transport and transit risk	Transport: sea-lane bottlenecks; lack of investment; piracy Transit: political instability of transit countries; tense relations with exporting countries	Yes	Yes /No	Low-medium-high	Variable	x	x	–	–	–	x
Resource nationalism	Limited access for foreign investors to producing countries' resources	Yes	Yes	High	Years	x	x	–	(x)	–	–
<i>Economic risks</i>											
Under-investment	Transition towards liberalisation; lack of investment incentives; capital shortage; public opinion opposition	No	Yes	High	Years	x	x	x	x	x	x
Market disruption	Regulatory failure/shortcoming	Yes	Yes	Medium	Variable	x	x	–	–	x	x
Price fluctuation	Supply-demand imbalance; lack of spare capacity; speculation	Yes	Yes	High	Months, years	x	x	–	–	–	x
<i>Environmental risks</i>											
Accidents	Major oil spill (land or sea)	No	Yes	Medium	Variable	x	–	–	–	–	–
	Nuclear accident	No	Yes	Low	Variable	–	–	–	x	–	x
Climate change	Increasing greenhouse gas emissions	Yes	Yes	High	Permanent	x	(x)	x	–	–	x
From production	Coal extraction and combustion	No	Yes	Medium	Variable	–	–	x	–	–	x
	Radioactive waste form nuclear	No	No	Medium	Permanent	–	–	–	x	–	–
	Unsustainable biomass production	No	No	High	Decades	–	–	–	–	x	–
<i>Technical risks</i>											
System failure	Extreme weather conditions; under-investment; technical neglect; major pipeline burst	Yes/no	Yes	Medium	Days, weeks	x	x	x	x	x	x
Intermittency risks	Absence/low inputs (e.g sun, wind)	No	No	Medium	Hours, days	–	–	–	–	x	x

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