# EIB PAPERS

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## An efficient, sustainable and secure supply of energy for Europe

### *Global and European policy perspectives*



European Investment Bank

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# Contents



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# Preface

***Philippe Maystadt***
***President***

Energy has returned to the top of the economic policy agenda of the European Union and its Member States. It was there before, following the two oil crises of the 1970s, but interest in energy matters dwindled in the mid-1980s with low international energy prices, faith in the ability of energy markets to ensure supplies and, thus, make Europe's energy import dependence largely irrelevant, and ebbing concerns about the reliability of foreign energy suppliers.

Alas, the situation is different today: oil prices have reached new highs, risks associated with Europe's dependence on energy imports from a narrow set of energy-exporting countries have increased, and Europe's energy infrastructure has moved from a state of plenty in many energy sub-sectors to one in need of capacity upgrading and modernisation across all sub-sectors. What is more, the environmental impact of producing and using energy, combined with the rightful aspiration of poorer people across the globe to eventually enjoy those energy services taken for granted in rich countries, puts into question the sustainability of our current energy systems. Although these concerns are not new at all, they seem to have become more serious with hardening evidence that man-made greenhouse gas emissions change the Earth's climate. And the energy sector is arguably the main source of such emissions.

European policy makers have responded to these challenges. The European Council of March 2007 agreed on an Energy Policy for Europe. The hallmark of this agreement is what may be called the 20/20/20 targets – to be achieved by 2020: (i) reduce EU Member States' greenhouse gas emissions by at least 20 percent compared to 1990; (ii) increase energy efficiency by 20 percent compared to baseline projections; and (iii) raise the share or renewable energy resources in the EU energy mix to 20 percent. The investment needed to meet these targets will be substantial – both in energy production and energy-consuming sectors. In addition, there is the ongoing need to better integrate Member States' energy sectors to form a truly internal market in energy.

The lending of the European Investment Bank to the energy sectors of EU Member States needs to be seen in this context. While lending in support of EU energy objectives has been a Bank priority for a long time, this priority has been reinforced recently. The Bank's action in the energy sector distinguishes between support for renewable energy; energy efficiency; research, development, and innovation in energy matters; diversification and security of internal supply; and external energy security and development, which pertains to Bank lending to EU neighbours and partner countries.

Ensuring that the thrust of Bank lending is well aligned with EU energy policy objectives is key for the Bank to make a difference, that is, to add value to investments pre-dominantly financed by financial markets and commercial banks. Equally important is, however, that the Bank closely follows the debate on energy policy and fully understands the role of public policies and public institutions in tackling Europe's energy and climate-change challenges. Part of that role is to separate the wheat from the chaff. To elaborate, economic analyses might show that some investments to increase energy efficiency, foster renewables, enhance energy security, or pursue other seemingly laudable causes do not make economic sense, and a key challenge for institutions like the Bank is to identify and finance those that do and to argue against those that do not.

The contributions to this volume of the *EIB Papers* are set against this background. Drawing on presentations made at the *2007 EIB Conference on Economics and Finance*, the contributions address a wide variety of questions. To illustrate, cognisant of the global dimension of the energy and climate-change challenges, this edition of the *EIB Papers* (Volume 12, Number 1) examines why the recent rise in international energy prices has affected the global economy far less than the oil price shocks of the 1970s; what distinguishes the state of Europe's energy sector in the last decades of the twentieth century from that of today; why designing a credible and predictable long-term policy framework for Europe's energy sector is more important than the setting of specific policy targets and instruments; how policy uncertainty blocks or delays essential investment in the EU energy sector and what needs to be done to substantially reduce policy uncertainty; why ensuring energy security falls primarily in the realm of geo-politics rather than economics; why apparently dirty fossil fuels could play a considerable role in a clean and sustainable energy system; and why low international energy prices prevailing in 1985-2000 can be considered a historical accident that is unlikely to repeat itself.

The companion edition (Volume 12, Number 2) to this edition of the *EIB Papers* addresses more specific energy policy issues, including diversification benefits arising from restructuring Europe's electricity mix, the costs and benefits of investing in the security of energy supply, the forces driving the extension of the transport system for gas exports to Europe, barriers to investment in energy efficiency, the pros and cons of alternative policies aimed at promoting renewables, and the rationale for promoting new energy technologies.

To conclude, the task of ensuring an efficient, sustainable and secure supply of energy for Europe is a tough one. Yet, as the contributions to this volume of the *EIB Papers* will argue, it can be accomplished.

# An efficient, sustainable and secure supply of energy for Europe

## Global and European policy perspectives

The *2007 EIB Conference on Economics and Finance* – held at EIB headquarters in Luxembourg on January 25 – examined challenges towards an efficient, sustainable and secure supply of energy for Europe. Presentations addressed broad policy issues – the credibility and predictability of policy frameworks, for instance – and specific policy questions, such as the rationale for promoting renewable sources of energy, energy efficiency, and new energy technologies.

Speakers included:

**Juan ALARIO,**
of the EIB

**Shimon AWERBUCH,**
of the University of Sussex, UK

**Bassam FATTOUH,**
of the Oxford Institute for Energy Studies, Oxford, UK

**Dominique FINON,**
of the Centre National de la Recherche Scientifique, Paris

**Dieter HELM,**
of New College, Oxford, UK

**Franz HUBERT,**
of the Humbold University, Berlin, Germany

**Mark JACCARD,**
of the Simon Fraser University, Vancouver, Canada

**Machiel MULDER,**
of CE Delft, The Netherlands

**Armin RIESS,**
of the EIB

**Dominique RISTORI,**
of the European Commission

**Joachim SCHLEICH,**
of the Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, Germany

**Coby VAN DER LINDE,**
of the Clingendael International Energy Programme, The Hague, The Netherlands


## ABSTRACT

***The main purpose of this paper is to preview the other contributions to this volume of the EIB Papers.*** *In this context, it offers a few additional perspectives. One highlights why energy issues have re-emerged as a matter of policy interest. Another concerns the difference between the macroeconomic impact of the oil price shocks of the 1970s and that of the recent rise in international energy prices. A third perspective – set against concerns about the security of energy supply for Europe – pertains to the wide variation in energy import dependency across EU countries. Lastly, the paper comments on the energy efficiency ambitions of the European Union.*

**Atanas Kolev** (a.kolev@eib.org) and **Armin Riess** (a.riess@eib.org) are, respectively, Economist and Deputy Head in the Economic and Financial Studies Division of the EIB. The views expressed are strictly personal.

# Energy – revival of a burning matter

***Atanas Kolev***

***Armin Riess***

## 1. A sense of *déjà vu*

Insinuating – as the title of this overview paper does – that energy matters are subject to ebbs and flows seems to be odd. Leaving aside the role of energy in the production of goods and services, its profound importance is obvious when we imagine how its absence would derail daily life in modern societies. Take the case of electricity (Bodanis 2006). A local, short-term electricity blackout is unlikely to be more than a nuisance – although perhaps a memorable one when people get stuck in elevators, miss decisive moments of major sports events on TV, and so on. Inconvenience rises if blackouts are widespread – nation-wide, for instance – and last hours, severely disrupting rail and air traffic and inner-city road transport, communication, air conditioning, heating, hospital services, that is: everything powered by electricity. Although cars and mobile phones continue to work for a while, once tanks and batteries are empty, this lifeline goes, too, because neither refuelling cars nor recharging batteries works without electricity. When blackouts go on for a few days, refrigerated food will perish and fresh food supplies will not be available – not even from the bakery next door. And even if they did, people run out of cash at some point, cannot get fresh money – neither from automatic teller machines nor the friendly clerk of their local bank because neither can process transactions without electricity, and for the same reason credit cards turn into what they are made of – just a piece of plastic. For modern, energy-reliant societies, a blackout striking for a week or more would truly be nightmarish, with public safety crumbling, no police or ambulance to call, and hospitals of no value. All in all, for modern societies, energy is vastly more valuable than what its share in gross domestic product suggests,[1] and although a secure supply of energy is the more vital the more 'modern' a society is, its importance does not rise and fall over time.

One reason why it is nonetheless apt to speak of a revival of energy matters is that the degree to which societies can be, or feel, certain of their energy supplies varies over time – in particular in energy-importing countries. In this respect, there has been a sea change since the beginning of the new millennium for a number of reasons. The import dependency of EU countries has increased since the mid-1980s and is projected to rise further due to dwindling oil and gas production in EU countries. In addition, prospects for international energy companies to be involved in developing oil and gas resources of energy-exporting countries are not as good as they appeared some twenty years ago. What is more, there is growing anxiety, rightly or wrongly, that energy-rich countries might not be as reliable as they used to be – because of political instability in these countries or their neighbours, politically motivated supply disruptions, or both. Last but not least, the rise in international oil prices, notably since end-2003, combined with emerging economies' growing demand for energy back the notion that a secure supply of energy at affordable prices cannot be taken for granted.

A simple way to illustrate the renewed interest in energy is to examine the attention it has received in the financial press. According to the print-edition archives of *The Economist,* the number of articles in that newspaper containing the word 'energy' averaged 290 a year in

1 In the European Union, for instance, the energy sector accounts for around 3 percent of GDP.

1997-2000, but increased by around 50 percent to 430 in 2001-07.[2] The reporting in *The Economist* also nicely captures how energy issues, or their assessment, changed over time. In 1999, the newspaper famously ran an article with the title "The next shock?  The price of oil has fallen by half in the past two years to just over $10 a barrel. It may fall further – and the effects will not be as good as you might hope", and the article considered the possibility of oil prices plunging to $5 a barrel (*The Economist* 1999). As the world found out pretty soon thereafter, it escaped the shock of falling prices, but experienced rising ones instead, leading the newspaper in 2006 to ask how high oil prices can go and to express "Nostalgia for calmer days" (*The Economist* 2006a).

***Interest in energy matters has re-emerged for reasons similar to those prevailing in the 1970s, but there is more than history repeating itself.***

Global warming is the other main reason why energy is a hot topic again, with energy production and consumption arguably being the main source of man-made greenhouse gas emissions. At the risk of simplifying a little and taking an advanced-country perspective, one might say that climate-change concerns have replaced fears of the 1970s and 1980s about acid rain and other environmental and health damages caused by emissions of sulphur dioxide and nitrogen oxides. One reason why fears of the 1970s and 1980s rescinded is that advanced countries succeeded in substantially cutting emissions of sulphur dioxide and nitrogen oxides. This being said, mankind's possible contribution to global warming is not a new concern either, but the uncertainty surrounding it seems to be much lower now than it was ten to twenty years ago.

Reviewing the coverage of global warming in *The Economist,* we find that the number of articles mentioning it went up by some 20 percent from an average of 58 a year in 1997-2000 to 70 in 2001-07. Perhaps more telling is how the tone of articles on global warming has changed. In the run-up to finalising the Kyoto Protocol in December 1997, the newspaper though recognising the danger of global warming recommended "For Kyoto, a modest proposal", stressing that "If you want a cool planet, keep a cool head" (*The Economist* 1997). Indeed, this advice was in the tradition of earlier commentary suggesting to "Stay cool" and noting "penguins and people can afford to relax for many years yet" (*The Economist* 1995). More recently, the flavour of articles has become less relaxed, with "The sound of distant howling – Signs of climate change are hard to be sure. But the latest look alarming" (*The Economist* 2005), "The heat is on – The uncertainty surrounding climate change argues for action, not inaction. America should lead the way" (*The Economist* 2006b), and "The melting tongue of ice – global warming gives our correspondent the shivers" (*Economist.com* 2007). In sum, although only illustrative, the transformation in the coverage of global warming by a newspaper known for the rigour of its analyses and its sceptical view of global warming indicates that the climate-change challenge is real and closely linked to the use of energy.

To conclude, for a variety of reasons, interest in energy matters has re-emerged since the turn of the millennium. To some extent, it is *déjà vu* as today's interest is driven by factors known from the 1970s, notably environmental challenges related to energy production and consumption and concerns about the security of energy supply. What is more, as in the 1970s, improvements to energy efficiency are perceived to be key for tackling both problems. Yet, there are differences too. Environmental challenges were largely regional and local in character while they now have a global dimension. As for security of supply, oil was the focus in the 1970s while today worries about a reliable supply of natural gas seem to be of importance as well – at least from a European perspective. Another conspicuous fact is

2 To be a little more precise, both figures are annualised averages because the archives contain articles since June 1997 and the data for 2007 cover only the first five months of the year. Obviously, the figures are inflated (in both sub-periods) as they include articles on other 'energy' issues, such as how astrophysicists study dark energy in the universe.

that the energy price shock of the 1970s adversely affected the economic performance of energy-importing countries. By contrast, despite the recent surge in energy prices, the world economy continues to steam ahead without noticeable inflationary pressure. The reason for this is one of the themes reviewed in this paper (Section 2). But our main purpose is to offer a guided tour of the contributions to this volume of the *EIB Papers*. In this context, we will examine how energy import dependency varies across EU countries (Section 3) and we will elaborate on the role of energy efficiency in reducing energy consumption (Section 4). Section 5 concludes.

## 2. Energy and the macroeconomy – now and then

To start with some facts, Figure 1 shows developments in the real price of crude oil since the beginning of the 1970s. Following a few ups and downs during the first years of the new millennium, prices have been on an upward trend since end-2003. In real terms, today's oil prices are three times higher than five years ago and five times higher than seven years ago. Such a steep rise in oil prices is without doubt reminiscent of the oil shocks of 1973-74 and 1979-80. Indeed, although the real price of oil has not yet reached its peak of 1980, it is well above the level prevailing after the first oil shock and firmly in the range of the second one.

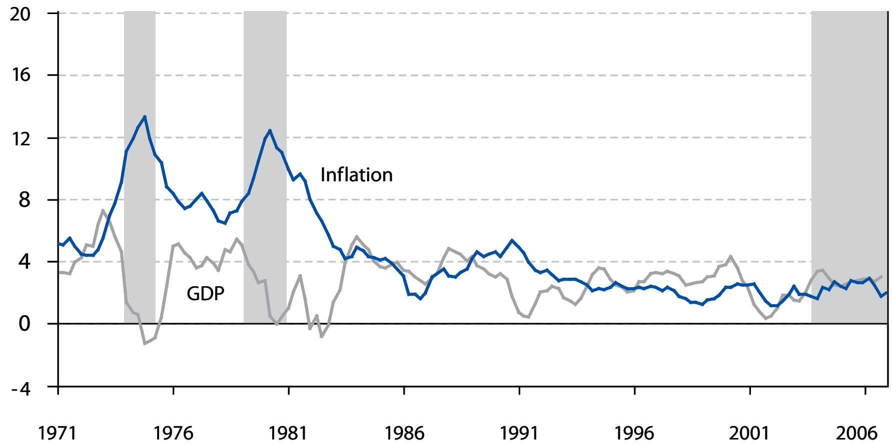
***Despite the recent surge in energy prices, the world economy continues to steam ahead without noticeable inflationary pressure – in contrast to the 1970s.***

**Figure 1. Inflation-adjusted oil price in USD per barrel, 1970-2006**


Source: IMF, International Financial Statistics.
Notes: The shaded areas mark the periods of the oil shocks in the 1970s and early 1980s and the period since November 2003. Data are in 2005 prices.

Given the similarity between the size of the price shocks of the 1970s and the recent surge in oil prices, a hypothetical macroeconomic forecast made in 2000 on the assumption that oil prices increased as much as they did, would probably have projected a severe slowdown in economic activity and a rise in inflation. As Figure 2 shows for OECD countries, such a forecast would have been widely off the mark. To recall, the oil price shocks of the 1970s coincided with a steep rise in inflation. In contrast to the pre-1970 experience, faster inflation was not accompanied by higher economic growth. On the contrary, economic activity in most advanced economies plummeted, and with the concurrence of economic stagnation and inflation, the term stagflation was born. This time, the experience with rapidly rising oil prices seems to have been a happier one. Inflation and economic growth in OECD countries averaged, respectively, 2.5 percent and 3.0 percent a year in 2004-06. For the world as a whole, the comparable figures are 3.7 percent and 5.2 percent.

Figure 2. Real GDP growth and inflation (in %) in G-7 countries, 1971-2006

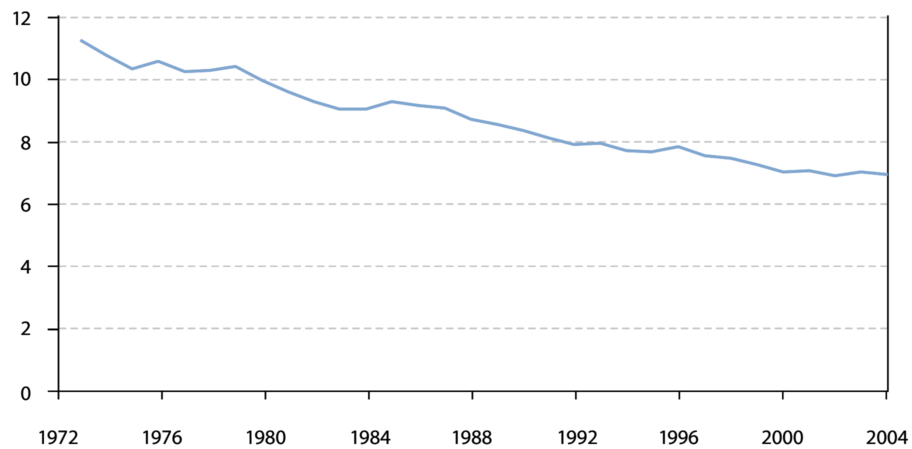



Source: OECD, Main Economic Indicators.
Notes: The shaded areas mark the periods of the oil shocks in the 1970s and early 1980s and the period since November 2003.

***Advanced economies are less energy intensive than some thirty years ago, implying that any increase in the cost of energy hurts them less than it used to.***

There are four main reasons why the recent surge in energy prices has not spoiled the macroeconomic performance of the world economy. To begin with, advanced economies are much less energy intensive than they used to be thirty years ago, that is, they need far less energy per unit of output produced. As Figure 3 shows for the EU-15, energy intensity fell by 37 percent in 1973-2004. That said, the process has been uneven and there was almost no change in the mid-1990s and the early years of the new millennium. Figure 4 indicates that the downtrend in the oil intensity of industrial countries has been more pronounced (a decline of 50 percent), with the use of oil in these countries largely confined to the transport sector and the chemical industry, where it is an important non-energy input. In sum, because of lower energy intensity, any increase in the cost of energy hurts advanced countries less than it used to.[3]

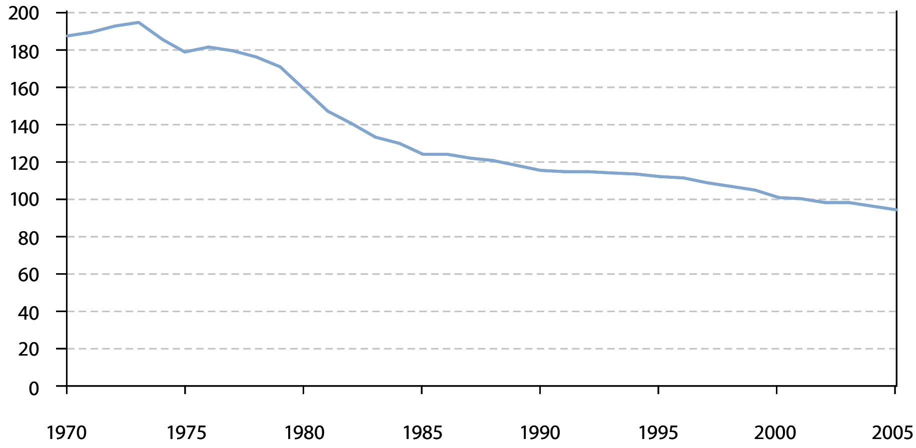
Figure 3. Energy intensity of EU-15 countries in megajoule per euro of GDP




Source: EUROSTAT and own calculations.
Notes: GDP in 1995 prices.

3 Considering the importance of energy sketched in the introduction, one could detect a dichotomy: although modern economies are increasingly vulnerable to being without energy, they are better at weathering an increase in its cost.

**Figure 4. Oil intensity of OECD countries (index 2000=100)**




Source: US Department of Energy database and OECD WEO database.

***The underlying structure of most advanced economies is also more flexible, helping them to adjust to an increase in energy prices.***

Second, in contrast to the 1970s, economies in this day and age can absorb energy price shocks without too much impact on real economic activity and inflation. This is largely because labour and product market conditions today tend to foil workers' and firms' efforts in energy-importing countries to claw back the international transfer of income associated with a hike in the price of primary energy and other raw materials (Carlin and Soskice 2006). A variety of factors have contributed to this change. Substantial labour and product market deregulation in many developed countries is one of them. Another is fierce foreign competition – coming with external trade liberalisation – which is keeping a lid on wages and prices. And then, there is the globalisation of financial markets, making all types of capital more mobile and thereby limiting the bargaining power of labour. Finally, while labour markets were very tight at the time of the first oil shock, unemployment in many countries continues to be high today, curbing wage demands and thus inflationary pressures.

Third, macroeconomic policies of today benefit from the lessons learned in the context of the first oil shock and are free of the constraints that characterised the macroeconomic situation around the time of the second one. In response to the first shock, and hoping the oil price hike would be transitory, policy makers tried to stem the rise in unemployment with expansionary aggregate demand policy. In the event, this policy proved to be futile not only because oil prices remained high, but also because demand policy is inherently of little use to offset an adverse supply shock. The legacy of this policy was high inflation and unemployment when the second oil shock hit. This time around, the policy response was different. To suppress the inflationary effect of yet higher oil prices and, indeed, to initiate a process of disinflation, monetary policy was tightened in many countries, eventually anchoring inflation expectations at low levels. The recent oil price rise has happened in different circumstances. Cognisant of the limits of demand policy and thanks to the success in stabilising inflation expectations, macroeconomic policies have been free to play their role in promoting non-inflationary economic growth.

Fourth, an oil price shock can have different causes and there is evidence that its macroeconomic impact depends, in part, on what triggers the shock. Kilian (2006), for instance, distinguishes four types of shocks – two caused by supply-side disturbances and two caused by demand-side disturbances – and examines their short-term and long-term impact on GDP and inflation in oil-importing countries. The first type of supply shock is triggered by political events in OPEC countries, such as the Iranian revolution, the Gulf war, and so on. All other things being equal, this type of shock

– characteristic for the oil price hike of the late 1970s – is estimated to result in a sustained reduction in real GDP growth. The second type of supply shock includes all other disturbances to the supply of oil, such as a cut in production by OPEC in response to oil market developments. Disturbances of this nature are estimated to dampen economic activity over the short term, but leave long-term growth unaffected. The first type of demand shock reflects disturbances that are specific to the oil market, a build-up in precautionary oil stocks for instance. Similar to supply shocks set off by political events, this type of demand shock – characteristic for the oil price hike in the mid-1970s – is estimated to adversely affect economic activity not only in the short run, but also in the long run. Finally, the second type of demand shock captures changes in aggregate demand – the worldwide economic boom since 2003 being a case in point. Oil price increases associated with shocks of this nature are found to boost economic activity in the short run even though they do not affect long-run economic growth. In sum, difference in the type of shocks help explain why the oil price spikes of the 1970s (oil-market specific demand disturbances and political supply shocks) slowed economic growth and why the recent rise in oil prices (aggregate demand shock) have done no harm.

***The spare capacity that contributed to low oil prices in the period 1986-99 was not the outcome of rational investment decisions and is thus unlikely to re-emerge.***

To take stock, over the last 30 years or so, real oil prices have seen sizeable ups and downs, but the economic repercussions of the first and the second oil price shocks were very different from those of the recent surge in oil prices. But what drives oil prices in the long run? This question, which is of broader importance given the impact of oil prices on the cost of other primary energy resources and energy services, is at the heart of the contribution by **Bassam Fattouh**. He reviews three main approaches to analysing long-run oil price behaviour: the economics of exhaustible resources, the supply-demand framework, and the informal approach. While the first approach suggests that oil prices must exhibit an upward trend, the other two do not offer such clear-cut predictions. All three approaches are frequently used to project long-term oil price developments and various actors – governments, central banks, international oil companies, and so on – rely on these projections for planning energy policy, evaluating investment decisions, and analysing the impact of various supply and demand shocks on the oil market. Acknowledging the usefulness of all three approaches for a better understanding of oil markets, Fattouh also stresses that using them to predict oil prices and to push for policies based on these predictions defeats their purpose and is bound to result in errors. Besides this overall conclusion, Fattouh emphasises that the spare capacity that contributed to low oil prices in the last one and a half decades of the previous century was not the outcome of rational investment decisions and is thus unlikely to re-emerge.

In these circumstances, oil prices will remain fairly sensitive to oil market disturbances – real or imagined. This takes us to concerns about energy security since stable and affordable prices are typically considered an important feature of energy security.

### 3. Energy security and import dependency: EU member states are not equal

Concerns about energy security have at least two aspects: the threat of abrupt supply disruptions and the fear of excessive prices and price volatility. Obviously, there is a link in that actual or expected supply disruptions affect prices and their volatility. This is the background against which **Machiel Mulder**, **Arie ten Cate**, and **Gijsbert Zwart** explore the welfare effects of policies aimed at enhancing the security of energy supply. In setting the stage, they distinguish between a political and an economic perspective. From a political perspective, ensuring security of supply often means that a stable supply of energy needs to be guaranteed at 'affordable' prices, regardless of circumstances.

From an economic perspective, less ambitious though more reasonable considerations guide the debate. A key economic question is whether or not markets succeed in achieving an efficient balancing of supply and demand in the short run and an efficient level of investment in the long run. Taking the economic perspective, the authors assess two policies directed at the security of energy supply: investments in strategic petroleum reserves and a cap on the production of gas from the largest Dutch gas field. Their main conclusion is that both policies are unlikely to be welfare enhancing, but they might be in specific circumstances. More generally, considering the economic costs and benefits of such policies, the authors argue that it would often be wiser to accept the consequences of supply disturbances than to avoid them. Governments should thus proceed carefully in taking such policies.

***From an economic perspective, the key security-of-supply issue is whether or not markets succeed in achieving an efficient balancing of supply and demand in the short run and an efficient level of investment in the long run.***

Energy price risks also feature prominently in the paper of **Shimon Awerbuch** and **Spencer Yang**. They apply portfolio-theory optimisation concepts from the field of finance to develop and evaluate optimal EU electricity generating mixes. They consider portfolio theory highly suited to the problem of planning and evaluating electricity portfolios and strategies on the grounds that energy planning is similar to investing in financial securities where financial portfolios are widely used by investors to manage risk and to maximise performance under a variety of unpredictable outcomes. Awerbuch and Yang find that compared to the EU electricity mix currently projected for 2020, optimal mixes generally include greater shares of wind, nuclear, and other non-fossil technologies, which often cost more on a stand-alone engineering basis. Optimal mixes are also found to enhance energy security and reduce $CO_2$ emissions. As perhaps the single most important lesson of the portfolio optimisation analysis the authors consider the fact that adding a fuel-less technology (such as wind energy) to a risky generating mix lowers expected portfolio cost at any level of risk, even if the fuel-less technology costs more when assessed on a stand-alone basis.

The contribution of **Franz Hubert** turns the spotlight on the extension of the Eurasian gas transport network. In the past, gas transport through that network was interrupted occasionally when Russia and other members of the supply chain for Russian gas (Ukraine and Belarus) failed to reach agreement on gas prices and transit fees. These very rare, very short, but highly publicised events gave the impression that due to conflicts along the transit routes, Russian gas is unreliable and expensive. The game-theoretic model Hubert develops in his paper suggests the opposite might be true. As there are currently no international institutions that could enforce multilateral contracts and because the members of the supply chain for Russian gas failed to develop a stable long-term cooperation, the pipeline system is expanded and diversified beyond what is in the interest of Russia, Ukraine, and Belarus as a group. Investment is partly driven by strategic considerations to increase bargaining power *vis-à-vis* transit countries, rather than consumers. A key conclusion emerging from this analysis is that Europe's energy consumers might benefit, both in terms of prices and energy security, from a diversified transport system with substantial spare capacities. At the same time, energy dependency will grow because the fraction of Russian gas in the energy mix becomes larger.

Dependency on gas imports from Russia and the energy-security challenges arising from it are issues also addressed by **Dieter Helm**. Emphasising that Russia has tended to avoid dealing with the EU as a whole and, instead, has entered into bilateral deals with individual countries, he argues for a new European energy policy that diversifies away from Russian gas and improves Europe's bargaining power. Such a policy would have a number of elements, including a credible target for the level of gas import dependency on Russia, schemes that reward investments (such as LNG terminals) for enhancing supply security, and steps to improve gas interconnections within Europe and to further develop interconnections between Europe on the one hand, and the Caspian area and North Africa on the other. Helm also reminds us that Europe's energy security has an internal dimension, too, and that, in fact, improvements to internal energy security would strengthen the EU's bargaining power *vis à vis* foreign energy suppliers. Steps towards enhanced internal security of supply include further internal EU energy market reforms and investments aimed at better interconnecting and integrating Europe's physical networks.

***From a political perspective, the energy risk landscape has changed fundamentally in recent years, with a re-politicisation of energy and geopolitical rivalry over access to energy-rich regions characterising the scene.***

The last paper focussing on the security of energy supply is that of **Coby van der Linde**, who introduces us to the art of managing energy security risks. The key theme running through her paper is that the energy risk landscape has changed fundamentally over the last decade or so, requiring a re-evaluation of risk assessment and management tools and strategies. Many of these tools currently used in most energy-importing countries – risk spreading through financial markets, holding of strategic reserves, environmental risk management, diversification of both energy supply and sources of supply, and so on – were developed after the 1973-74 oil crisis and adapted to the market-oriented conditions prevailing in the 1980s and 1990s. Since then, following two decades of a largely market-based system of energy supplies, a re-politicisation of energy is taking place; investment options serve national interests rather than the international market; new players – such as Brazil, India, and China – are becoming increasingly important; geopolitical rivalry over control of and access to energy-rich regions characterise the scene; and geopolitical tensions show that energy security will become firmly integrated in the foreign and security policies of a nation. Although traditional risk assessment and management tools continue to be useful in these circumstances, van der Linde argues that a new set of international rules is needed in order to prevent geopolitical clashes over energy security.

The energy-security perspective of all papers introduced so far is European, if not global, and the common thread is Europe's dependency on fossil fuel imports from a narrow set of countries, many of them perceived as politically unstable or unreliable. Against this background, the security of energy supply has moved to the top of the EU policy agenda. In fact, given the EU's dependence on energy imports, there have been calls for a common EU policy *vis à vis* energy-supplying countries, Russia in particular. It is fair to say that the willingness to coordinate security of supply policies among EU member states, or even delegate such policies to the EU level, differs across member states. The history of bilateral relationships between individual members, on the one hand, and energy-supplying countries on the other hand partly explains why the support for a common security of supply policy might not be equally strong in all member states. At the same time, differences across member states in the degree of import dependency probably play a role too. But how unequal are EU member states in this respect and why are they unequal?

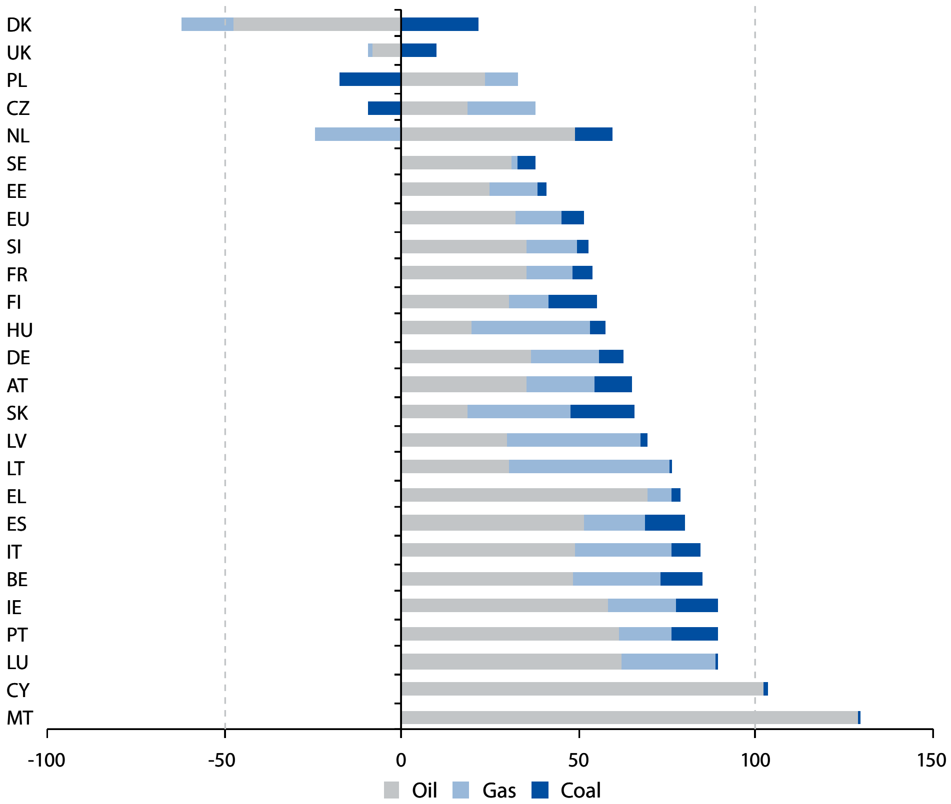
EU energy import dependency is projected to increase considerably in the years to come, largely because of an anticipated drop in EU production of primary energy. More specifically, the EU import dependency ratio – that is the ratio of net imports to total consumption[4] – is projected to increase from 53 percent in 2006 to 65 percent by 2030 (European Commission 2006b). This uptrend is most pronounced in the case of natural gas, with dependence on natural gas imports foreseen to rise from 54 percent to 84 percent by 2030.

Not all EU members are equally dependent on fossil fuel imports, however. In fact, there is a great deal of dispersion around the EU average. Figure 5 plots the share of net imports for each fossil fuel in relation to total consumption. As can be seen, the ratio of total fossil fuels imports to total

4 Total consumption is gross inland consumption defined as follows: primary production + recovered products + net imports + variations of stocks – bunkers (=quantities supplied to sea-going ships). All data refer to EU-25.

consumption ranges from around −40 percent for Denmark, which is thus a net exporter, to more than 80 percent in countries such as Belgium, Ireland, Italy, and Portugal.

**Figure 5. EU countries' import share of coal, oil, and gas in total consumption (in %), 2005**




Source: Eurostat.

*Energy-import dependency varies considerably across EU countries, and there seems to be a North-South divide.*

As described in more detail in Box 1, there are essentially two reasons why import dependency differs across EU countries. One is variation in the domestic production of fossil fuels. The other is variation in the use of nuclear energy and renewables.[5] Distinguishing between (i) least import-dependent EU countries, (ii) medium import-dependent EU countries, and (iii) most import-dependent EU countries, the following picture emerges. There seems to be a North-South divide, with northern countries being relatively well-endowed with fossil fuel resources and/or relying to a large degree on renewables and/or nuclear. In virtually all countries of the first group, domestic production of fossil fuels covers more than half of total consumption; the exception is Sweden, with no fossil fuel production to speak of but an exceptionally large contribution of renewables and nuclear. Countries in the second group rely on nuclear energy and/or renewables to a degree that is close to or way above the EU average; Latvia and Austria are the exceptions as they have no nuclear energy but an unusually high share of renewables (about one quarter) in total energy consumption. Finally, although some of the most import-dependent EU countries have significant domestic fossil fuel production (Greece), nuclear energy (Belgium), or renewables (Portugal), in none of them are domestic sources of energy large enough to prevent a high degree of import dependency; interestingly enough, this group of countries comprises all EU Mediterranean countries, except for France.

5 Reflecting common practice, nuclear is treated as a domestic source of primary energy irrespective of whether uranium is imported or not. The EU imports almost its entire natural uranium requirement, supplied by a diverse set of countries. By contrast, around 70 percent of enriched uranium originates in the EU, with most of the remainder imported from Russia.

**Box 1. Why energy import dependency varies across EU countries**

To examine why energy import dependency varies across EU countries, we have sorted them according to the degree of their import dependency and classified them in three groups – as shown in the following table.

**EU countries grouped by energy import-dependency ratio (IDR)**

| | |
|---|---|
| Least import dependent:<br>IDR < 40 percent | Denmark, United Kingdom, Poland, Czech Republic,<br>The Netherlands, Estonia, Sweden. |
| Medium import dependent:<br>50 percent < IDR < 80 percent | Slovenia, France, Finland, Lithuania, Hungary, Germany,<br>Slovak Republic, Austria, Latvia. |
| Most import dependent :<br>IDR > 80 percent | Greece, Spain, Portugal, Italy, Ireland, Belgium, Luxembourg,<br>Cyprus, Malta. |

Source: Own classification based on Eurostat data for 2004.

Although the demarcation line between groups of countries is somewhat arbitrary, classifying countries in this way helps to bring out clearly the relative importance of domestic fossil fuel production, on the one hand, and nuclear energy and renewables, on the other hand, in explaining differences in energy import dependency. A simple visual inspection of the three equally-scaled charts on the next page shows the differences across country groups, but some of the finer points are worth highlighting.

**Least import-dependent EU countries**

All countries in this group are from central-northern-eastern Europe. Domestic production of fossil fuels covers a considerable share (more than 50 percent) of gross inland consumption in all of these countries – with the notable exception of Sweden. In the case of Denmark and the United Kingdom, there is significant production of both oil and gas. In Poland, the Czech Republic, and Estonia, it is coal that largely explains the relatively modest dependence on fossil fuel imports. By contrast, in the Netherlands, it is natural gas. Noteworthy, Sweden produces virtually no fossil fuels, and its relatively low import dependency is due to an exceptionally large contribution of renewables (30 percent of consumption) and nuclear (35 percent). Renewables also make a notable contribution in Denmark (14 percent) and Estonia (10 percent) while nuclear plays some role in the Czech Republic (16 percent) and the United Kingdom (10 percent).

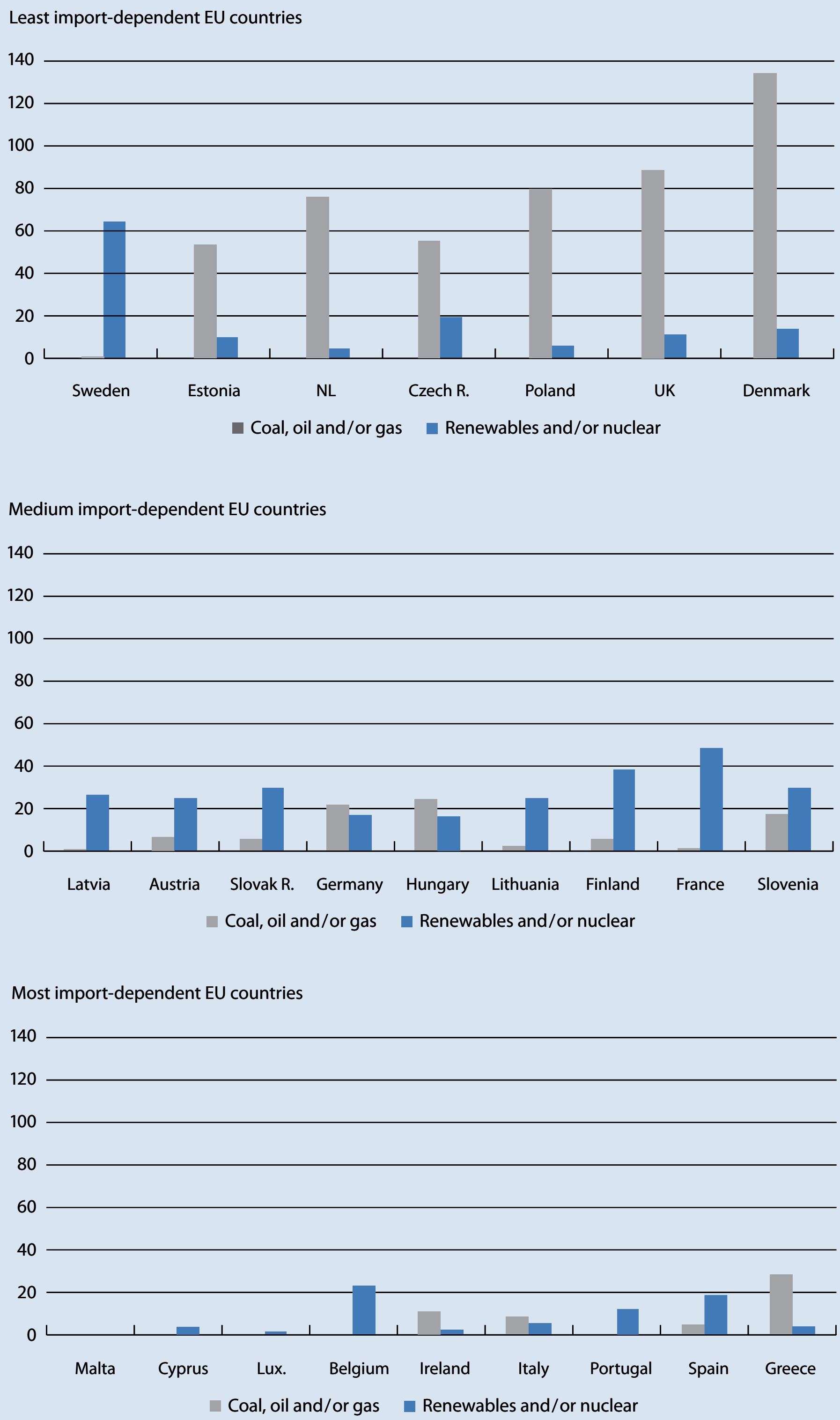
**Medium import-dependent EU countries**

With the exception of Germany, Slovenia, and Hungary, no country in this group extracts fossil fuels sufficient to account for more than 10 percent of its total consumption. In the case of Germany and Slovenia, domestic fossil fuel production largely comprises coal mining (around 16 percent of consumption) whereas in Hungary, there is a fairly balanced mix of coal, oil, and natural gas production (24 percent) that contributes to limiting import dependency. Except for Latvia and Austria, which have no nuclear power plants, all countries rely on nuclear energy to a degree that is close to or way above the EU average (around 14 percent of total consumption), with France (41 percent) and Slovakia (26 percent) relying the most on this source of energy. The reason why Latvia and Austria are in the group of medium import-dependent countries is due to an unusually high share of renewables (about one quarter) in total energy consumption. There are three more countries where the contribution of renewables is considerably above the EU average of 6½ percent: Finland (22 percent), Slovenia (11 percent), and Lithuania (9 percent).

**Most import-dependent EU countries**

Not surprisingly, the domestic extraction of fossil fuels contributes close to nothing to total consumption in these countries, with the exception of coal in Greece (27 percent), oil and natural gas in Italy (9½ percent), and coal and gas in Ireland (9 percent). Nuclear is a source of energy only in Belgium (21 percent) and Spain (11½ percent), and the share of renewables exceeds the EU average only in Portugal (12½ percent) and Spain (7½ percent).

**Ratio of domestic energy production to total energy consumption (in %), 2004**




Source: Own classification based on Eurostat data for 2004.

An important caveat to make is that we have presented a snapshot of today's situation. With EU fossil fuel extraction liable to fall in the decades to come and without a major shift towards renewables and nuclear, energy import dependency will increase and intra-EU disparities will narrow.

EU countries also differ widely in terms of their dependency on natural gas imports from Russia – an issue featuring prominently in the current energy security debate. Eurostat data suggest that there are at least five countries in the EU – Slovakia, Finland, Lithuania, Latvia, and Estonia – which presently import all their gas from Russia. The Czech Republic, Poland, and Slovenia follow with 74 percent, 62 percent, and 60 percent, respectively.[6] Norway is a very important supplier for the United Kingdom as nearly 72 percent of British gas imports come from there. Algeria has strong positions in Portugal and Spain, accounting for around 63 percent and 51 percent of gas imports. Overall, the gas market is relatively segmented, with Russia supplying countries in central and eastern Europe, Norway supplying largely northern and western Europe, and Algeria delivering gas to southern Europe. Thus, reliance on Russian gas is far from uniform across EU member states, possibly weakening the will to forge a common policy. What is more, even if a common stance were beneficial for the EU as a whole, it might not necessarily be for individual members that see benefits in continuing long-established bilateral relationships with Russia.

## 4. The quest for sustainable energy systems

***An energy system can be considered sustainable if it has good prospects to endure indefinitely and is benign to people and ecosystems in the sense of having low impacts and posing low risks.***

Pondering about sustainable energy systems obviously needs a sensible working definition of energy system sustainability. **Marc Jaccard** – whose contribution focuses on the quest for sustainable energy systems like no other in this volume – offers the following: to be sustainable, an energy system must, first, have good prospects for enduring indefinitely in terms of the type and level of energy services it provides and, second, it must be benign to people and ecosystems in the sense of having low impacts and posing low risks. Using three criteria (cost, extreme event risk, and geopolitical risk) and taking a global, long-term perspective, he explores the respective role of energy efficiency, fossil fuels, renewable energy, and nuclear power in a sustainable energy system. He finds both nuclear power and energy efficiency constrained in their potential over the 21st century to deal with the rapidly rising demand for energy services, leaving renewables and zero-emission fossil fuels, especially coal in the latter case, to compete for dominance of the global energy system. As for this competition, he reasons that while the market share of renewables will grow significantly, they are unlikely to unseat fossil fuels, even as these are required to reduce substantially their greenhouse gas emissions. Jaccard also puts forward unmistakable policy recommendations: policies for clean energy should not be biased against or in favour of any particular form of energy and should not require a minimum production of renewable energy or nuclear power or a minimum amount of energy efficiency, or set a target for abolishing fossil fuels. Instead, policies should focus explicitly on specific environmental objectives; in the case of the climate-change risk, this means levying a tax on greenhouse gas emissions or setting a regulated emissions cap that is consistent with the environmental imperatives that scientists are arguing for. For completeness, we note that similar policy recommendations transpire from the contribution of **Dieter Helm**, who discusses not only security-of-supply issues but also climate-change challenges.

It is perhaps useful to elaborate on the limited role that Jaccard ascribes to enhanced energy efficiency in a sustainable energy future for the 21st century. For one thing, his perspective is truly

6 Poland's reliance on gas coming through pipelines of its eastern neighbours is even higher given that 28 percent of its gas is supplied by countries of the former Soviet Union other than Russia. The Czech Republic gets 26 percent of its gas imports from Norway, while Slovenia receives 40 percent from Algeria.

global and takes into account the rapidly rising energy demand resulting from global population growth and the aspiration of people in less developed countries to eventually enjoy some of the energy services taken for granted in rich countries. For another, he makes the point that energy efficiency is a double-edged sword as it lowers the operating cost of energy services, which can result in a rebound in the demand for the service – such as demand for additional decorative and security lighting possibly triggered by the use of efficient light bulbs – or demand for new energy services – such as backyard patio heaters in wealthier northern countries. This being said, his scenario envisions global primary energy use by the end of this century to be some 14 percent lower than it would be if energy intensity declined at a business-as-usual pace. All in all, in his scenario for a sustainable energy system, the energy intensity of the global economy would decline at an average rate of about 1 percent per year through the century.

***Energy efficiency is a double-edged sword as it lowers the operating cost of energy services, which can result in increasing and new demand for energy services.***

Let us, then, consider gains in energy efficiency and reductions in energy intensity from a European perspective.[7] We already know from Figure 3 that the energy intensity of the EU economy has fallen by almost 40 percent since the beginning of the 1970s, implying an average drop of 1½ percent a year. The two oil price hikes of the 1970s have arguably induced a more efficient use of energy – both for productive and consumptive purposes. At the same time, they have lowered the profitability of energy-intensive industries relative to that of less energy-intensive industries, thereby boosting the latter at the expense of the former. In addition, reflecting concerns about the price and availability of imported energy resources and the environment, regulatory changes have mandated an increase in energy efficiency. One should also not forget that since the beginning of the industrial revolution, autonomous technological progress has been contributing to higher energy efficiency, and it is reasonable to assume that this has continued since the 1970s. Last but not least, the increasing integration of developing countries into the world economy has triggered a shift of industry from North to South, thereby reducing the energy intensity of more advanced countries.

Looking ahead, the EU has set itself the objective of accelerating the decline in energy intensity of the EU economy. In March 2007, the European Council agreed on an “Energy Policy for Europe”, the key objective of which is to reduce, by 2020, EU member states’ greenhouse gas emissions by at least 20 percent compared to 1990. To achieve this objective, the Council endorsed the proposal of the European Commission to raise the share of renewable energy resources in the EU energy mix to 20 percent and to reduce EU energy consumption by 20 percent relative to baseline projections. The energy savings target and measures to achieve it are spelled out in the Commission’s “Action Plan for Energy Efficiency”, which observes “it is still technically and economically feasible [for member states] to save at least 20 percent of total primary energy by 2020 on top of what would be achieved by price effects and structural changes in the economy, natural replacement of technology and measures already in place” (European Commission 2006a, p. 5).[8]

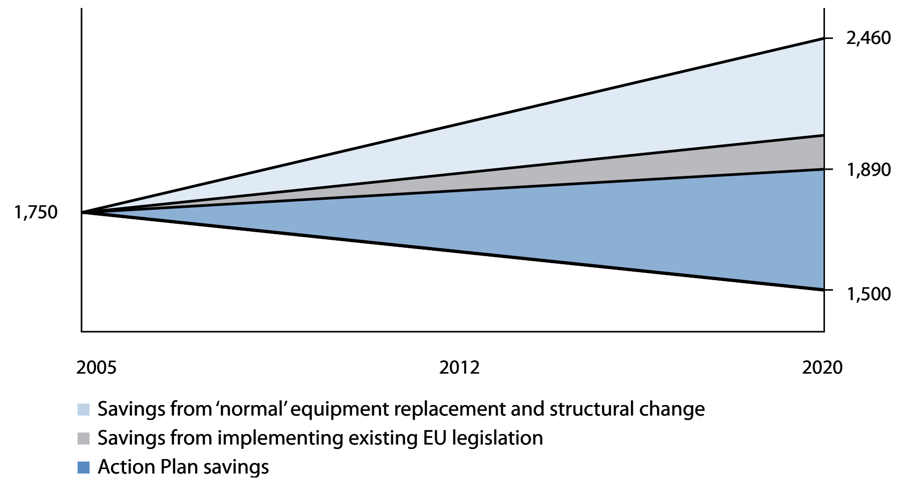
Figure 6 shows a stylised presentation of alternative EU energy consumption paths for the period 2005-2020, including the path underlying the 20 percent energy savings target. The steepest upward-sloping line shows how energy consumption would increase if consumption were to grow in line with projected GDP growth (2.3 percent a year). Energy consumption would be around 2,460 million tonnes of oil equivalent (Mtoe) in 2020.

7 All other things equal, the energy intensity of an economy falls with an increase in energy efficiency. But energy intensity might drop for other reasons too, notably changes in the structure of economic activity such as a rising share of less energy-intensive services at the expense of energy-intensive industry.

8 The Commission estimates that this would result in annual fuel cost savings of around €50 billion by 2012, increasing to around €100 billion by 2020 (for a crude oil border price of $48 per barrel). The decline in carbon emissions resulting from the targeted energy savings are estimated at 780 million tonnes of $CO_2$.

The next line indicates the combined effect of changes in the structure of EU economies and autonomous changes such as normal replacement of obsolete energy-producing/using equipment with more energy efficient one. By extension, the area (light blue) between these two lines indicates the energy savings caused by these structural changes.

**Figure 6. Trends in EU primary energy consumption (in Mtoe) under alternative assumptions**




Source: European Commission (2006a).
Notes: Stylised presentation; Mtoe ≡ million tonnes of oil equivalent; EU-25.

The third line from the top shows the effect of fully implementing policies already legislated at EU level. This consumption path corresponds to the baseline scenario the Commission used for its annual estimate on future developments in energy (European Commission 2006a). In this baseline scenario, EU energy consumption grows at an annual average rate of ½ percent, resulting in a total of 1,890 Mtoe in 2020. Energy consumption growth at this rate combined with GDP growth of 2.3 percent implies an annual decline in energy intensity of around 1.7 percent, that is, 0.2 percentage points more than what was achieved in 1973-2004. The grey area in Figure 6 pictures the energy savings resulting from fully implementing policies already legislated at EU level.

***EU countries have committed themselves to an energy-savings target that is truly ambitious by historical standards.***

The downward-sloping line illustrates the consumption path associated with the Action Plan and the dark blue area indicates the additional energy savings resulting from its implementation. In 2020, total energy consumption would amount to about 1,500 Mtoe, that is, 20 percent less than baseline consumption of 1,890 Mtoe and 14 percent less than consumption in 2005. Relative to 2005, total energy consumption of 1,500 Mtoe would imply an annual average decline in the energy intensity of the EU economy of around 3.2 percent – a truly ambitious goal compared to the drop in energy intensity observed over the last three decades.

To achieve this ambition, the Commission considers it essential that 'best available technologies' be used. Specific additional measures envisaged under the Action Plan include an accelerated use of fuel-efficient vehicles; better use of public transport; tough standards and better labelling on appliances; improvements to the efficiency of heat and electricity generation, transmission, and distribution; and rapid improvements to the energy performance of existing and new buildings. While acknowledging that these measures will not be for free, the Commission maintains that fuel cost savings will more than offset additional cost.

In this context, some of the hoped-for gains in energy efficiency are occasionally described to be as easy to collect as the proverbial twenty-euro note lying on the sidewalk. According to this view, it is a combination of lack of awareness (that there is indeed money on the sidewalk), market failures, and market barriers that prevent energy consumers from realising profitable energy savings. This takes us to the contribution of **Joachim Schleich**, who reviews barriers to profitable investments in energy efficiency and examines the relevance of such barriers in the German higher education sector.

His analysis tries to answer three questions. First, do individuals and organisations really 'leave money on the floor' by neglecting cost-effective measures to improve energy efficiency? Second, what is the nature of the barriers to energy efficiency, that is, the mechanisms which inhibit a decision or behaviour that appears to be both energy efficient and profitable under existing (and expected) economic conditions? Third, do these barriers impede an efficient resource allocation? And, if so, can these barriers be overcome by adequate policy intervention? Considering a variety of possible barriers – such as excessive risk aversion, imperfect information, lack of access to capital, and split incentives – he stresses that policy making needs to distinguish between barriers that would obstruct economic efficiency (and thus warrant policy intervention) and those that do not. Although he does not say so explicitly, it is fair to conclude that technology-based, engineering-economic modelling on which the Commission's Action Plan rests is bound to over-estimate the economically efficient potential for energy savings. Schleich also emphasises that economically relevant barriers are more likely to be found in organisations where the share of energy costs in total production costs is low – such as in the services sectors and public administrations. As for the German higher education sector, he finds that there are indeed mechanisms that inhibit the adoption of profitable energy-efficient measures. A case in point are split-incentives barriers that could be removed or reduced efficiently through measures such as global budgeting at the level of universities and devolved budgeting at the level of departments.

To wrap up our discussion of energy efficiency and its role in a sustainable energy system, most energy specialists would agree that there is scope for economically viable investments in energy efficiency, but how big the scope is remains controversial. Jaccard (2006, p.96) has put his doubts in terms of the proverbial money lying on the sidewalk:

***There certainly is scope for economically viable investments in energy efficiency, but how big it is remains controversial.***

> "Yes, it looks like there is twenty dollars in nickels and dimes scattered along the sidewalk and in the muck of the ditch. On closer inspection, some apparent coins are just pieces of worthless metal, some are difficult to find, some will take effort to clean, and in climbing into the ditch to gather coins I risk falling and injuring myself. I might profit from the effort to recover the twenty dollars, but I might not. I might even suffer substantial losses. I need to consider this carefully before deciding how much, if any, of the apparent twenty dollars in coins I should try to recover because the costs of trying could exceed the benefits."

Let us then turn to the role of renewable energy in a sustainable energy system. In **Mark Jaccard's** vision of a sustainable energy future, they will gain considerable market share without replacing (near) zero-emission fossil fuels as the dominant source of primary energy. To illustrate, in his scenario for 2100, renewables are foreseen to have increased by a factor of eight and to supply primary energy equal to mankind's current total energy consumption. But what will or should drive the expansion of renewables? Many economists – Jaccard and Helm, for instance – argue that a key role should be given to policies that aim at internalising the environmental cost of fossil fuels. In practice, policies of this type – such as the Emissions Trading Scheme of the European Union – are still at an early stage and other policies to promote renewables have so far taken the lead. **Dominique Finon** analyses two of them.

***When choosing between alternative policies to directly promote renewables, one needs to consider possible trade-offs – between cost effectiveness and environmental effectiveness, for instance.***

Focussing on renewable electricity, he discusses the pros and cons of feed-in tariffs and of tradable green certificate systems. To simplify a little: the former guarantees a price for renewable electricity and leaves it to the market how much renewable electricity to produce, whereas the latter fixes the amount of renewable electricity and lets the market determine its price. With perfect information and zero transaction cost both instruments would lead to the same amount and price of renewable electricity. If these conditions are not met, however, results are likely to differ. In these circumstances, argues Finon, economic reasoning does not provide an unambiguous answer to the question which of the two instruments is best for promoting renewable electricity. This is because there is a range of criteria for assessing the pros and cons of alternative policies, and while one instrument might be strong when measured against one criterion, it might be weak when measured against others. There are then possible trade-offs to consider – such as a trade-off between good performance of an instrument in terms of cost-effectiveness and possibly less-than-satisfactory performance with respect to environmental effectiveness. Finon stresses that such trade-offs become more relevant when moving from the principles of a particular instrument to its practical application. Although he finds that, in principle, each of the two instruments could be designed so that its weaknesses are mitigated without compromising its strength too much, experience in various countries seems to suggest that, in practice, feed-in tariffs are easier to adapt to real-world situations than tradable green certificate systems – a conclusion that Finon finds to hold when considering a common European approach to promoting renewable electricity.

Renewables also take centre stage in the paper of **Kolev** and **Riess**. Acknowledging the need for policies to price in the environmental cost of energy and distinguishing between mature-technology renewables and new-technology renewables, they examine the rationale for specifically promoting new renewables. They affirm that it is intellectually easy to think of market failures that could hinder new renewables to establish themselves in the market, but they find it much harder to ascertain the practical relevance of such failures and to decide on the proper type, size, and duration of policy measures. In this context, they stress that so-called experience curves – typically seen as underpinning policies in favour of new renewables – do not inform about possible market failures and using them to gauge the scope of policies in favour of new renewables could cost society dearly. Leaving these issues aside and taking the rationale for promoting new renewables for granted, Kolev and Riess then look at policies in favour of new renewables and investments in new-renewable energy projects from a cost-benefit perspective. In contrast to conventional wisdom, a cost-benefit perspective suggests that new renewables need to do better than just become competitive with mature renewable technologies. Moreover, in contrast to conventional wisdom, a cost-benefit perspective suggests that environmental aspects are largely irrelevant for a rational decision on new renewables when equally clean mature renewables are available.

A common thread of all papers introduced so far is the awareness that the creation of sustainable energy systems will not happen without appropriate economic policies. There is also agreement that market failures provide the main rationale for such policies. And then, implicitly or explicitly all papers emphasise that policies need to set a reliable, long-term framework that encourages sustainable energy investments. The impasse energy-sector investors face in the absence of such a framework is the focus of the contribution by **Juan Alario**. Concentrating on Europe's electricity sectors, he notes that investment has been low in the last two decades but is expected to rise in 2010-20 given the age structure of the existing capital stock. But which type of electricity-technology should investors choose? Alario points out that meeting the EU energy policy objectives will require substantial investments in renewable electricity generation. At the same time, he envisages an accelerating replacement of old inefficient thermal power stations by modern ones. But he sees the timing of this and the choice of technology surrounded by considerable uncertainty, arguing that despite agreement on the broad energy policy orientations by the European Council of

March 2007, policy makers continue to debate the importance of different objectives and the ways to achieve them. A case in point is the arrangement for the post-2012 EU Emissions Trading Scheme and the associated price of $CO_2$. Uncertainty in this respect continues to be substantial, leaving electricity producers in doubt when to decommission existing plants and whether to replace them with coal-fired or gas-fired power plants. All in all, to make the necessary investment in low-carbon technologies happen, Alario argues, policy makers need to establish a credible long-term policy framework that reduces uncertainties.

## 5. Energy revival – for a long life or just a temporary show?

To conclude, energy has returned to the top of the economic policy agenda for good reasons. What is more, the private sector is increasingly interested in providing energy in a manner compatible with a sustainable energy future. To illustrate the point, let us call on *The Economist* (2007) as a witness one more time. In "Cleaning up: how business is starting to tackle climate change, and how governments need to help", the newspaper reports that energy has become the hot new area for venture capitalists and energy companies – all trying to profit from and thereby contributing to the creation of a sustainable energy system.

***Energy has returned to the top of the economic policy agenda, and businesses have joined the fray, seizing profit-making opportunities from the creation of a sustainable energy system.***

Is this all hype or will it last? Should energy-related environmental impacts, climate change in particular, turn out to be less damaging than currently thought, interest in energy matters will fade – for reasons as good as those explaining its recent ascend. Likewise, should stability in energy-rich regions of the world increase and relations among countries, cultures, and religions become more amicable, worries about security of energy supply will certainly recede. As both possibilities are rather unlikely, energy matters should remain high on the agendas of policy makers and businesses. But will they? And how to maintain the current momentum?

As for the climate-change challenge, a lot will depend on whether EU countries deliver on their commitment to substantially cut the emission of greenhouse gases. More important – given the global dimension of the challenge – will be to limit greenhouse gas emissions of rapidly growing developing countries. Making them join international efforts to reduce greenhouse gas emissions will not be easy, raising the thorny issue of a fair burden sharing between rich and poor countries. It will be politically impossible without the United States joining such efforts – not to speak of the substantial difference ambitious US emission reductions would make both for climate change and businesses' interest in contributing to its mitigation.

Being optimistic and presuming that efforts at reducing greenhouse gas emissions become more global than they currently are, which type of policies can we expect to do the trick and to maintain the interest of businesses in performing it? Trying to answer this question is beyond the scope of this overview article – books have been devoted to that question (Helm 2005, for instance). Yet, economic reasoning strongly suggests that trying to 'get prices right' on a long-term basis ought to be a major ingredient of the recipe. As market prices do not tell the economic truth because of various market failures, they are not 'right' and policies should aim at correcting them so that they do tell the truth. This will further redirect entrepreneurial energy and other market forces towards the creation of a clean, enduring, and secure energy system. It is true that getting prices right might not suffice, but without it creating such a system is liable to remain elusive, turn out to be costly, or both.

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## ABSTRACT

***The paper critiques current European energy policy. The key market failures are identified and the reasons for intervention set out.*** *In addition to the traditional concerns with monopoly and market failures, the public goods aspects of diversity and security of supply, together with environmental failures are highlighted. Whilst in the 1980s and 1990s, market power dominated in the context of excess supply, the new priorities of security of supply and climate change require new policy instruments – notably network interconnection, capacity markets, strategic storage, and enhancements to the EU Emissions Trading Scheme. The paper sets out the necessary reforms, together with the institutional structures at the EU level which would provide credibility.*



**Dieter Helm** (www.dieterhelm.co.uk) is Professor of Energy Policy at the University of Oxford, Fellow in economics at New College, Oxford, and an advisor to UK and European governments. He has also advised major private and public sector energy companies and leading financial and private equity institutions, in the United Kingdom and internationally.

# European energy policy: meeting the security of supply and climate change challenges

***Dieter Helm***

## 1. Introduction

It is now widely recognised that Europe faces major security of supply and climate change challenges, and that the myriad of current national energy policies and the underlying market structures are not fit for purpose. Europe requires major investment in its energy sector, after two decades of asset-sweating and cost reductions. This investment needs to meet not only the new realities of gas import dependency, particularly from Russia, but also the transformation from a high- to a low-carbon capital stock. To be fit for purpose – to achieve what the European Commission has called 'a new industrial revolution' – requires a new European energy policy framework.

Despite these challenges and the interdependency of Europe's energy markets, remarkably after a decade and a half of trying to complete the internal energy market, Europe still consists of a set of national markets, many with national champions, connected together by a series of bilateral links. There is not yet much of a European market at all, and only the rudiments of a European electricity grid and pipeline network (see Helm 2006 and European Commission 2007a). This is reflected even in the EU Emissions Trading Scheme (EU ETS), which is very much national in its workings.

This national, rather than European, physical structure of the market is reflected at the policy level too: almost all European countries have national energy policies, and indeed almost all are engaged in national energy policy reviews. In many of these cases, the European dimension has to date received scant attention.

A national approach would not matter if the domain of the problems confronting energy markets remained national too. But a core characteristic of energy policy is that the objectives of security of supply and climate change are now, respectively, European and global. The former necessarily requires a European policy response, and the latter requires Europe to take the lead in gaining global agreement and reducing its own emissions. The third objective – competitiveness – is better addressed too at the European level through the economic efficiencies that arise from integrating energy markets and their networks.

The main purpose of this paper is to outline a rational European policy response to Europe's energy challenges. To this end, Section 2 sets out key energy policy objectives and market failures that require intervention. These failures have a variety of domains, but a core part of the argument for a European energy policy is that they increasingly have a European dimension. Bearing this in mind, Section 3 considers the changing environment in which a European energy policy needs to be set. A salient feature of this change is that Europe, and the world in general, has moved from a situation of ample energy supply capacity in the 1980s and 1990s to one where major investment in capacity will have to be made in the next couple of decades. Cognisant of these investment needs, Section 4 turns to the challenge of ensuring a sufficiently reliable external supply of energy for Europe and Section 5 considers the climate change problem. Having thus prepared the ground, Section 6 presents the main message of the paper, namely that a successful European energy policy needs to be cast in a credible long-term institutional framework. Section 7 concludes.

## 2. Defining the problem: what is energy policy for?

*Energy policy ought to provide the framework within which private companies can be incentivised to promote the broad public good.*

The objectives of energy policy – like any other aspect of economic policy – are aimed at the broad public interest. But in the case of energy, there are some special features, market failures in particular, which provide a focus for the priorities. Energy is a complementary good and it has public goods characteristics (Section 2.1), its provision is characterised by natural monopoly elements and market power (Section 2.2), and its production and consumption create significant negative externalities (Section 2.3). Recognising these special features and multiple market failures, energy policy ought to provide the framework within which private companies can be incentivised to promote the broad public good. A starting point for considering European energy policy is therefore to identify what those failures are, and at what level they arise.

### 2.1 Energy: a complementary good and a public good

Energy is a fundamental input into production and consumption: its ready availability is a necessary condition for economies to function. In economic terms, it is a complementary good. A moment's reflection on a power cut or a crisis in petrol supplies confirms that energy supply is of much greater significance than its apparent share of GDP and – at the limit – its scarcity undermines defence. A number of European and Eurasian countries (notably Ukraine, Belarus, and Georgia) have recently discovered these unpleasant realities in the interruptions in supplies from Russia.

Complementarity is reflected in the fact that the costs of over- and under-supply are asymmetric: over-supply places a relatively small cost over a large number of customers whereas under-supply leads to much sharper cost effects. But since electricity, in particular, cannot at present be stored on a large scale (and storage is expensive for gas), demand and supply have to be instantaneously matched. Moreover, since demand is uncertain and capital investments tend to be characterised by large, fixed and sunk costs and take time to bring on stream, continuous supply means excess supply capacity in power station capacity and their fuel supplies, and in network infrastructure.

This simple observation has radical consequences: the requirement for excess supplies is one that the market will not meet on its own. Excess supply drives down prices, which has the impact of reducing the returns on assets below their economic level. In the absence of intervention, excess supply is likely to be insufficiently supplied, unless some mechanism is found to reward peak capacity. There are several options, including mechanism such as those under the New Electricity Trading Arrangement (NETA) in England and Wales and capacity markets. The former attempts to incorporate the latter in a single market price, but to succeed requires very demanding conditions – notably that governments and regulators do not intervene at moments of peak demand (so that the potential to 'win the lottery' arises) and that generation (and supply) is competitively provided. Capacity markets require a specific market design and regulation, with an external (system) setting of the capacity margin. This is then auctioned, with the added benefit of allowing competition in new generation to compete on equal terms. It does, however, need to be backed up by a duty to supply, which is translated into a duty to contract on suppliers.

If security of supply requires excess supply, it is important to recognise too that the capacity margin in plant and the network itself are together a public good – it is non-rival as well as non-excludable in its benefits. It cannot be disaggregated into a set of individual benefits. And the corollary is that a set of disaggregated decisions in a competitive market will not provide enough of the public good. Therefore, its economics needs to be considered as a whole, and this top-down domain is defined according to the underlying economies of scale.

In the early years of the electricity industry this was at the local level, with each municipality providing electricity systems. In the middle of the twentieth century, the grids moved to the national level – in the case of Britain and France, a high-level grid was defined by nationalised industries and planned accordingly. Power station locations were also part of the planning process. More recently, the domain moved up towards the European level, but without the corresponding coordination and planning. It is this shift in domain that provides part of the rationale for a European approach to both the planning and investment and the regulation of grids.

The gains from higher-level integration are not, however, confined to the technical efficiencies from high voltages and larger power stations. The gains are also in the plant margin and security of supply. The greater the interconnection, the smaller the required aggregate plant margin – from the portfolio effect – and interconnection brings its own insurance by providing greater resilience to shocks. Finally, interconnection reduces the costs of providing diversity. For example, as France becomes more interconnected, others can benefit from base-load, non-fossil fuels, whilst France benefits from having a broader mix of fuel sources.

### 2.2 Technical economies of scale, natural monopoly, and market power

Because of technical economies of scale, electricity and gas networks have significant natural monopoly elements. As a result, they are almost always explicitly or implicitly regulated, and subject to licensing regimes that place major public-interest requirements on their operators. For most, the prices are regulated on the basis of capital and operating expenditure assumptions, sunk capital assets (often called regulated asset bases), and an appropriate rate of return for the industry. Access to networks is also regulated – indeed, this is a major aspect of the attempts to complete the internal energy market. The Directorate General (DG) Energy and Transport of the European Commission (European Commission 2007a), with its supporting reports from the DG Competition energy sector inquiry (European Commission 2007b and 2007c), focuses almost exclusively on the access problem. It argues that ownership unbundling is a necessary condition for upstream and downstream competition.

***Because of technical economies of scale, electricity and gas networks have significant natural monopoly elements.***

It is very unlikely that the fundamental property of falling long-run average costs will be much altered by technical change, making natural monopoly an enduring feature. It follows that network regulation is likely to remain an important aspect of energy policy. The growth of distributed generation is unlikely to alter the fundamental natural monopoly characteristics of energy networks. And since network regulation includes (again explicitly or implicitly) oversight of capital expenditure, regulators (and hence governments) not markets, in effect, determine the investment and interconnection programmes.

Economies of scale have not only arisen in networks, but also in power plants. The trend throughout the twentieth century has been towards larger power stations. Although this assumption may be challenged by the growth of small-scale distributed generation, it is important to recognise that this is a property with some fundamental engineering science behind it, and even in distributed generation, such as wind, it applies at the plant or turbine level. The reason this is important is that it tends to encourage oligopoly as the natural market structure, and limit the possibility of radical micro-level competition. Add to these technical plant characteristics the advantages of operating portfolios of plants in a vertically integrated structure to address the demand and supply uncertainty, and the market form commonly observed in the electricity and gas industries throughout the twentieth century becomes comprehensible. Hence the issues relating to competition and competition policy are necessarily the complex ones of oligopolistic, rather than atomistic, competition.

Some have argued that the portfolio benefits and vertical integration have been radically altered by the coming of modern information technology – that what had to be done by planning within firms (because of the transaction costs before information technology) can now be done through markets. The argument runs: the costs of information coordination have fallen, so that the inefficiencies of central planning are no longer more than compensated for by transaction cost gains from planning.

There is much merit in this argument – cost conditions have been fundamentally affected. But the main effects have not only been within networks, and within generation and supply, but importantly between them. The most radical effect has been to enable transmission and distribution, as natural monopolies, to be operated and developed separately from generation and supply. This possibility is what facilitates the unbundling agenda and the possibility of competition in electricity markets. Prior to the 1980s, this would simply not have been feasible, and an element of command-and-control was then essential to coordinate.

But unbundling does not necessarily solve all the market failures, and it does not follow that there can therefore be many buyers and many sellers in generation and supply. For while information technology has enabled the possibility of a split between generation and supply on the one hand, and transmission and distribution on the other, within generation it has encouraged an element of consolidation of portfolios, and within supply it has added greatly to the economies of scale, scope and density in servicing larger portfolios of customers. Therefore, whilst information technology has facilitated the idea of arm's length networks through which all competitors can access markets, it has also tended to reduce the number of competitors. The result is the rather constricted model in Europe of a small number of very large companies dominating the market.

If unbundling is an effective tool for encouraging greater competition in generation and supply, it now confronts a highly concentrated set of companies. There are not many competitors (and far fewer than in the 1990s) to compete through the independent grids, not just because the European Commission's competition authorities have allowed this concentration to take place, but because the underlying cost structures militate against anything other than an oligopoly model emerging.

### 2.3 Negative externalities of producing and consuming energy

***Climate change is only one of a significant number of externalities from energy production and consumption.***

So far, we have established that energy is a complementary good, with public good characteristics, supplied under oligopoly or natural monopoly, and hence the determination of its capital expenditure (the challenge in meeting the policy objectives in the next couple of decades) will very much be influenced by regulators and governments. However, not only the volume, but also the type of investment matters. A main reason is climate change and carbon emissions. Energy is the core part of the carbon economy, and it is the use of fossil fuels that facilitated the great industrialisation of the twentieth century, and is driving the Chinese and Indian expansions today.

There are a significant number of externalities from energy production and consumption that have required intervention, of which climate change is only one. Coal burning – the main twentieth-century fuel source for electricity generation – produces nitrogen oxide ($NO_x$), sulphur oxide ($SO_2$) and carbon dioxide ($CO_2$). Coal mining generates methane, transport of coal creates emissions externalities, the mining itself consumes energy and coal stockpiles contain radioactive materials. There is heavy metal pollution of water systems and land, as well as health effects on miners, subsidence, and local amenity loss.

Some of these externalities are local, but two are beyond the national level. Acid rain (largely caused by emissions of $SO_2$ and $NO_X$) has required a regional approach to policy, and the EU's Large Combustion Plant Directive has proved an effective mechanism. Global warming is, by definition, global, and hence national policies are likely to be ineffective unless they have an impact on the global level. No individual economy in Europe is likely to make much difference on its own by cutting its emissions.

If climate change is now the dominant environmental problem facing the energy sector, and if it is global in its effects (it is a global public bad), then the policy issue is in two parts: can the EU, by cutting EU emissions, make a difference to the rate of warming and can it act to help create a global agreement for global action? As we shall see in Section 5, the answer to both questions is positive.

### 2.4 Summary

The energy sector is then characterised by multiple market failures. These are sufficiently serious to require significant intervention. This intervention has traditionally been local or national, but the security of supply and climate change concerns both have important European dimensions. Any intervention to address one of these market failures will affect the others – and, in particular, recent proposals (European Commission 2007b) to promote competition need to be considered in terms of their impacts on security of supply and climate change. These linkages are far from obvious. Competition may have mixed effects and it is, at best, not even a necessary condition for solving these other market failures – as demonstrated throughout much of the twentieth century. Indeed, for much of the period, it was assumed that competition was sufficiently pernicious as to require its legal prohibition. Nevertheless, properly applied, it can increase the efficiency of policy delivery. Competition is not a substitute for policy – it will not on its own achieve either security of supply or reduce $CO_2$ emissions. It is one possible means, and needs to operate in an energy policy framework. But before elaborating on this framework in Section 6, we turn next to the changing energy environment against which such a framework needs to be developed.

***The energy sector is characterised by multiple market failures that are sufficiently serious to require significant intervention.***

## 3. The paradigm shift – from the 1980s and 1990s to the new millennium

Throughout most of the twentieth century, national governments relied as far as possible on their own natural resources to meet energy demand. In electricity, that meant domestic coal (often heavily subsidised) and, after the OPEC twin shocks of the 1970s, nuclear power. By the last decades of the century, the three major economies in Europe had energy mixes that reflected these natural resources: for Britain and Germany the mix was coal and nuclear. In both cases the electricity generators were encouraged to purchase fuel supplies from indigenous sources – though, imports were required too, of course, especially in Germany. For France, with very few coal reserves, nuclear became the dominant source in the search for self-sufficiency. The arrival of natural gas provided an additional opportunity to be self-sufficient. The Netherlands and Britain took this route in respect of the North Sea.

As the OPEC shocks of the 1970s – particularly the 1979 shock following the Iranian revolution – took their toll, two key (and related) developments in the European economies had an impact on their energy sectors. First, the sharp recession in the early 1980s reduced growth below the level that had been predicted in the 1970s (and which had been built into the assumptions that determined power station construction programmes), and then changed the composition of developed economies more towards services and away from energy-intensive industries such as steel, chemicals, and aluminium (and indeed coal mining too, which itself is very energy-intensive). Second, and partly as a result of the recession but also because of the break-up of OPEC discipline, fossil-fuel prices fell back sharply, rendering two decades of low prices, well below the assumptions that had motivated the investments made in the 1970s in anticipation of the expected demand and costs of the 1980s and 1990s.

Taken together, these two developments meant that Europe as a whole experienced excess supply (and cheap energy) in the 1980s and 1990s, in some cases – such as that of Britain – massively so. There were exceptions but, for the main economies, this feature had the policy corollary that the priorities were asset-sweating and cost reductions, and the natural instruments to achieve these objectives were privatisation, liberalisation, and competition. They were broadly the right policies for that particular historical context and provided the rationale behind both domestic policies (at very different speeds, according to the political circumstances) and the EU's strive for an internal energy market.

The important point to note is that security of supply did not arise as a serious problem for these two decades at all. Given excess supply and low prices, these market failures did not matter much. There was excess supply and, thus, no need to incentivise companies to invest. And, because there was excess supply, complementarity and coordination problems simply were not manifest. As a result, almost all European countries moved towards energy policies that neglected these concerns – and, in the process, did not address the investment problem.

And, whilst excess supply reigned across Europe, for at least the 1980s, global warming did not figure as an important market failure either. The only serious environmental externality was acid rain, and the politics of the acidification of Scandinavian lakes and the death of Bavarian forests provided the impetus for command-and-control regulation that has largely (but not entirely) solved the problem. Fitting flue-gas desulphurisation to coal-fired power stations, and then bringing on gas-fired power stations at the margin in the 1990s, provided an effective European solution – one of the major successes of the EU to date.

But by the 1990s, the scale of the climate change problem was beginning to be recognised, and the mismatch between a predominantly fossil-fuel-based set of economies, and the need to decarbonise them, began to exercise policy makers. When the 1980s and 1990s came to an end, so too did the predominant market conditions in which they had operated – but, sadly, not their policies. At the end of 1999, oil prices started their fundamental shift (against expectations). Oil prices first doubled from around \$10 and then tripled to reach \$70 in 2006, before falling back (and with a falling dollar) in early 2007. Very cheap oil – and gas – came to an end in a gradual, sustained way. But so, too, did the excess supply conditions across the energy sector (including in oil refineries and oil and petrol delivery systems).

***Asset-sweating and low investment in the 1990s meant that demand and supply came back into balance.***

Eventually, asset-sweating and low investment meant that demand and supply came back into balance. The early signs came in networks where a series of apparently unconnected failures produced power cuts in a number of different areas within Europe (and in the United States). The causes were often trivial – from 'fitting the wrong fuse' in London, to a tree breaking the line in Switzerland blacking out Northern Italy, to a bridge being opened on a German river causing power failures across northern Europe. But these individual and separate cases were symptoms of networks under stress from cost-cutting and low investment. Similar events happened in the oil industry too – notably the BP refinery accident in Houston and the pipe leakage in Alaska, both widely blamed on a dominant strategy of asset-sweating and cost cutting, the predictable response to very low oil prices.

Next came signs that the capacity margins in generation might be under pressure. The dash-for-gas in a number of European countries from the 1990s onwards was not matched by a corresponding development of pipelines and storage. This was most apparent in Britain, where reliance on the main gas interconnector and a single major gas storage facility (Rough) produced a security of supply crisis in the winter of 2005/06. This resulted in a very sharp rise in prices – the way most security of supply crises are reflected – and (almost) compulsory physical demand reductions. Further vulnerability was displayed in the winter of 2006/07 as major faults appeared in the British AGR (Advanced Gas-cooled Reactors) nuclear power stations – a vulnerability mitigated in large measure by extremely mild weather.

The scale of the investment requirements across Europe to replace ageing power stations and to provide the infrastructure for electricity and gas is very large. It is fortuitous that precisely at the time when such investment is needed, it is also necessary to switch from a carbon to a non-carbon capital stock. The new paradigm priorities of security of supply and climate change are primarily investment problems, and it is apparent that the legacy of the asset-sweating decades of the 1980s and 1990s has left the individual countries and Europe as a whole ill-prepared to meet these challenges.

***The scale of the investment requirements across Europe to replace ageing power stations and to provide the infrastructure for electricity and gas is very large.***

In addressing these challenges, a core requirement is that they are solved jointly in a consistent fashion by encouraging investment that fosters both supply security and a reduction in greenhouse gas emissions. To date, each challenge has been addressed separately, and this is a feature too of the most recent policy proposals of the European Commission (European Commission 2007a, 2007b, and 2007c). The Commission has to date concentrated on competition and internal aspects, that is, completing the internal market. Whilst this has merits, what is not shown is how promoting the particular model of competition advocated by the Commission, solves the security of supply and climate change problems too. Indeed, it is notable that many of the proposed interventions on security of supply and climate change are (unlike the internal market approach) explicitly not market-based, but rather pick technologies and involve political and regulatory interventions.

## 4. Security of supply: Russia and Europe's external gas dependency

Unless there is very substantial policy intervention, a defining feature of European energy markets over the coming two decades will be the growing dependency on gas imports, in the context of a further dash-for-gas as the fuel of choice for electricity generation. That gas will come from two primary external sources – Russia and Norway – for the bulk of European demand, augmented by North African supplies into Spain and Italy. North Sea gas will continue for some time to come, but it has been depleted rapidly at a time of low prices in the 1980s and especially the 1990s – indeed, this rapid depletion in the British sector, has been a corollary of the overall asset-sweating approach. There will also be some LNG supplies.

The focus of policy will be on Russia, and for a variety of reasons. It is not only the largest supplier, but also the marginal one, in both economic and political terms. Norway is a reliable supplier, with its volumes determined by the pipeline capacities and the supporting long-term volume contracts. But given Norway's small population and relatively large oil and gas reserves, it has no need to maximise depletion, or to price below the market price for European gas (which will be set by Gazprom). Its gas has nowhere else obvious to go to, except via LNG. The North African supplies are similarly somewhat pipeline-constrained. The North Sea operators may find new ways to extend the lives of fields and small additional reserves, but there is little scope to expand production from what is a mature set of fields. Pipeline gas is almost always cheaper than LNG, except for very long pipelines, and hence LNG will be concentrated on those markets where there is no other alternative – because of geographic isolation – and on those areas where access to market necessitates LNG in the absence of pipeline alternatives. In Europe, LNG will act primarily as a price cap, against the monopoly power of pipeline suppliers.

***Russia has pursued a strategy of maximising the economic rents from its carbon resources, and taken a path similar to other oil- and gas-producing countries in renationalising its resources.***

Russia has pursued a strategy of maximising the economic rents from its carbon resources, and taken a path similar to other oil- and gas-producing countries in renationalising its resources (some 90 percent of worldwide oil and gas reserves are now in state hands). For gas, this has taken a variety of forms, including asserting a legal monopoly over all pipelines in Russia in Gazprom's hands, forcing (through political and other means) incumbents to give up resource rights to Gazprom (for example, most recently, the Sakhalin II project), forcing near neighbours to cede pipeline control, and insisting on long-term contracting methods for supply. Gazprom itself has become highly political and an integral part of the Russian political regime – to the extent that its management is largely politically appointed; it has deep connections with the security services (the FSB); it has bought into the national media to assist the government; and has been used as part of the wider aims of reasserting Russian prestige abroad through Russian foreign policy to near neighbours. Recent events in the Ukraine (winter 2005/06), Belarus (winter 2006/07), Chechnya (ongoing), and Georgia (ongoing) have all had both narrow rent-seeking economic rationales and broader political contexts. The Russian government and Gazprom cannot be considered as independent entities and, given Europe's dependency on Russian gas, security of supply becomes largely a matter of political cooperation and agreement, rather than driven by independent commercial activities.

In this political context, the Gazprom strategy is already fairly clear – at least in outline. Gazprom has identified a series of 'strategic partners' and entered into bilateral deals with individual countries. It has tended to avoid dealing with the EU as a whole, and the slow progress over negotiating a new Partnership and Cooperation Agreement (to replace the current one that expires in December 2007) illustrates this well.

The European position has been focused on the Energy Charter and the Transit Protocol within it (which, in turn, has had a wider context in the negotiations for Russia to join the WTO). The core of the Charter argument between the EU and Russia is a clash of models: Europe favours what might be called the 'British model' – the separation of pipelines from production and supply, and full third-party access to pipelines not only for the EU itself (as set out in European Commission 2007a), but externally too. Russia favours the fully vertically integrated model, with a statutory monopoly over pipeline access conferred on a single monopoly, Gazprom.

So far, this conflict of approach has produced a stalemate – or, rather, enabled Russia to maintain, and indeed enhance its position. Whilst the Energy Charter negotiations have been going on without result, Russia has reinforced Gazprom's monopoly over Russian pipes, and indeed used this control actively to squeeze independent reserve owners into 'cooperation' with Gazprom in return for access to markets for their gas. Furthermore, as noted above, it has pursued an active strategy of gaining control of pipelines downstream from Russia, notably by forcing both Ukraine and Belarus to cede control of pipelines on their territory in return for more gradual price increases.

This strategy has taken a step further with the agreements over the Baltic pipeline and the associated decision about the Shtokman field. Russia has identified Germany as its preferred partner and gas hub in Europe, and Gazprom and Ruhrgas (owned by E.ON) have consolidated this relationship in a number of agreements. In addition to Ruhrgas' long-term shareholding in Gazprom and the long-term contracts between them, Gazprom has publicly supported Ruhrgas and others against the EU plans to force the ownership unbundling between pipelines and gas supply.

But the most significant aspect of this relationship between Russia and Germany – what might be called the 'special relationship' (Helm 2006) – is the Baltic pipeline. This provides a powerful physical link, bypassing Poland and the Baltic states. It increases Gazprom's control over Belarus and Ukraine and, by concentrating the point of entry, it strengthens Gazprom's market power. The fact that the pipeline was approved by Chancellor Gerhard Schröder in his last weeks in power, and that he has become chairman of the company overseeing its development, graphically illustrates the political content of the project.

These developments demonstrate that Gazprom has pursued with the Russian government a coherent and well-designed (from the Russian perspective) strategy in respect of gas exports. It is highly predictable. Russia is likely to concentrate its efforts on limiting independent access to Caspian gas reserves, and in the short term to focus on Georgia (having dealt with Ukraine and Belarus, and with the Baltic pipeline bypassing the Baltic states and Poland). Its downstream pipeline acquisitions and control agreements are likely to continue to feature in its strategy – currently focused, after Germany, on agreements with Italy, France and Hungary. It is likely to resist the Commission's efforts to further the Energy Charter – either by watering down the Transit Protocol or through outright opposition – and (if allowed) it may gradually build up its downstream supply presence in EU countries. This may be gradual and small-scale, or involve larger acquisitions, as the much-discussed Centrica option in Britain.

These considerations point to one necessary component of a new European energy policy – the need to diversify away from Russian dependency and to improve Europe's bargaining power in this very political context. Both are essentially investment problems – in the former, in terms of new investment in power stations and alternative gas sources; in the latter, to provide greater resilience to shocks by better interconnecting and integrating Europe's physical networks. The former is not, in itself, a competition issue, but rather one of the incentive framework within which competition operates. The latter is a regulatory matter – networks are natural monopolies and hence competition cannot solve this problem in providing the appropriate investment. It turns out, as we shall see next, that the former has a direct tangency with the climate change requirements (although security of supply does not necessarily imply non-carbon sources), and the latter will have (beneficial) consequences for the optimisation of the system in ways that can reduce carbon emissions.

## 5. Climate change

### 5.1 The Kyoto Protocol – the current attempt to find a cooperate solution to global warming

The climate change problem has a number of dimensions. As noted in Section 2, climate change is a global public bad. Thus, the appropriate domain is at the global level, and the solution is an international carbon cartel in which all agree to reduce their carbon emissions. Such an agreement is wide open to the obvious free-rider incentives – it is better for each party if the others reduce emissions while it continues to emit them. Hence, the task is to find institutions and policies that create credible incentives for all to cooperate, and to prevent *ex post* cheating.[1]

***The solution to the climate change problem is an international carbon cartel in which all agree to reduce their carbon emissions.***

This challenge is formidable – indeed, so formidable as to have few comparators. Perhaps only nuclear disarmament treaties fit into this category. Yet, given the scientific evidence, this is the challenge facing the international community. Europe's climate change policies should be viewed in

1 See Barrett (2003, 2005) for an exposition of the climate change game and strategies to overcome the free-rider incentives.

this context: as attempts to encourage cooperation, through advocacy and adherence to the Kyoto framework and by European unilateral actions.

So far, the focus has primarily been on the Kyoto Protocol within the United Nations Framework Convention on Climate Change (UNFCC). This provided for quantity targets for a list of developed countries, and Europe's contribution has been in three main parts: to adopt targets for itself; to (successfully) persuade Russia to ratify so that sufficient countries had joined to bring the Protocol into force (by supporting Russia's WTO application); and to (unsuccessfully) persuade the United States to join. It has launched the EU Emissions Trading Scheme (EU ETS) as a market-based instrument to help achieve the Kyoto target, alongside a host of other interventionist policies.

Having got this far, the task facing both the international community and the EU is that this painfully constructed set of targets and policy interventions are, to a considerable extent, time-limited – they mostly come to an end in 2012 at the close of the first Kyoto period. The parties are now engaged in trying to agree on what happens thereafter. So far, very little progress has been made. At its latest meeting in Nairobi, the Conference of the Parties to the Climate Change Convention (COP) and the Meeting of the Parties to the Protocol (MOP) did not agree on a substantive way forward, and despite the growing recognition of the scale of the climate change problem and the gradual change of sentiment in the United States, only Europe has proved willing to speculate on its contribution to a post-2012 agreement, with a proposed reduction of greenhouse gas emissions of at least 20 percent by 2020 compared to 1990, or 30 percent if the United States follows suit (see European Commission 2007a) – subsequently agreed at the European Summit in March 2007 together with an EU target of 20 percent for renewables by 2020.

### 5.2 The leadership argument and unilateral targets

***The adoption of European unilateral $CO_2$-reduction targets can be rationalised on the grounds of equity and global leadership.***

The adoption of European (or, particularly in the British case, national) unilateral targets has a number of rationales. The first (notable in the British case) is that it shows 'leadership' – that, by demonstrating that emissions can be sharply reduced at low cost, this persuades others to follow suit. A global agreement, it is argued, will follow, as a response to the initial first-mover altruism of Europe. Yet, on this argument, Europe (and especially Britain) has failed. In themselves, the targets set under Kyoto do not represent the sort of sharp reductions necessary to tackle the underlying scale of the climate change problem, and make little impact. And even these have proved difficult (and, for some countries, very difficult) to achieve. Few European countries are on course to meet their sub-targets, on the basis of internal policy efforts, and many will have to rely on buying in emissions reductions from outside – via the Clean Development Mechanism (CDM) and through Joint Implementation (JI). The costs – largely in terms of investment in wind power – have proved relatively high, and finally as yet there is little evidence that the United States, or more importantly China and India, have been persuaded by the European efforts.

A second argument is that there is an equity case for European unilateral action – that Europe's industrialisation is responsible for much of the stock of $CO_2$ in the atmosphere, and hence it should bear a greater share of the burden of de-carbonisation. Whilst this has a factual basis, it does not necessarily help solve the underlying problem, which is to include others within a forward-looking agreement. It is easier for others to agree if they have to contribute less (because Europe does relatively more), but the overarching challenge is how to facilitate the industrialisation of China and India, and accommodate another 3 billion people on the planet by mid-century, without significantly increasing emissions. The scale of this challenge needs to be appreciated: world $CO_2$ emissions are projected to rise by around 50-60 percent by 2030, when scientists suggest that a fall in emissions by around 60 percent by 2050 may not be enough to avoid serious climate change damage. As many environmentalists have pointed out, existing policy initiatives are trivial compared with the scale of the problem – mere marginal shifts in scale of the damaging consequences of climate change.

### 5.3 Bringing in other countries

International agreements, however, inevitably take time, and they tend to be built up in an evolutionary and piecemeal fashion, gradually creating expanding coalitions of the willing. For the EU, this means bringing in the United States and Russia as important players. As far as the United States is concerned, the EU ETS plays an important part because this trading scheme is open to a gradual expansion by sectors, such as aviation, and by countries, like the United States, or states within countries, such as California.

***An important step for the EU to create an international agreement on climate change action is to bring in the United States and Russia.***

But whilst the EU ETS provides a framework on which greater participation can be built, its achievements should not be overstated. To date, it has achieved very little in terms of tackling climate change and it has demonstrated just how hard it is to negotiate property rights in carbon even for a limited amount and for a very short period. The heated debates in Europe about the National Allocation Plans (NAPs) for both phase one (2005-08) and now phase two (2008-12) have demonstrated how hard it is for an agreement to be reached even over such very modest caps. The political necessity to grandfather permits and the recognition that competitive markets are necessary to efficiently price them have further complicated matters. The price of permits has been volatile, very susceptible to measurement and reporting, and there have been significant windfall profits. The value of permits to incumbents as entry deterrents has also been apparent.

The EU ETS, given that it expires in 2012, as yet provides no credible basis for investment in the energy sector – almost all the significant new investment required both to decarbonise the European economy and to meet the security of supply considerations discussed above will come on stream after 2012 and will be financed on the basis of the revenues (and hence incentives) available after 2012. This applies especially to renewables, nuclear, and more speculative and R&D-intensive options such as carbon sequestration and storage. The EU ETS does not (yet) provide a long-term price of carbon – perhaps the most important incentive to reduce carbon emissions. And since the price is a matter of political and regulatory risk, the absence of a long-term price of carbon increases the cost of capital, which is a key variable for nuclear, renewables, and R&D investment decisions.

Thus, the core energy policy requirement – low-carbon investment – is not much affected by the EU ETS. Indeed, it might be argued that some of its effects are actually negative as carbon-intensive interests are able to argue that while we are waiting for the post-2012 EU ETS framework, other actions, such as the introduction of carbon taxes, should be postponed. It is therefore not surprising that many carbon-intensive interests have been enthusiastic about the EU ETS – in fear of other, more effective, policies.

The European Commission (2007a) tries to address these concerns and shape this post-2012 context by proposing two targets. The first – adopted at the European Summit in March 2007 – is a 20 percent reduction by 2020; the second is a 30 percent reduction by 2020 if the United States joins in with reciprocal arrangements. But here we need to separate out the difference between a credible target – which can be banked as part of an investment appraisal – and a mere aspiration. If there is no agreement on a post-2012 EU ETS framework until, say, 2011, as seems likely, the prospects of the EU ETS including caps sufficiently tough to achieve the 20-percent or 30-percent targets may be slight, especially if large-scale investments are delayed until the outcome of the caps is known. For technologies such as nuclear, the timescale for large deployment is such that if a new investment programme does not start until 2011 or 2012, then not much could be contributed by 2020. In the meantime, much of the existing nuclear capacity would start to be decommissioned (especially again in Britain), and be displaced by gas, increasing relative emissions and reducing security of supply.

The approach to Russia is more complex. Last time, Europe used the WTO membership card as part of its negotiating strategy – EU support for Russian WTO membership was a *quid pro quo* for ratifying Kyoto – thereby allowing it to come into force. Next time around, the bargaining counters are less obvious. What inducements could Europe offer to what is largely a carbon economy? Despite claims to the contrary in the Stern Review,[2] the Russian political elite has little to gain by agreeing to a radical international climate change agreement. Global warming has a number of obvious benefits to an economy currently constrained by ice-bound ports and permafrost. And from the narrower political perspective of the Putin regime, global warming does not look that bad, and this will reinforce its negotiating position – and the effect of this negotiating position on its client states.

### 5.4 Summary

***Mitigating climate change is, like security of supply, primarily an investment problem, with the added twist that it requires global cooperation and agreements.***

To summarise, climate change is, like security of supply, primarily an investment problem, with the added twist that it requires global cooperation and agreements. Whilst Europe can tackle security of supply as a problem determined by the external constraints (and, in Russia's case, it may just have to take these as given), on climate change the challenge is to persuade others. So far, the Kyoto targets do little more than scratch the surface, and although very timid relative to the wider problem, they have proved hard to achieve. The EU ETS as a chosen instrument has made a positive, but limited, contribution and is yet to be tested as a mechanism to create a long-term price of carbon. Neither the United States nor Russia has been persuaded to take significant action.

## 6. Creating a credible framework for a European energy policy

### 6.1 From liberalisation to a broader energy policy agenda

To date, European energy policy has been almost entirely focused on liberalisation and competition. The aim of the 1992 Single Market Programme was to complete the internal energy market, and the 1990s witnessed a long-drawn-out tussle between the European Commission and the large energy companies, primarily in Germany and France. Their governments lent at least tacit support to this feet dragging, and the resulting Directives (1996 Electricity Directive, 1998 Gas Directive) were the lowest common denominator.

The war of attrition continued into the 2000s. The oil shock in 2000 resulted in all main countries having second thoughts – the 2000 EU Green Paper on Security of Supply (European Commission 2000) treated security as a separate issue to competition, with only the British maintaining that competition was the route to security. The United States similarly produced an energy plan in 2000, which mirrored the concerns in Europe over import dependency, but in the US case concentrated on oil dependency and self-sufficiency, rather than gas.

Quite separately from the energy concerns, the Lisbon agenda promoted liberalisation more generally, setting out a programme to free up a range of economic activities. Though services became a core controversial target, energy was kept on the agenda, and this eventually resulted in the sectoral inquiry launched by DG Competition in 2006. This quickly focused on one core issue: whether there should be ownership unbundling of networks.

2 See Stern (2006).

The security of supply issue did not, of course, go away – on the contrary, the Hampton Court Summit under the British Presidency in November 2005 tabled a paper on energy policy (Helm 2005b), which was carried through to a new EU Green Paper in March 2006 (European Commission 2006). At the core of these papers was the idea of completing the physical networks – the European grids.

And whilst these two separate strands of policy – competition and security of supply – were being developed, a third strand was the development of climate change policy in general, and the EU ETS in particular. Finally, again quite separately, the EU was engaged in two parallel negotiations with Russia: on the Energy Charter and the Transit Protocol, and on the Partnership and Cooperation Agreement.

The communication "An energy policy for Europe" of January 2007 (European Commission 2007a) marks a further stage in this policy evolution. It has the merit of bringing all various strands within a single set of papers, but the connections between them are far from apparent. The reason for this is partly the timing: the main driver is the DG Competition inquiry (European Commission 2007c), and its conclusions dominate the communication. The other bits are tagged on – with a host of targets and measures, the result of a corralling together of the items on the energy agenda and a political compromise – playing to each of the interests and constituencies.

### 6.2 Building blocks for a credible framework for a European energy policy

It is a core result of economic analysis that there needs to be at least as many instruments as targets. An energy policy framework starts with the objectives and targets, before the instruments are set. For EU energy policy, as argued above, the two key objectives are security of supply and climate change. On security of supply, the EU does not have any formal targets at all. It wants more security through diversity, but does not say how much. Similarly on the networks and interconnections: interconnections are a 'good thing', but the Commission approach is then to identify specific links, without providing the rationale as to why these links are consistent with the objectives as compared with other candidates and, more importantly, what the desired target level of interconnection is. On climate change, the Commission provides no rationale for the targeted 20 percent reduction in greenhouse gas emissions for 2020 (30 percent conditional on United States doing likewise) as opposed to any other target (15 percent? 25 percent?) and no clear linkage between this target and the stabilisation of greenhouse gas concentration as proposed by the Intergovernmental Panel on Climate Change (IPCC) or other scientific bodies.

The first task in creating a coherent EU energy policy is then to set clear targets, grounded in appropriate analysis. On security of supply, the diversity target does not need to be based upon specifying technologies. Rather, it should follow a route to rewarding investors for the system value provided by diversity in new plant and infrastructure. For example, LNG terminals reduce dependency on Russia, and might command a premium in the market for doing so. Similarly nuclear plant diversifies away from gas imports, as does new coal investment. The EU might set an overall target for the level of gas import dependency on Russia for example, but such a target is only credible (rather than an aspiration) if there are means to achieve it. Plant capacity margins within countries might be set, and these could automatically have a European dimension if interconnections are added into the calculation.

***The first task in creating a coherent EU energy policy is to set clear targets, grounded in appropriate analysis.***

On climate change, the choice of a medium-term target has the merit of being achievable, but only if it is then embedded into the national actions of member states. The obvious way to do this is to set the EU ETS National Allocation Plans on the same basis.

*Security of supply requires excess supply and there are a variety of mechanisms by which this might be achieved.*

We noted in Section 2 that security of supply requires excess supply and that there are a variety of mechanisms by which this might be achieved. On the assumption that NETA-type mechanisms will not suffice,[3] the first step in instrument design is to establish the required investment levels to meet the security of supply targets. These can then be auctioned through capacity markets. In the absence of interconnections, it has to be on a national level, but as interconnection grows, it could be European-wide. And in the meantime, as interconnection grows, it is important that member states harmonise their approaches to incentivising capacity margins, so that they become fungible. For example, Britain could build new nuclear plants in the south of England, or it could import through new interconnections from France, which could build the plants for Britain. As the evolution from different local electricity systems to national ones in the middle of the twentieth century shows, harmonisation across EU countries could foster an analogous European evolution and associated efficiency gains in the next decades. Given that incumbents are unlikely to welcome the competition that comes through new interconnections, they have little incentive to harmonise, and hence it needs to be imposed.

Diversity could similarly be rewarded through diversity markets. Traditionally, the approach has been to designate fuel shares (for example, a 20-percent share of renewables in total electricity generation). However, such policies require governments to pick technologies (and in the case of renewables, to define them first), and the history of 'picking winners' is not a happy one. The alternative is to create a 'value for diversity' – analogous to the loss of load probability – and reward technologies accordingly.

In both cases, harmonisation is not only an important feature of an efficient approach, but there needs to be a common base against which to apply the security and diversity costs. Many incumbents argue that this can be achieved through long-term take-or-pay contracts. These have merits, and are a core feature of competitive as well as monopolistic energy markets. But the tie-in still needs to be established and the most appropriate base is the suppliers' licence. In effect, the duty to secure supplies is translated into a requirement for suppliers to contract for sufficient capacity margins, and for sufficient diversity. Both are purchased through the respective markets.

In Section 2 we also noted the public good characteristics of energy networks. To recall, interconnections allow portfolio benefits to be reaped from the mutual reliance on each other's capacity margins and from greater diversity as a result of the heterogeneity of connected systems. In the case of emergencies, mutual support becomes feasible. For example, in the Ukrainian crisis in January 2006, the ability of EU countries to come to the aid of those facing shortages of gas supply was limited because the pipeline interconnections did not exist. Similarly, Britain's exposure to shortfalls from continental suppliers was exacerbated by reliance on a single interconnection.

The public goods characteristic has another implication: the benefits of a particular interconnection arise not just between the two parties at each end of the wire or pipe, but to everyone else interconnected to the two parties. Thus, the gains from interconnection between the two will underestimate the broader value to the internal market as a whole.

From this observation follows an important implication: the optimal European gas and electricity grids will not arise in a piecemeal evolutionary way – they need to be thought through from a system-wide and top-down position. The task of the EU is not only to encourage particular interconnections, but also to provide the map within which they fit, and the target should be the completion of the overall map, and not just assisting particular new bilateral links.

3 See Helm (2004), Chapter 17.

Let us then turn to the external dimension of Europe's supply security and instruments to achieve it. Improving gas interconnections within Europe and further developing interconnections between Europe on the one hand, and the Caspian area and North Africa on the other (that is, alternatives to Russian pipelines) all improve gas security of supply, as does LNG. However, none of these is likely to make Europe entirely safe from a physical interruption of supplies from Russia (or an explosion or terrorist act on pipelines), since the demand for gas is growing at a rapid pace and a further likely dash-for-gas will exacerbate this trend. The Baltic pipeline and the coming on stream of the Shtokman field will add to the tendency towards dependency.

In such circumstances, it makes sense to consider strategic (as opposed to commercial) gas storage. The argument is analogous to that for electricity capacity margins. Commercial storage exists to match contract requirements. Strategic storage is additional to commercial requirements because it represents a deliberate excess supply to the system as a whole. Naturally, as with electricity capacity margins, incumbents resist the concept, since excess supply tends to suppress prices and hence profits. However, again as with capacity margins in electricity, the strategic storage is an insurance service to the system, and should be paid for. The extra requirements should be auctioned, and a strategic storage market created as a result.

Finally, there is the foreign policy dimension of import dependency on Russia. At one level, there is little the EU can do about it. Gazprom (and by implication the Russian government) is behaving very rationally, as argued in Section 4. The rents from natural resources are being maximised by control of the pipelines to the exclusion of all others. This approach is unlikely to change, but to the extent that Russia can be induced to act in a more benign way (in particular in refraining from interrupting supplies as a result of disputes with its near neighbours), the broad foreign policy payoffs need to be taken into account. The EU-Russian relationship is multi-dimensional. As noted above, Russia ratified the Kyoto Protocol in part because the EU promised to help out on the WTO membership issue. Currently, the EU and Russia are engaged in debates about Iran and nuclear weapons, and human rights. Energy is just one component, and a priority for the EU must be to gain greater bargaining power through internal EU energy market reforms along the lines discussed above, that is, completing the physical European gas and electricity grids; creating greater strategic gas storage, capacity margins in general, and diversity of gas supplies; and further developing non-gas technologies.

Across Europe there is a host of different *ad hoc* interventions to address climate change, some directly and others loosely linked to the overall targets. Almost all member states have policies for energy efficiency, renewables, information provision, government procurement policies, forms of carbon taxes and levies, and command-and-control on large plant emissions. These have been built up in a piecemeal, national basis.

***Across Europe there is a host of different* ad hoc *interventions to address climate change, some directly and others loosely linked to the overall targets.***

Within this patchwork of policy initiatives, the EU has tried to provide an overarching set of instruments. The primary one is the EU ETS. It has many merits, but as identified above, it has major limitations in its current form, notably the short-term nature of the scheme (with little impact over investment horizons), grandfathering, and the negotiating approach to the NAPs. The immediate task is to tie the EU ETS into the longer-term (2020) targets, so that a long-term price of carbon develops.

Renewables obligations are more difficult. The European Commission (2007a) proposed a 20-percent target for the share of renewables by 2020 (which was then adopted at the European Summit in March 2007). Although it is fashionable – and therefore politically expedient – to be in favour of renewables, the policy suffers from a number of obvious weaknesses: there is no distinction between zero- and low-carbon technologies; nuclear is excluded; network development is often not coordinated and the costs of developing networks are not taken into account in most member states' calculations of contributions to the target; and there is little or no trading of the renewables targets between countries. This last consideration is particularly important from a cost perspective: there is no reason why each country should have the same target to be achieved within their own geographical domain – it may be much cheaper to pay another member state to deliver (or another non-EU country since climate change is a global public bad, and hence it makes no difference to the overall climate change where the renewables operate).

If there is to be a zero-carbon technology quota, it should be as broadly defined as possible (i.e., include all zero- or near-zero carbon technologies) and it should be an EU-wide policy with trading in renewable certificates between member states and with a buy-in mechanism, based around the CDM and JI in the Kyoto Protocol.

The rationale of a quota for renewables is better grounded in the new or infant technology argument. But this requires an R&D policy solution, for which European energy research projects, demonstration projects and subsidies are more appropriate than a general quota that has in practice focused overwhelmingly on wind power.

Energy policy needs a framework, within which companies compete, typically in oligopolies. The framework needs to be credible: private investors need to be able to rely on the framework, and predict how it will evolve. Given the incentives for *ex post* opportunism by governments to expropriate investors, and that these incentives are readily supported by examples (windfall taxes, changing the nature of renewables and nuclear support, altering taxes, and so on), credibility and the cost of capital are closely related. Gaining credibility involves institutional design – independent regulatory bodies and agencies, climate change agencies and related bodies are all part of building credibility by raising the cost to governments of *ex post* interventions.

***Regulation of networks is inevitable because of their natural monopoly characteristics.***

This is where the issue of a European regulator comes in. Regulation of networks is inevitable because of their natural monopoly characteristics. As the European networks develop, power stations will only be efficiently dispatched if the dispatcher has access to the system as a whole, and at prices which reflect the underlying (marginal) economic costs. But to date each network has developed its own accounting and regulatory principles. These need to be harmonised for an efficient dispatch, and hence regulatory competition between the national agencies needs to be replaced by a common approach. The existing college of national regulators needs to be brought together under a common set of rules.

It is in this area that separating out grids helps considerably. Separate grids, with independent system operator (ISO) functions of their own, will be licensed separately. Alongside the college of regulators, a college of ISOs might sit, and it is a small step to harmonise the licences they are issued with.

This is the minimum institutional step. But there is more to add at the European level. Next is the issue of the grid maps, of providing a common picture of the optimal grid to which the investments should be directed. The coordination benefits would be very considerable – and not just to the independent grids. The investment appraisal of future power stations and the choice of locations is much more straightforward if the future shape of grid investment can be predicted. Complementarity and coordination reduce the cost of capital.

The forms and operation of the capacity and diversity markets identified above also fit into a common European institutional framework. As argued, market designs need to be harmonised and this is best done according to European rather than national criteria.

***Market designs need to be harmonised and this is best achieved based on European rather than national criteria.***

The final institutional component comes from the climate change side. The EU ETS is already effectively regulated by the European Commission, which is also the focus for setting NAPs. By separating this out from the Commission to an independent regulatory body or European energy agency, the negotiations would become less amenable to capture by political lobbying, and the necessary expertise to develop the markets could be focused within a single body.

These various considerations point towards the creation of a single regulatory agency for European energy policy, within which the various dimensions of energy policy can be established and developed, from security and diversity markets, to the auctioning of strategic capacity, the development of an EU-wide renewables obligation certificates market, and the enhancement of the EU ETS.

## 7. Conclusions

Market failures are endemic to energy markets, and they are multiple. Energy policy is the design of a framework within which a number of different objectives can be met through markets, supported by appropriate instruments.

For the last two decades of the twentieth century, these failures were largely masked by excess supply and low fossil-fuel prices. Since 2000, this context has gradually changed. Europe now faces serious security of supply problems and, at the same time, the climate change challenge has become urgent.

Energy policy in Europe – as elsewhere – has been chasing to catch up with the agenda of the 1980s and 1990s, and liberalisation and fostering competition have been the main instruments. The latest policy proposals (European Commission 2007a) are aimed at completing that agenda. However, the world has moved on, and while competition might have many benefits, it cannot alone solve the other market failures. Recent fears over Ukraine and Belarus, combined with growing alarm over climate change, have begun to shift this complacency.

This paper has reviewed the main components of an energy policy in Europe and suggested a number of changes that might improve the current position. These steps are not, however, discrete and distinct – they need to be integrated into an overarching policy framework, and they need a significant element of harmonisation that goes well beyond enforcing liberalisation and grid separation, which are the Commission's main concerns (European Commission 2007a). A Europe-wide regulatory agency is required to achieve this necessary harmonisation and to ensure that capacity, diversity, renewables, and carbon markets function effectively on a EU-wide basis.

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## ABSTRACT

***Countries thus far realise their energy security predominantly with energy policies (e.g., diversifying the energy mix and suppliers) and their energy security risk instruments mostly address the risk of short-term supply disruptions.*** *Lack of commercially viable sustainable energies and a renewed concentration of oil and gas supply in the future will reduce the effectiveness of traditional energy policies. Before sustainable energies become widely available, consumer countries are likely to experience increased competition for diversified oil and gas supplies. At the same time, geopolitical enmity shows that energy security will become firmly integrated in the foreign and security policies of a nation. In fact, the current risk landscape is determined by geopolitical rivalry over control of and access to energy-rich regions and by regional risks arising from politico-economic instabilities.*

**Coby van der Linde** (clinde@clingendael.nl) is Director of the Clingendael International Energy Programme (CIEP), Institute Clingendael, The Hague; Professor of Geopolitics and Energy Management at the University of Groningen, the Netherlands; and member of the Dutch Energy Council.

# The art of managing energy security risks

*Coby van der Linde*

## 1. Introduction

Energy risks have fundamentally changed in the period after the demise of the Soviet Union, the rapid rise of India and China, and the start of the 'war on terror'. Following two decades of a largely market-based system of energy supplies, a re-politicisation of energy is taking place, with far reaching effects at the global system level, for countries, and for energy companies. Deep uncertainties about the structure of the emerging oil and gas market and the rise of resource nationalism in producing countries are forcing member countries of the Organisation for Economic Cooperation and Development (OECD) to rethink their energy policies in light of increased levels of political uncertainty. For member states of the European Union (EU), the high degree of asymmetric risks in oil and gas security is a challenge to the integration agenda. Risks are shifting at the national level, and growing in the global system.

Many of the risk assessment and management tools used by most western consuming countries, and by (international) oil companies, were developed after the 1973-74 oil crisis. These tools were adapted to the market-oriented approach prevailing in the 1980s and 1990s. This toolset is unlikely to be anywhere nearly as effective in the emerging risk environment, even though it worked well for decades when market forces largely determined supply and demand. The problems that arise in the new environment have been at the heart of economic policy in recent years.

The wide ranging effects of this transformation need to be understood in a framework that distinguishes the three different levels of the international system. There are sub-national actors such as large energy companies, whether private or state-owned. Next, there are countries, whether energy suppliers or consumers. Finally, there is the global system itself, including supranational groups like OPEC, the UN, the EU, and other international organisations that bear on energy matters. To appraise the energy security risks at the global level and the responses of governments and other actors to the new environment, an analysis of the evolving international system and the divergent government strategies is presented in the form of scenarios. Although the scenarios touch on many different problems, they are necessarily truncated. In this context, they are a tool that illustrates the new energy security risks that arise from competing energy security strategies and force us to make assumptions about the rationality of policy makers and market actors. As it turns out, the bounded rationality of policy makers distorts the ability of states to create coherent and economically robust energy strategies – that is, strategies that would allow policy makers to anticipate a shortfall in supply and to apply appropriate energy risk management instruments. At the same time, the concentration of supplies on a limited number of energy-producing countries shows that the required diversification of risk decreasingly applies to oil and gas.

The basic insight of this paper is that the performance of the old toolset is declining at all levels of this system because of the re-politicisation of energy. Risk spreading through financial markets (e.g., forward and derivative markets); environmental risk management (e.g., double hulling tankers); and diversification of both energy supply and sources of supply (e.g., renewables), remain important. These risk management tools will continue to be used, as they must be. But alone they are not able to handle the newly added political risks of a world where supply is increasingly concentrated in the Middle East, the Caspian Sea region, and Russia – where investment options serve national interests rather than the international market – and where new players, such as Brazil, India, China, and others, are increasingly important actors. The success of the old security of supply mechanisms rested with the availability of sufficient oil supplies outside OPEC in the period 1980-2000 that stripped all supplies of its national interests in the international markets. In the current setting, oil and gas supplies are becoming more concentrated, demand from new high-growth economies is growing, and climate change policies limit the fossil options. The fear of losing easy access to energy and markets and inadequate institutions to deal with the social and political risk arising from resource competition has exacerbated the emphasis on national interests in producing and consuming countries and has thus elevated energy to a geopolitical issue. Current efforts to deal with conflicts arising from resource competition are difficult to reconcile, as the existing rules shaping the game are the result of an unequal development pattern that is exacerbated by market imperfections and inadequate existing institutions. Thus, this paper will focus on the two highest levels of aggregation: nations and the global system itself and it will show that international markets have been too insensitive for too long to national political and social interests. While the national response was predictable, a new set of international rules is needed to account for the changed circumstances of the global system in order to prevent geopolitical clashes over energy security and climate change.

The remainder of this paper is structured as follows. In the following section we develop a framework for understanding the changes in the international system and their impact on international energy relations. In Section 3, we document some key oil and gas facts and explore some future expectations. In Section 4, energy policy and energy risk management instruments are explained. In Section 5, the risk landscape in a changing world will be explored, focusing on the relations among consumer and producer countries in the framework of a new international order. In Section 6, risk management options will be explored. Section 7 concludes.

## 2. Paradigm change

***In the early 1990s, the view was that globalisation would be followed by a shift to more effective legal, institutional and political structures.***

To better understand the changed environment in international energy supply, it is useful to contrast it with the expectations of the early 1990s. At that time, changes in the international political and economic system were heralded as an important breakthrough for the proponents of globalisation. Both the United States and Western Europe expected a rapid integration of the global economy. There was a surprisingly optimistic view that globalisation of the economy would be followed by a positive shift to more effective legal, institutional and political structures that would contribute to equity and growth (see, for instance, CIEP 2004, Van der Linde 2005, and Hoogeveen and Perlot 2005). Oil- and gas-producing countries were themselves expected to make the transition to globalisation. Membership of the World Trade Organization (WTO) and foreign direct investments (FDI) were an important tool in facilitating this integration.

It is important to understand that this globalisation scenario contained implicit and explicit risk management strategies. It greatly limited political risks by forcing nations to operate as if market forces were the primary ones determining supply and demand. It further envisioned a major shift in global values. Environmentalism, democratic movements, and a stigma of illegitimacy attached to the use of force were seen as more or less inevitable outcomes of economic globalisation (Giddens 1990).

But this scenario failed to materialise, despite the high hopes that it would. Rather, what happened can be called 'weak' globalisation, as distinct from the 'strong' globalisation envisioned in the early 1990s. It is important to understand that global anarchy did not occur or anything close to it. But neither did a strong form of globalisation. It was 'weak' because it was mainly accepted at the conceptual level, although the self-interest of (nearly) all states in macroeconomic stability was also a major factor in its acceptance. The evidence indicates that it did not go deeper than this into the underlying institutions of the nations that make up the international system. For example, despite the recycling of oil dollars through the private banking system, some Middle East OPEC nations actually reduced their level of integration within the financial system. For this group of countries, the growing population and low oil prices since the mid-1980s undoubtedly increased pressure on the state to facilitate economic growth and social development. On the spending side, economic and social pressures from below crowded out the governments' ability to invest in new oil production capacities. The expectation in the early 1990s was that these countries would gradually open up for foreign direct investments to finance the replacement of mature production capacities at home and abroad. But this did not happen either.

***In the event, most governments of oil-producing countries re-centralised power over political and economic life and liberalisation of the economy, let alone the oil sector, was no longer appealing.***

The Asian crisis of 1997 exposed the risks of rapid integration in the international economy without providing for proper political and institutional reforms to accompany it. The interaction between weak institutions and the crisis, which led to large financial losses, reinforced the lesson that integration in the world economy required deep institutional and political reforms in the domestic economy. Precisely because the costs of reform are high and the shift to stronger regulatory and supervisory structures are politically difficult to implement, many governments and political elites shied away from these policies to avoid creating even larger social and economic instability, and in the process losing their power base. In many oil-producing countries, the oil riches had not brought about a lasting increase in economic welfare, but rather created a boom-bust type of economy entirely dependent on natural resources. Furthermore, the distribution of oil wealth was extremely skewed. The Asian crisis was accompanied by a steep drop in oil prices and resulted in an economic crisis in most of the oil-producing countries (among them the OPEC countries), limiting their appetite for further reforms. Only some smaller countries with mature oil industries were able to restructure the economy. In contrast to the globalisation scenario of the early 1990s, oil-producing governments re-centralised power over political and economic life. Liberalisation of the economy, let alone the oil sector, was no longer appealing.

At the turn of the 21st century, the optimism of realising fast-track integration in the world economy became further subdued with the 9/11 terrorist attacks on New York and Washington and the subsequent strategic reorientation and economic downturn in the West. Taken together, all of these factors radically altered the energy risk landscape. The view that the integration into the world economy would automatically bring about more political and social progress, adherence to international norms of law and order, and would reduce the risk of failed states and violent internal conflicts, was rudely proven misguided. Despite the success of some countries to make a rapid transition into open and democratic societies that are fully integrated in the world system, many countries – among them the largest oil and gas producers – are not on such a development path at all, but remain rather stuck in their non-integrated ways.[1] Their integration was at best only partial and did not include the legal, institutional, and political changes required for full integration.

'Weak' globalisation poses challenges for some large oil- and gas-producing countries. In the period from the mid-1980s to the late 1990s – after OPEC countries had experienced a substantial loss in market share as a result of their earlier price policies – they kept the global economy supplied with sufficient oil and were sensitive to keep the price at a level acceptable to the consumer countries. The role of swing producer was performed by Saudi Arabia and the United Arab Emirates (UAE). Kuwait could no longer perform this role after 1990. The world economy relied heavily on the ability of these two major producers to provide the market with buffer capacity.

1 The central European countries are notable examples. Perhaps because they integrated in the EU rather than into a more anonymous world, they were able to make such a rapid transition. Yet, three years into EU membership, domestic political stability is waning and the disappointment among the population is growing.

Still, the integration of China and India into the world economy assumes the availability of energy, in particular oil and gas, which is abundantly available in the Persian Gulf region and Central Asia, but also in some other countries such as Venezuela and Russia. With the oil production in non-OPEC countries maturing and the continued increase of consumption, in particular in the big emerging market economies, the confidence that the required capacities will be developed using a market system can no longer be counted on. In other words, for two decades the oil market transformed political uncertainty into price risk. This was a major structural achievement. Price risk was managed by market-based solutions, including forward markets and derivatives. But the market system now is not performing this role nearly as well, not because of financial inefficiencies but because of a geopolitical restructuring in the strategic environment of energy.

***New alliances and major constraints on energy development fundamentally alter the existing risk landscape of energy.***

With the expansion of Liquefied Natural Gas (LNG), a similar development was expected to emerge on the natural gas market, increasingly linking regional gas markets and making take-or-pay long-term contracts ever more obsolete with the deepening of gas market integration. Thus, the enthusiasm with which gas-consuming countries wished to apply market-based principles on their gas markets was not shared by producer countries that were at the onset of huge investments to realise the new export capacities. They perceived the market-oriented approach of consumer countries as a means to shift the investment risk to them and their national companies without the security of demand that such investments warranted (Van der Linde *et al.* 2006). Increased distrust in the ability of the international market economy to produce the energy requirements according to market rules can create a substantial crisis at the global system level that will ripple through to nations and companies. Consequently, oil consumers who believe they can no longer rely on the international market system to provide them with sufficient oil will 'explore' more politically oriented strategies to satisfy their needs. Whilst not predicting energy wars, they cannot be ruled out *prima facie*. Rather, new alliances – as exemplified by deals between Iran and India and China – and major constraints on energy development – as in Russia – fundamentally alter the risk landscape of energy and may lead to more struggles.

This development, in turn, changes the risk map for the United States, the European Union, and Japan. The change of the international system away from the economically integrated and multilateral cooperative world renders some of the energy security approaches and risk management policy tools much less effective.

For a discussion of the current and future energy security risks, it is important to review the development of supply and demand. The current oil and gas markets have invoked the current energy security fears and will prompt new policy directions.

## 3. Some basic energy facts and expectations (1980-2020)

### 3.1 Reserves

Since 1984, world proven oil reserves have continued to grow, but there continues to be an uneven distribution of reserves, with countries in the Middle East – in particular the countries around the Persian Gulf – dominating oil reserves (see Figure A1 in the Annex). This uneven distribution is even more pertinent in the case of natural gas, with a mere 3 countries (Iran, Qatar, and Russia) representing 57 percent of world proven reserves.

The share of North America and Europe, traditionally large consumers of oil, in proven conventional oil reserves is declining, while the share of reserves of Asia, with its fast increasing share of world oil consumption, remains low. The outlook for the main consuming countries is that they will increasingly rely on imported oil and gas. For the North American market, the outlook is somewhat different if unconventional oil is included because the distribution of these reserves differs significantly from the distribution of conventional oil. The share of both American continents in this type of reserve is substantial. The International Energy Agency expects that increasingly unconventional oil will find its way to the market (IEA 2006). The major constraint on developing unconventional oil resources is the production and environmental cost, particularly in terms of $CO_2$ emissions. A continued tight oil market with high prices could trigger investments and technological breakthroughs that accelerate the unlocking of this potential for the market.

Based on the calculations of the BP Statistical Review of World Energy 2006, the world proven (conventional) reserves would suffice to satisfy current demand for another 40 years (the reserve-to-production ratio). However, demand is predicted to grow, which implies that new reserves are required to prevent the ratio from dropping.

Investments in the past resulted in new additions to reserves, although super mega-fields, like those in the Persian Gulf, have not been discovered since the 1970s, and more recent additions come from smaller fields. It is important to note that the cost of finding oil is increasing and that important non-OPEC oil provinces are maturing.

The natural gas reserves of the Middle East – which amount to about 38 percent of world proven reserves – were until the recent developments in LNG-captive reserves unable to commercially reach a market (see Figure A2 in the Annex). The natural gas markets are still predominantly regional markets, with the North American and European markets mainly supplied by pipelines and the Asian market by LNG. The European market is largely supplied by Norway, Algeria, and Russia. Domestic EU supply is declining, against the background of growing demand from the power sector. Natural gas is relatively clean compared to oil and coal, and the current environmental policy stance is expected to translate into a larger demand for imported gas in the coming decades.

### 3.2 Production

***The combination of demand growth and the slowing growth of non-OPEC oil production implies an increasing call on OPEC oil in the future.***

Oil produced outside the OPEC has steadily increased, with OPEC becoming a swing producer in world oil markets after 1973 (see Figure A3 in the Annex). OPEC production varied from a high of around 31 million barrels per day (mbd) in 1979 to a low of 16½ mbd in 1985 (BP 2005) and increasing thereafter to a high of 34 mbd in June 2005.[2] The combination of demand growth and the slowing growth of non-OPEC oil production implies an increasing call on OPEC oil in the future. Due to the long lead-time, the combination of underinvestment in the 1990s and demand growth has created the current tight oil market – a topic explored in greater detail by Fattouh (this volume). This was expressed in both relatively high oil prices and a dramatic decline in buffer capacity of OPEC after 2003.

In the 1980s, the buffer capacity came into existence because the market preferred to consume non-OPEC oil that was priced competitively against the OPEC marker crudes. OPEC prices were at that time determined by the OPEC conference. In the period 1980-1985, the OPEC price level was above the market price and OPEC subsequently lost a large market share to competing non-OPEC crudes despite the lower production costs of OPEC oil. Perhaps more significantly, future projections show that non-OPEC supplies, which include producing regions such as Africa, the Caspian Sea region and

2 www.eia.doe.gov/emeu/steo/pub/3atab.html

Russia, will be losing market share incrementally beyond the year 2010. This process is expected to accelerate over time. Indeed, non-OPEC supply is expected to peak around 2010 at 48 mbd, or 54 percent of world supply at that time, and will decline slowly but surely thereafter (IEA 2002, p 95).

The buffer or spare capacity in the international oil market in the 1980s and 1990s fulfilled an important role in stabilising the market. OPEC's role as a swing producer depends on sufficient levels of spare capacity that can be introduced to the market when other sources are at capacity or when certain producers can temporarily not supply the market.

***The current tight market and the lack of spare capacity are among the main drivers of the debate about future oil supply and demand.***

The distribution of spare capacity in OPEC is uneven, however. Only Saudi Arabia, Kuwait, and the United Arab Emirates have spare capacity in their system, other OPEC producers nearly always produced close to capacity. In recent years, spare capacity levels declined to the extent that only Saudi Arabia is able to increase production slightly when there is a shortfall elsewhere. The current tight market and the lack of spare capacity are among the main drivers of the debate about future supply and demand.

The supply side of the oil market is thus very asymmetrically concentrated. The Persian Gulf countries possess 90 percent of the Middle East oil reserves while they are simultaneously key members of OPEC. Because the cheapest and most plentiful oil is located in the Persian Gulf, OPEC will continue to influence oil prices with its production policy – as argued by Noreng (2002), for instance. It is important to note, however, that when the oil market is unable to restore its required level of spare capacity that can compensate for incidental shortfalls or demand spurs, all producing countries potentially gain the power to drive prices up.

All projections of future consumption statistics show an increasing call on OPEC oil, juxtaposed by the fact that by 2030, Persian Gulf production is expected to form the bulk of OPEC supply increases. Indeed, as the International Energy Agency has pointed out, "of the projected 31 mb/d rise in world oil demand between 2010 and 2030, 29 mb/d will come from OPEC Middle East" (IEA 2004, p.110).

Hence, the Middle East – the Persian Gulf in particular – is a geopolitical focal point. Moreover, the Persian Gulf is also increasingly important in the international gas market, now that LNG developments can unlock the previously stranded reserves.

### 3.3 Consumption

World primary energy demand will continue to grow over the next decades, reflecting the continued importance of fossil fuels in world energy demand (see Figure A4 in the Annex). More specifically, oil demand in the next two to three decades will predominantly grow in the developing countries, and to a lesser extent in developed economies, while growth of natural gas demand is more prominent in OECD countries. In particular, oil demand in countries such as China and India is projected to grow substantially. According to the Energy Information Agency of the US Department of Energy, China is projected to consume 12.8 mbd in 2025 of which 9.4 mbd must be imported.[3] In 2002, OECD countries consumed 52 percent of world primary energy demand compared to 38 percent for developing countries. By 2030, the OECD share is projected to decline to 43 percent and the developing country share is expected to increase to 48 percent (IEA 2004). In terms of $CO_2$ emissions, China will soon surpass the United States in absolute emissions levels, although per capita emissions remain far below those of the United States.

3 www.eia.doe.gov

Shifts in the demand for and supply of oil and gas will also shift trade flows. The Persian Gulf is already a major supplier for Asian economies. Naturally, the maturity and decline of non-OPEC supplies in the coming decade will also increase demand for Gulf oil in the United States and Europe (see Figure A5 in the Annex). This could lead to intense competition for oil flows among the major consumer nations.

***Shifts in the demand for and supply of oil and gas will also shift trade flows.***

Diversification of supply and local pollution is expected to stimulate demand for natural gas in the coastal urban areas in China. At present, the Chinese natural gas market is still relatively small and localised. However, in the coming decades the pull on LNG supplies and possibly on Russian and Caspian supplies will become stronger.

The growing import dependence and the expectation that oil and natural gas supplies will become more concentrated on a few net exporting countries – such as Russia, the Caspian Sea region, and the Persian Gulf – have led to growing security of supply concerns among the consumer countries.

### 3.4 The role of OPEC and the Persian Gulf producers

Much of the new demand must be satisfied by increased Persian Gulf oil and gas production. The Iraqi production potential is large enough to become a game changer but the uncertain political future could imply, like in the past, that the potential largely remains untapped. Both the internal situation in Iran and the troubled US-Iranian relations have stunted the development of its oil and gas sector. As a result, Saudi Arabia's role as a large and reliable supplier to world markets gained importance. The call on Gulf oil as projected by the IEA relies mainly on increased Saudi supplies. Saudi Arabia has indicated that it was confident it could produce 15 mbd by 2020, but said it was doubtful that it could produce more (*Financial Times* 2005). The projected IEA call on Saudi oil could then, according to Saudi officials, be 4.5 mbd higher than Saudi Arabia would actually be able to supply. The fact that Saudi Arabia voiced doubts about any increase of its production capacity above 15 mbd is significant for future international oil market developments.

The discussion of Saudi production potential, which flared up again in 2005, is important against the background of uncertainties surrounding the other producers in the Gulf. Experts like Campbell and Simmons have repeatedly questioned the future Saudi production capacities and reserve data and the debate on a nearing decline in world oil production continues until today.[4] Both point out that earlier reserves additions of OPEC members cannot be verified and most of these additions took place in 1985-90, when OPEC quotas were determined on the basis of each member's share in OPEC reserves. The fact that the international oil market currently lacks the transparency to verify reserve data can be a continued source of uncertainty in the future. The debate is important for strategic reasons: if world conventional oil production is peaking soon, the upward pressure on oil prices will increase to the point that alternative energy resources must be introduced in the energy mix much sooner than anticipated. Competition for scarce resources among consuming countries will increase during that transition. For some developing countries, the outlook of persistent higher oil prices might thwart their economic take-off and frustrate the international Johannesburg agenda to make commercial energy available to more people in the world.

It is important to note that OPEC's performance in coordinating market activities whilst accommodating the economic needs of its members has not always been optimal. That is to say, internally, the cartel's members have been in situations of imperfect cooperation over the last three decades. Essentially, the basis for bargaining over oil prices within OPEC can be observed in the correlation between withholding capacity and idle capacity, which determines the strength

4 Campbell and Laherrère (1998) and Simmons (2005).

of those who want higher prices and those that want lower ones (Noreng 2002). When oil is withheld from the market, it enlarges the spare capacity but simultaneously requires higher levels of investments. Not all OPEC members are able to bear these costs to an equal extent. Hence, by nature of its constitution, OPEC is subject to a conflict-ridden decision-making process because members have differing objectives. In the past, Saudi Arabia, the United Arab Emirates, and Kuwait – until 1990 – carried the bulk of the costs of maintaining spare capacity. The ability to continue with this policy indefinitely is decreasing with the increasing societal costs. The asymmetries within the cartel are hereby deemed to sharpen, accompanied by increasingly acute economic and financial difficulties in many OPEC countries. Despite recent market conditions, the long-run developments point to increasing difficulties for the cartel's members to cooperate, given the disparity between the economic compositions of the member states, the ability to share the cost of maintaining and exerting market power, and the sharpened geopolitical tensions in the region.

Hence, two opposing trends are taking shape at the dawn of the 21st century. On the one hand, the cartel has internally been facing imperfect cooperation.[5] On the other hand, long-run supply projections show that the cartel's core, the Gulf producers, will regain extensive market power as non-OPEC producers lose market share over time. After all, the vast majority of incremental world oil demand can only be met over time by those countries with the largest reserves (Bahgat 2003). As for natural gas, similar concerns about producer cooperation are surfacing.

### 3.5 Natural gas

***The international market for natural gas was regional in nature until the recent LNG developments.***

The international market for natural gas was regional in nature until the recent LNG developments. In North America and Europe, markets were supplied through pipelines, while the Asian market relied on LNG from the start. The North American market was largely self-sufficient. The Asian market was mainly supplied with LNG from Brunei and Indonesia. The West European market was supplied by the Netherlands, the United Kingdom, and Norway. In addition, substantial imports were necessary from Algeria (to supply southern European markets) and the Soviet Union. Natural gas from the Soviet Union was mainly supplied through the Ukrainian corridor to eastern and western Europe on long-term take-or-pay contracts. After the demise of the Soviet Union, Russia continued to supply gas to the European markets despite the radical change in the ownership structure of the pipelines and the inability of some transit countries to pay for their gas imports in hard-currency prices. Particularly the countries of the Commonwealth of Independent States (CIS) initially paid substantially lower prices than European countries, in part to cover the transit fee. Early in 2006, the Russia-Ukraine gas crisis was a conflict over the terms and price of gas sold to the Ukraine, the transit fee to Europe, and control over the corridor (Stern 2006). In 2007, renegotiation also took place with Belarus – both on oil and gas sales and transit fees. Russia has in recent years actively contracted gas from the Caspian Sea region, in part to satisfy increasing domestic demand and to free up Russian gas for export to Europe. At the same time, the EU saw the energy resources of the Caspian Sea region as a possibility to diversify suppliers (Stern 2005). The often referred to 'great game' about oil supply routes could easily also refer to gas supply routes, except that in gas, new routes will have to compete with existing routes through Russia.

Also in North America, natural gas gained prominence in the energy mix and despite substantial domestic supplies, LNG imports were expected to play a growing part in supply (Yergin 2006). Robust US natural gas prices were expected to attract new gas into the market from South America, Africa, and the Gulf (Thorn 2006).

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5 The recent changes in Iraq and the resulting regional and national instability could potentially further compound this problem in the medium to long term.

With the growing pressure to reduce $CO_2$ emissions and the favourable economics of gas-fired power stations, the natural gas market was until recently predicted to grow substantially in all major consumer markets. However, security of supply concerns have dampened these expectations somewhat and other options are being studied.

### 3.6 Concluding remarks

Two-thirds of the world's oil and gas potential (including Iraq) falls within the realm of developments controlled by governments or state-owned companies, while foreign direct investments can develop a little over a third of current reserves (IEA 2004). It is clear that any decision of a legitimate government in Iraq to allow foreign direct investments would have a huge impact on investment possibilities for foreign oil companies, immediately increasing their access to (cheap onshore) oil by 10 percent.

***Two-thirds of the world's oil and gas potential falls within the realm of developments controlled by governments or state-owned companies.***

Suffice it to say that increasing reliance on OPEC and large gas producers such as Russia has profound geopolitical and economic implications for the world's oil-importing blocs. Resource nationalism is presently on the rise in countries like Russia and is still a current factor in many Gulf countries (*The Economist* 2005a). Accompanied by the political and economic instability in many of the world's non-OPEC producers, these ramifications will have a major impact on the behaviour of the world producers and consumers of oil. The pressure of the international market system to induce economic and institutional reforms conducive to mobilising sufficient investment capital has been building up. However, the resistance to such reform is still very large. A way to avoid these reforms seems to be to accept the investment offers from countries such as China and India. These countries are prepared to invest public funds in oil and gas projects in return for oil and gas supplies. They do not have, at least not initially, any further demands on the political and economic structure of producing countries. Of course, this could change when producing countries cannot deliver on their promises, and further integration into the world system also becomes an issue for these new oil consumers.

Despite soaring oil prices over the past years, demand has proven to be remarkably price inelastic (*The Economist* 2005b). Economic stability and growth can only be achieved through a steady flow of energy and – to an ever-present extent – the flow of oil. Due to ever-rising future demand, oil-importing countries are striving to diversify their sources of oil imports. Against the background of increasing oil and gas imports of major consumer countries and the inevitable politicisation of energy relations that accompanies this structural dependence, energy security risk management is gaining prominence on governments' agendas (CIEP 2004). Most instruments to manage energy risks were developed after the 1973-74 oil crisis and geared mostly at the energy sector. The instruments were not designed for disruptions or situations of undersupply with a longer duration nor were they really tested in a crisis situation. The issue that must be raised here is whether the energy risk management instruments are capable of dealing with near-term and future risks in the oil and gas market.

## 4. Energy risk management instruments

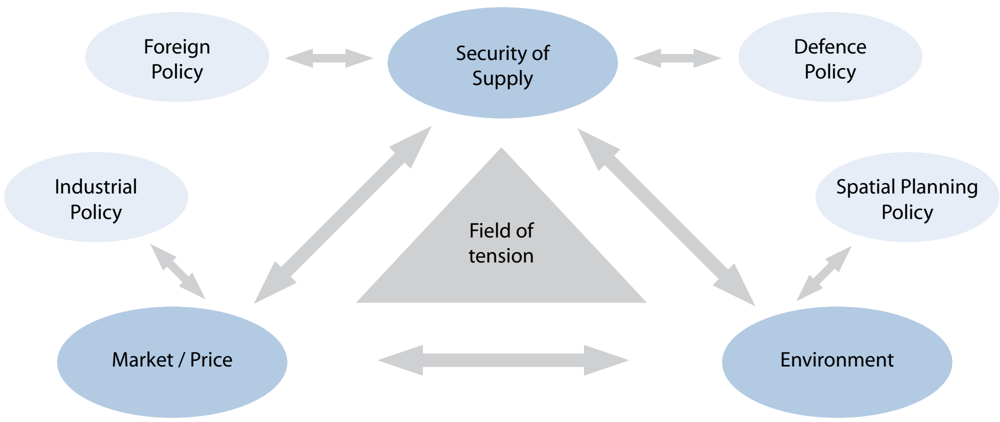
### 4.1 Priorities of energy policy

Security of supply is one of the key policy goals in energy policy making, together with the objectives of ensuring reasonable prices and environment protection. Each government of consumer countries must find a balance in pursuing these policy goals because there is a certain amount of tension among them. In general, security of supply policies and environmental goals increase the cost of energy, which could be at loggerheads with reasonable prices and short-term market efficiency. Most governments are fairly successful in pursuing two out of these three policy goals.

***The importance attached to various energy policy objectives varies among consumer countries and across time.***

The importance attached to each goal (and the price society is willing to pay to achieve it) varies among consumer countries and across time. Moreover, the use of, or emphasis on, certain policy instruments varies among the consumer countries and in time. In part, this is due to the influence of other policy objectives on energy policy-making priorities – as sketched in Figure 1. As such, energy policy is an expression of the value that society attaches to a certain component of its energy policy and the efficiency of its instruments. For one consumer country, an import dependency ratio above 50 percent of domestic demand sets off alarm bells in policy circles, while in other countries they have learned to live with much higher levels of dependency.

**Figure 1. Context of energy policy making**




Source: Hoogeveen and Perlot (2005).

### 4.2 Energy risk management instruments

The energy security risk management instruments can be subdivided into four groups (CIEP 2004). Two of them aim at external energy relations (prevention and deterrence) while two other groups aim at managing the domestic energy economy (containment and crisis management). The intensity and style of the policy instrument used depend on the type and level of risk. The schematic presentation in Figure 2 shows the variety of energy risk management instruments employed by consumer countries to manage the divergent levels of risk in producer countries. The last category of risk management tools is the response to increasing risk levels and the use of far-reaching sanctions or force. These can be employed unilaterally or in a coalition.

On the face of it, there is a number of risk instruments that consumer countries can choose when implementing their energy policies (see Figure A6 in the Annex). They evolve dynamically as the risk profile changes. Moreover, each country has its own assessment of the risks and legal and regulatory constraints on the optimal mix of risk management tools. When a country does not have to be concerned about its security of supply, the risk management instruments focus on maintaining good political and trade relations with the exporting countries and perhaps close cooperation among certain like-minded consumer countries. Examples are: multilateral cooperation, foreign policy, trade policy and economic cooperation, allowing horizontal and vertical integration of companies across borders, and diversification of resources. These instruments fit in with an efficient international oil and gas market.

When a country becomes increasingly uncertain about its security of supply, a combination of external and internal risk management tools will be favoured. The preferred strategy is geographical diversification, thereby reducing dependency on the country or region being the source of insecurity. Another type of diversification is to switch to other fuels, such as gas, coal, and increasingly renewables and nuclear. Often, consumer countries hold strategic stocks that they can draw on in the event of a sudden disruption. Since 1974, OECD countries have pursued a cooperative approach within the framework of the International Energy Agency (IEA) in maintaining strategic oil stocks (equal to 90 days of consumption), sharing oil, and coordinating emergency and demand management policies. For gas, there are no formal agreements to cooperate in case of a supply shock.[6] Strategic gas stocks are not widely held because of high storage cost (compared to oil), but to some extent oil stocks can double as a crisis mechanism for gas-fired power stations with dual-firing possibilities. Other dual-firing capabilities also provide short-term solutions for gas shortages. It is important to note that China and India, but also countries such as Brazil, are not part of any cooperative agreement to enhance energy security.

**Figure 2. Key energy risk management instruments and risk situations**

| Risk situation | Risk management instrument |
|---|---|
| Energy-supplying country/region is stable | Prevention |
| Stability in energy-supplying country/region is uncertain | Prevention<br>Containment<br>Deterrence |
| Turmoil in energy-supplying country/region | Containment<br>Crisis management<br>Response |

Sources: Based on CIEP (2004).
Notes: See Figure A6 in the Annex for a more comprehensive illustration of energy risk management tools.

When there are great uncertainties about security of supply – because the producing country or region has (nearly) crossed the threshold into political and/or economic turmoil – a consumer country that is a follower rather than a rule setter can only attempt to reduce the effects of a crisis on its economy with containment and crisis management instruments. For such a country, the external risk management tools will be insufficient to avert a crisis or disruption of supplies. By contrast, a geopolitical and geo-economic power (a rule setter) could contemplate intervening in the affairs of exporting countries to remove the obstacles to export, even though the result is uncertain.

The effectiveness of these risk management instruments depends on the size and the political importance of a particular consumer country and/or the alliance in which it participates. In case of the EU, the use of deterrence or response instruments is fairly limited because the EU has neither a common defence nor a common foreign policy and, to exert pressure, it can only operate in alliances. As a matter of fact, the EU does not have a common energy policy. It is the limitations of one set of risk instruments that very often explains the emphasis on other risk instruments.

***The effectiveness of risk management instruments depends on the size and the political importance of a particular consumer country and/or the alliance in which it participates.***

The asymmetric exposure of consumer countries to energy supply risks also explains why they use different risk management instruments and energy security strategies. Furthermore, energy security risk management must be consistent with other policies, such as foreign and security policies

6 Gas is different from oil because its transportation is more rigid (pipelines, LNG terminals, and ships) and more bilateral by tradition. The IEA is formally only concerned with oil market emergencies, although the organisation follows gas market developments closely.

– which link to the function of a country and its stakeholders within the international system. The power of a country to shape these policies can also affect the choice of risk instruments. Therefore, the asymmetric risk landscape can affect the efficiency of an alliance of consumer countries to avert a crisis (Van der Linde 2003).

***The evolving asymmetric risk landscape determines the scope and effectiveness of the currently available risk management instruments.***

The evolving asymmetric risk landscape determines the scope and effectiveness of the currently available risk management instruments. We have already argued that the opportunities to diversify oil and gas supply – the best security instrument so far – are declining in the coming decades. Moreover, diversification away from oil has reached a point where oil dependency is traded for gas import dependency, which relies on the same politically and economically unstable regions. Coal and heavy oil consumption are facing environmental constraints, which new technologies could eventually release. The anticipated transition to domestically produced non-fossil fuels (renewables and nuclear), which can reduce both import dependency and environmental problems, is still far away. The wider use of nuclear energy suffers from concerns about safety of the fuel cycle and safe waste management. Between the currently available short-term oriented energy risk management instruments and the transition to a less carbon-intense economy remains, however, a substantial time gap and new energy security risks.

## 5. Risks in a changing world: present and future trends

Given the present patterns of demand and supply, their long-run projections, and the inadequacies to fully manage the energy security risks, it is possible to develop a risk landscape for the international oil and gas market and the actors involved. As for future risks, key questions are: How will geopolitical rivalry influence the global risk (macro) landscape of the world oil market in years to come? How will political, social, and economic instabilities in producer countries influence foreign and security policies of the world's major powers as they pursue their energy security? And then, how and why is energy security becoming a political and strategic problem?

### 5.1 Global risks

To begin with, it is obvious that there are four major power blocs in the aftermath of the Cold War and at the beginning of the 21st century: The United States, the EU, China and Russia. The former three (group of) nations are bound to become the leading oil-consuming countries, while the latter has the obvious advantage of being an energy-rich country. Today's question is how the emergence of China (and India) as an economic and political power challenges the hegemonic position of the United States as a centre of innovation and growth. As part of the process of uneven growth and structural change, new powers challenge old ones, creating and destroying trade at the same time. As long as the hegemonic power or dominant economies can move on to new economic activities that create growth, the hegemon remains the engine of growth. However, the faster the change and the faster newcomers gain in world markets, the greater the challenge for the dominant states to remain the centre of economic growth. This is particularly important because periods of structural change usually are periods of intense nationalistic competition (Gilpin 1987). This could have a crucial bearing on the way the risk landscape evolves in the future, given that access to (energy) resources is a centrepiece of modern geopolitics.

The control over geopolitical pivots in or close to energy-rich areas can have a fundamental impact on the extent to which a region can be controlled and denied to geopolitical rivals. Brzezinski (1997, p.41) claimed that attaining geo-strategic pivots "in some cases gives them a special role either in defining access to important areas or denying resources to a significant [geo-strategic] player."

Great powers seek to prevent rival great powers from dominating the wealth-generating areas of the world and will attempt to occupy those regions themselves (Mearsheimer 2001). In this respect, geopolitical pivots will play an increasingly important role in competition for and access to oil and gas. As far as the Persian Gulf is concerned, should the consolidation of Iraq by the United States as a geopolitical pivot be successful, it would be an ideal pivot for strategic control of the Middle East and the Persian Gulf whilst providing the oil market with a valuable source of oil supply in the long-run.

***Great powers seek to prevent rival great powers from dominating the wealth-generating areas of the world and will attempt to occupy those regions themselves.***

Given the overall changing structure of oil and gas supply in the medium- to long term and the inherent instability in many producing countries, access to and control of energy-rich regions via geopolitical pivots will prove to be vital for the world's major powers. Not only is political and economic volatility a reason for exercising control over strategically located countries; shrinking diversity (i.e., increasing concentration) of supply is another compelling trend and reinforces the necessity for strategic leverage. Increasing market power in the hands of few producer countries gives undue influence over the price of oil and gas, from the perspective of consumer countries. This broad trend has a significant bearing on the competition between oil-importing countries and, therefore, on the risk landscape of energy security.

At the heart of today's international risk landscape, then, lays the fate of Iraq and the other Persian Gulf countries as the world's true long-run excess-capacity oil and gas producers. The inability of the United States to eliminate the insurgency in Iraq is in itself a real problem in that it undermines the security and stability of the entire Persian Gulf region because it increases the danger of an eruption of the underlying conflict between Shiia and Sunni Muslims in and among neighbouring countries. This not only negatively impacts the energy security of the United States but also the security of the EU and China. The Caspian Sea region, West Africa, and South America will all become correspondingly more important due to the wish for diversification away from the Persian Gulf suppliers and the strong possibility of a lack of spare capacity in the international oil market.

### 5.2 Controlling supply lines and transportation bottlenecks

Supply disruptions can take place not only due to internal trouble in an oil-producing state, but also due to actions on the part of rival powers. In practical terms, great powers place a high premium on having a powerful and dynamic economy while preferably the economies of its rivals grow slowly or hardly at all (Mearsheimer 2001).

Even if a certain country does not directly possess resources, it can still act as a pivot if it is located on a transit route or close to supply route choke points. Turkey, for instance, is a country strategically located between the Middle East, the Caspian Sea region, and the Eurasian plateau. Hence, Turkey forms a vital link between oil-rich countries such as Iran and Azerbaijan and oil-consuming blocs such as the EU and the United States (by sea transport). Moreover, Turkey controls the Dardanelles Strait, a major choke point for Russian oil exports to the international market.

Currently, the control over the Strait of Hormuz and the Strait of Malacca are vital oil and LNG supply choke points. In 2002, 44 percent of interregional oil trade passed through the Strait of Hormuz and in 2030 this is expected to grow to 66 percent of oil trade (IEA 2004). In addition, the expansion of gas production in the Persian Gulf region and the subsequent growth of international gas trade, in particular the sea bound trade in LNG, implies that the share of interregional gas trade will increase from 18 percent in 2002 to 34 percent in 2030. The share of interregional oil trade in the Strait of Malacca will increase from 32 percent in 2002 to 37 percent in 2030, while interregional gas trade will

***Access to various geopolitically sensitive countries, particularly in Central Asia, is of paramount importance since this region of the world is largely landlocked.***

decline from 27 percent in 2002 to 14 percent in 2030. The declining share in interregional gas trade in the Strait of Malacca is a result of the much faster expanding LNG trade flows to the EU and the United States. The absolute flows of LNG through the Strait of Malacca are expected to continue to grow in that period (IEA 2004). The importance of the Strait of Hormuz is shared among all importing countries of oil and gas, while the Strait of Malacca is particularly important to China, Japan, and Korea. The fact that the US navy patrols both straits gives the United States a strategic advantage.

Especially with respect to Central Asia, access to various geopolitically sensitive countries is of paramount importance since this region of the world is largely landlocked. It is for this reason that the struggle over the designation of pipeline routes plays such an important role in Central Asia. While Russia would like to retain control of oil and gas flows from the Caspian Sea region to markets in the West, the United States, the EU and China look for alternative ways of transporting resources from the Caspian Sea region to consuming countries.

### 5.3 A different geopolitical landscape

While security of supply has been an issue for all major oil-consuming nations since the first oil crisis of 1973-74, the parameters of supply security have changed since the collapse of the Soviet Union. A new period of uncertainty and asymmetry in power politics was heralded in, changing the geopolitical map of the world. The collapse of the Soviet Union was initially seen as a victory for the international market system. The original expectation was that globalisation would become the major driving force in international political and economic relations. In such a globalised international system, it was thought that the role of the nation state would diminish, while multilateral relations would flourish and other stakeholders would be important players (CIEP 2004). It was assumed that the previously centrally-planned economies would become integrated in the global economy and that the economic integration would automatically integrate them in the social and political rule set that belonged to the international market system as promoted by the West.

On the whole, geopolitical developments underpin the developments in the world oil market. Though no organised and politically motivated export restrictions or disruption of supply have taken place since the 1973-74 oil crisis, other than the OPEC production policy, a number of other fundamental discontinuities of oil supply have occurred (e.g., the Iranian revolution of 1979, the Iran-Iraq War of 1980-88, the Gulf War of 1991, the strike in Venezuela 2002-03, and so on).[7] To a greater or lesser extent, these fundamental discontinuities have led to sharp oil price spikes. The resulting economic side effects on consumer countries have been well documented (CIEP 2004).

### 5.4 Towards a single world order?

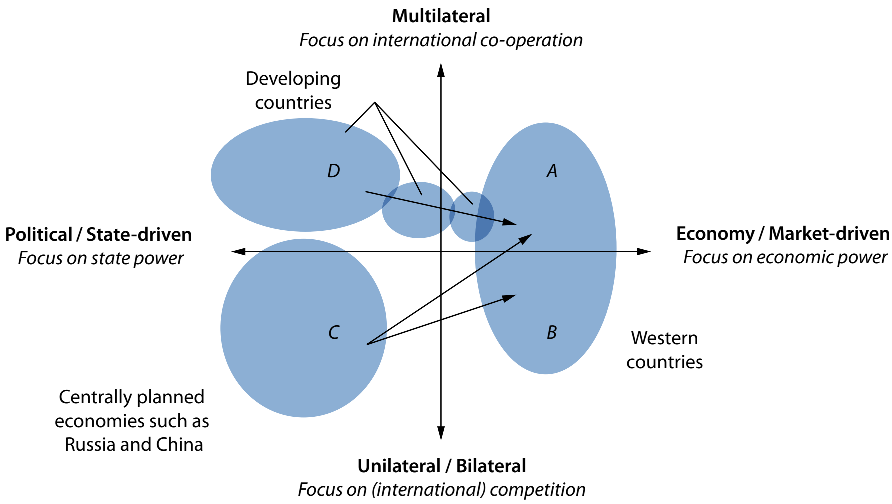
In the early 1990s, in the United States and Europe, it was commonly thought that a single world order would develop before too long, in which all countries would be subject to the same political, economic, legal and social mores. The mores of this system are based of two key elements. First, the expected decrease in national political power over economic actions – because economic decision-making would become decentralised. Second, the role of the government would be limited to facilitating and regulating markets, and in its role as a political authority it was assumed that the government could prevent and solve conflicts in the system. Thus, it was assumed that companies would increasingly operate in an open international environment, competing for capital, labour and markets. The hegemon was assumed to manage the regulation of international political, economic,

7 Such discontinuities can occur in the form of *force majeure* disruptions (internal or external conditions in producing countries, such as civil unrest), export restriction disruptions (deliberate restriction of exports) and embargo disruptions (deliberate restraint imposed by consuming countries on certain producer countries); see CIEP (2004).

legal and social pre-requisites and impose them if necessary. This role fell upon the United States in the absence of other contenders, but it seemed initially wary of setting the mores too openly and mainly stressed its domestic economic successes. The result was that mainly the legal-economic component of the system was portrayed as an ideological idea.

Globalisation offered the prospect of political and economic barriers to, for instance, international investment, being rapidly abolished. After all, even in China, the process of creating openings towards the international market-oriented system had started in the 1980s and the transition of the former Soviet Union and Eastern Europe was partly shaped by western institutional funding. The developing countries were also encouraged, often after a monetary or financial crisis, to liberalise their economies and adapt to the demands of the international market. In Figure 3, this movement towards one market-based system is graphically illustrated.

**Figure 3. Expected post-1989 development**




Source: Van der Linde (2005, p. 237)

The United States, the only remaining hegemon and the most dynamic economic power at that time, also set the trend for Europe. The EU, in the role of 'assistant hegemon', hurriedly opted for rapidly incorporating 10-12 Central and Eastern European countries as well as for deeper integration by adopting Economic and Monetary Union. An added advantage of this double stroke, which had been prompted by the new geopolitical relationships, might be a more important role for Europe at the regional level, but possibly also at the world stage.

***The United States, the only remaining hegemon and the most dynamic economic power by the end of the 1980s, also set the trend for Europe.***

So Europe explicitly backed the formation of a single world system, but had the ambition to claim its own role in the system, next to the United States. For that reason, not only would total economic integration have to be pursued, but also Europe's political and strategic role would have to be strengthened.

As far as the energy market was concerned, globalisation would thus remove political barriers that limited access to raw materials, oil and gas resources, and attractive new markets. In the West, foreign direct investments were seen as the best tool to denationalise oil and gas. In practice, an important role was foreseen for the existing multinational oil companies as procurers of capital and expertise and as outposts of the system in the 'learner' market economies. Thus seen, globalisation would reduce and remove political differences and national interests, marking the end of history as described by Fukuyama (1992).

Certainly this might explain the motivation of the EU, in line with its own programme for the future and as a prerequisite for closer political and economic relations, to coerce Russia into adopting the EU gas-market proposal. Moreover, in the light of the imminent, more dominant, market position of Russian gas in the European market, it would be difficult for an internal market to develop with monopolistic suppliers at the external borders. The rapid decline of the Russian economy and the weak political development in the 1990s were all the more reason why the EU approached Russia on the basis of an unequal power relationship. It was believed that the energy *acquis* could be exported to a major energy supplier of Europe.

***The recovery of the Russian economy and the growing internal political stability around the year 2000 caused the Russian energy interests to quickly become a national priority.***

The recovery of the Russian economy and the growing internal political stability around the year 2000 caused the Russian energy interests to quickly become a national priority. Brussels struggled with getting accustomed to the new balance of power, whereas the leaders of several EU member states, in particular Germany, rapidly adjusted their policies in line with the new position of Russia.

During the dot-com boom in the 1990s, the West largely neglected further defining the mores of the international market system, whereas other countries were busy developing all sorts of ideas on the details of their preferred mores. Russia, but also, for instance, Iran, seriously considered various aspects of post-modernism and international relations. According to these countries, globalisation could accommodate various national identities and alternative directions of progress. They thus formulated their own set of references for globalisation. Thus, the United States, being the only hegemon left, made a capital mistake in the early 1990s at first by not defining the 'new international order', as announced by Bush senior, with a coherent vision on the necessary mores, but, instead, relied by default on market forces to bring about full integration. After 9/11, the United States changed track and began, for the sake of US national security, to impose the mores top-down. Thus it chose to brush aside other ongoing processes in favour of its own mores and interests. Consequently, this blocked any potential for convergence.

So while, at first, globalisation seemed an option of attractive simplicity, the mores of the system eventually threatened to destroy the diversity and self-determination of nations and societies for the sake of the hegemon's national security. In the post-2001 approach, globalisation could offer the ruling elites in the emerging countries much less than their own interpretations could. The transition from being supposed partners in the globalisation process to followers of the hegemon did not proceed smoothly and evoked intense, adverse reactions.

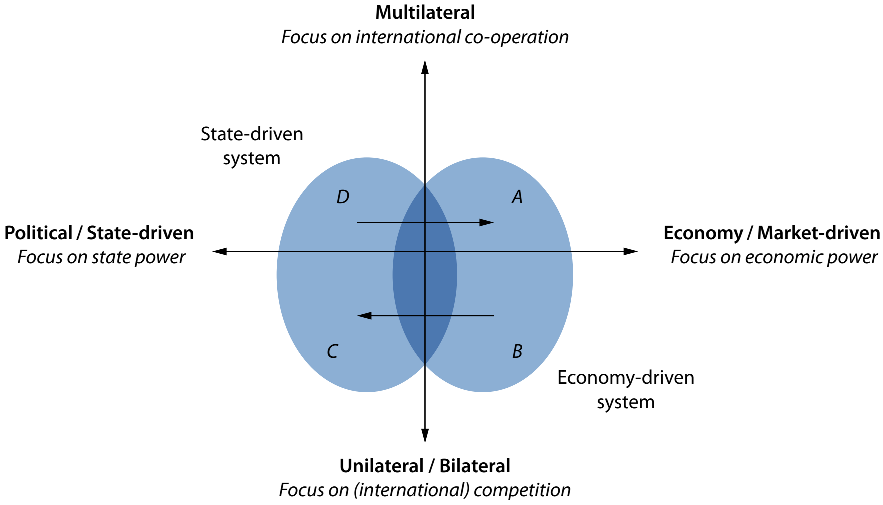
Since then, clearly successful autocratic regimes have emerged, for instance in Russia, Venezuela, China, and other Asian countries. These countries participate in the international economy, but on their own terms, and give priority to their own national interests. Instead of being the intended 'mores followers', these regimes are increasingly becoming 'mores setters'. In the geopolitical situation after the 2003 invasion of Iraq, these regimes felt even more justified to follow their own course. National interests, according to countries like China, can no longer be entrusted solely to the hegemon of the international market system. They found the answer in what we can now call 'weak' globalisation: participating in the international economy, but on condition that the state's long-term political, strategic, and economic national interests are served. Since 2001, and even more so since 2003, this attitude has increasingly started to clash with the US approach to globalisation.

The rise of China and India in recent years has created sufficient momentum for these countries to set their own conditions for access to the market, investment, and competition – without running the risk of being shut out from raw materials, capital, and markets. Moreover, they offer a perspective to other autocratic regimes that are still searching for the proper balance between economic growth and preserving their political power.

The perspective of free access to oil and gas resources and the role of Western energy companies and banks in accessing these resources, which is the basis of the American and European energy policies, will change drastically if the oil-and-gas-producing countries in particular would embrace weak globalisation and adopt China's, India's and Russia's attitude to international relations. Weak globalisation makes national interests the yardstick of international conduct, instead of a hegemon's interests. There is sufficient reason to assume that oil-and-gas-producing countries are more likely to opt for weak globalisation in combination with strong state control than to enter into the political and social experiments that go with full globalisation.

***The perspective of free access to oil and gas resources will change drastically if the oil-and-gas-producing countries adopt China's, India's or Russia's attitude to globalisation and international relations.***

**Figure 4. Two competing systems?**




Source: Van der Linde (2005, p. 241).

Assuming that the Unites States, Europe, and some countries in the Asia-Pacific region continue to promote market-based solutions for their own economies, albeit with a sometimes political-strategic dressing, and that the successful emerging economies and the energy-producing countries opt to remain in a national-interest driven system, two competing systems will emerge (see Figure 4). In such a situation, a serious confrontation, particularly about energy, between the main players of the two competing systems seems more likely to occur than in a single-system solution of either a state-driven or economy-driven type. The strength of the market-based system will also depend on its ability to attract and secure sufficient oil and gas flows, and, at the same time, its ability to reduce its import-dependency from countries belonging to the 'other system'. In this context, the new EU energy policy (European Commission 2007) is a decisive move in this direction and attempts to bundle security of supply and environmental objectives into a single approach.

### 5.5 Concluding remarks

Foreign policy and military dimensions now accompany the economic aspect of a smooth flow of oil from producer to consumer countries. In essence, access to energy has become securitised, with extensive military implications. This implies that oil-importing power blocs possibly need to move from assuring energy supply through international markets (realising sufficient imports) to actively managing the rising spectre of geopolitical risks to energy supply in energy-rich areas of the world.

No other energy market than the oil market manifests such an acute need for increasingly active policy making in both the foreign policy and defence dimensions. The risk profile of gas is different, but with its growing internationalisation (and call on Persian Gulf reserves) it is possible that at some point the security of gas supplies develops into a situation akin to oil (CIEP 2004).

The development of sustainable and renewable fuels also forms part of such a strategy for managing the risk associated with geopolitical shifts and instability. It is this route that the EU has recently decided to pursue. Besides benefits for the environment and the climate, such fuels partly offer a way out of the dependency dilemma for oil-importing countries. The drive to create sustainable and renewable fuels, particularly those that can be produced domestically, reflects the awareness of various governments and countries that oil and gas import dependency is strategically undesirable. Hence managing risk with respect to energy security can become a strategic problem, coloured not only by political considerations but also economic and military ones.

## 6. Managing risk in a changing world

### 6.1 Bounded rationality

The dimensions of risk discussed above combine to form the risk landscape that policy makers face today when dealing with energy security. New global and regional risks together with new forms of energy, technological innovations, industrial developments, and so on all redefine the issue of security of supply and subsequently determine the (in)efficiency of existing energy security risk management instruments. In theory, it is easy to observe that energy security needs to be addressed proactively.

***Bounded rationality relates to the problem of how countries differ in terms of culture, for many of them tend to act rationally only to a certain extent.***

In practice though, it would be difficult, particularly since policy makers tend to be faced with bounded rationality: the limited foresight, imprecise language, the costs of calculating solutions, and the fact that policy makers cannot solve complex problems arbitrarily, exactly or instantaneously (Milgrom and Roberts 1992). Herbert Simon, one of the pioneers on bounded rationality, points out that most people are only partly rational, and are in fact emotional/irrational in the remaining part of their actions (Simon 1957). Moreover Williamson, a student of Simon, contends that "boundedly rational agents experience limits in formulating and solving complex problems and in processing information" (Williamson 1981, p. 553). In essence, bounded rationality relates to the problem of how countries differ in terms of culture, for many of them tend to act rationally only to a certain extent. This is particularly important for the assessment of how the international system will develop in the coming years. Will the international system become more cooperative and will economic integration be an acceptable approach to political leaders in the United States, Europe, China, and so on – or will the international system develop more nationalistic competition?

Insofar as cultural differences amongst relevant players are concerned, bounded rationality goes a long way in explaining how the characters of both consumer and producer countries change. Since countries often act in a way bound to their cultural identities, they are boundedly rational by definition. What matters in that respect is what organ or groups of organs (in any given countries) do to help shape foreign and security policies. Rational ignorance (Downs 1957) is another term to describe behaviour in a country, meaning that "rational ignorance on the part of constituents [in a country] is going to increase the role, in many situations, of incomplete subjective perceptions playing an important part in choices" (North 1991, p. 51). Though this concept pertains to institutional economics, its basic meaning relates directly to transactions and economic behaviour in the oil and gas markets.

Of particular concern here is the economic behaviour both of producer as well as consumer blocs and the differences between them in terms of rational ignorance. Relevant players make choices based on information, which is necessarily incomplete, and differences in culture and national priorities further compound the problem of making rational choices. Each country's rational ignorance and to a great extent its rational choices are influenced by national considerations and cultural conscience. Producer and consumer countries are asymmetric in this respect; so bounded rationality is essentially skewed when observed against the backdrop of cultural differences between players.

***The way in which the recent relationship between the EU and Russia is developing is explainable both as geopolitical rivalry and as an expression of bounded rationality.***

Rationality may play a great role in one country and less in another due to the inclination of the presiding government in question. The combination of imperfect information, rational ignorance, and cultural asymmetries could contribute to instability in oil and gas markets, further shaping the risk landscape of the future. The way in which the recent relationship between the EU and Russia is developing is explainable both as geopolitical rivalry and as an expression of bounded rationality. Bounded rationality limits the rational, purely wealth-maximising behaviour of countries to a great extent. A sound energy policy will involve not only the close interaction of foreign and security dimensions, but also economic and environmental policies with respect to alternative fuels and fuel diversification. Diversification of supply, buttressed by military and geopolitical activity, is, on its own, no longer satisfactory as an energy strategy. Energy security is realised both at home, with demand management and policies to optimise domestic production capacities, and abroad with foreign trade and foreign investment policies in the knowledge that most existing energy risk management instruments do not guarantee security of supply in case of a prolonged supply shock. New decisions and strategies with respect to mixing fossil and alternative fuel types have to be made in order to enhance energy security. In this sense, sustainable energies become an important part of future energy security strategies.

Information is not perfect from the outset; hence, combining different fields into one single coherent energy approach will enhance the bounded rationality of top strategists. When it comes to managing energy security risks, policy makers will have to integrate policy fields that hitherto have been quite separate from one another. A greater number of contingencies need to be accounted for, but not all of them can be, so that policy makers tend to act in an intentionally rational manner given their limitations (Milgrom and Roberts 1992).

### 6.2 Policy options in a changing world

Countries will inevitably have to import more energy and accept that in the coming years a large share of the energy mix will remain fossil fuel-based. Yet, the energy mix and the composition of imports can be altered by optimising the use of cleaner fuels, such as renewables, natural gas, clean coal and eventually hydrogen-based energy. Despite earlier efforts to move away from oil, the dependency of the transport sector has remained very large. Nevertheless, energy demand can be made more efficient than today. Still, it must be concluded that most of the traditional risk management instruments for energy supply security largely offer short-term solutions for a long-term problem. Rapid diversification away from oil could limit some of the risks attached to future oil consumption but without a ready-to-go alternative it might create other transition related risks. There is no obvious alternative fuel available yet, which implies that the gap can only be closed by a transition period in which multiple energy sources are used, such as synthetic fuels, biofuels, renewables, hydrogen, and nuclear.

*The ability of market-driven economies to pre-emptively move away from oil without coercive regulation is small.*

But how can such an energy mix be realised within a competitive and by nature short-term rewards-oriented market system? The oil price does not yet reflect the costs of the long-term political and economic risks. The option to diversify away from oil in a competitive environment is not easily pursued unless the main competitors move along the same path. The ability of market-driven economies to pre-emptively move away from oil without coercive regulation is small. Countries that experienced a structural change of path usually realised such a shift with substantial fiscal and regulatory backing. A number of industrialised consumer countries successfully moved away from oil for electricity generation in the 1980s and replaced oil with nuclear (France and Belgium), coal, and natural gas. In these economies, oil is predominantly used as a transportation fuel. Although new fuels and car technologies are entering the market, the replacement of oil as the preferred fuel in transportation is still not imminent. In the absence of a prevailing option, the gap might have to be closed by developing multiple fuel options that need to be prioritised and fully assessed, considering their viability and cost effectiveness (Jacometti 2005). The capacity to redistribute assets in the economy through government spending and inhibiting consumption of certain fuels in order to achieve long-term energy security can have a detrimental effect on the short-term competitive position of the country. Moreover, it requires a strong government that can enter into long-term agreements with stakeholders in various sectors of the economy and preferably cooperation among various consumer governments to create such a new market place. Cooperation would help to reduce the costs of creating this market and governments can opt to collectively use the 'infant-industry' principle to jump-start the new market. Naturally, such a strategy is counter-intuitive to proponents of the market-based economy that worked so hard to remove barriers to trade and competition in the past. Thus, governments would have to enact this paradigm shift in order to move away from initially conventional oil and perhaps later to some extent from natural gas, if similar security risks were to develop.

That said, the dilemma is: how to weigh the short-term risks of a serious disruption or undersupply against the longer-term security of more domestically produced (cleaner) energies as long as prices do not reflect all the risks?[8] Pursuing an aggressive strategy to structurally move away from oil and, to some extent gas, could easily create a self-fulfilling prophecy with regard to the position of the oil- and gas-producing countries in the world system. The prospect for producing countries, under this strategy, could be very uncertain with regard to investment in future production capacities. They may prefer to intensify cooperation with countries that do not pursue such a strategy and tailor investment levels to a certain demand profile of the preferred markets. Depending on the speed of transition in the economies moving away from oil, the oil market could become less tight, thus creating additional short- and medium-term competitive advantages for those countries that stuck to oil.[9] In terms of the international system and competition among rule setters, this dilemma is clear. For the United States, the EU and Japan, such a long-term strategy might further stimulate competition in world goods markets with China (and others) if China would not opt for shifting away from oil. China might be able to generate more economic and political power unless trade barriers prevent unwanted oil-generated goods from China (and others) from entering these markets. However, such a strategy would substantially raise the threshold for China (and others) to integrate into the market-driven system, effectively creating two systems.

8 Prices should reflect: (i) the real long-run economic and social costs of proceeding with the use of oil combined with the higher expected discount rates required to reflect rising political risk in countries whose overall instability is deemed to rise over time; and (ii) the benefit from using clean fuels both in terms of energy independence from risky oil-rich countries as well as the environmental gains, which translate directly into less long-run economic and social costs and thus a higher payoff.

9 Brazil attempted to introduce alcohol from sugar cane in the 1970s and 1980s but the programme collapsed when oil prices declined substantially in the mid-1980s and consumers switched back to petrol.

The uncertainty about the viability of the new energy technologies and the time needed for the transition might create a large upfront risk to the power position of Western countries in the world. It is therefore more likely that such a strategy will in the end not be pursued and that the risk of a major oil crisis and the accompanying international system risks remains the preferred option. Competing for oil with China and thus increasing the energy costs of the country could be an effective short-term instrument of the market-driven economies to attempt to set the rules for China's (and others') integration. If a structural shift away from oil is not feasible in the short- and medium term, the best strategy may be to continue to attempt to firmly integrate the producing countries into the marked-based system. To achieve such an integration it is likely that a fuller array of foreign, security and trade policy tools, in addition to smarter employment of prevention, containment and deterrence instruments, will be required than in the past because Western countries were unsuccessful in gaining the confidence of the producers in the early 1990s. Larger short- and long-term benefits for producing countries – for instance, by helping them to face the social and economic problems of oil-rich economies and creating security of demand – should be offered in order to win their confidence in the market system. Signals that Western countries might opt – both for security and environmental reasons – for a less oil (and perhaps later gas) dependent economy, have for now raised the distrust of producing countries. In that sense, China's (and others') proposition to offer their markets is more appealing.

## 7. Conclusion

The market structure of oil supply is bound to change over time, with increasing reliance on the OPEC and the Persian Gulf. Meanwhile, as present trends indicate, geopolitical enmity shows that a new form of realism will shape geo-strategic behaviour in the future. This means energy security should become firmly integrated in the foreign and security policies of a nation, regardless of whether or not clean fuels can eventually be used to a greater extent. The risk landscape is determined by geopolitical rivalry to control and access energy-rich regions and by regional risks arising from politico-economic instabilities.

The effects of oil supply disruptions or undersupply can be harmful to any major economy. In the mean time, the active management of risk requires an entirely new approach to security of supply: energy security. In this new paradigm, there is no more room for an energy strategy that is geared merely towards a majority of oil in its energy portfolio. Increasing the share of gas in the energy mix only temporarily reduces the energy security problem. The failure of countries to acknowledge this problem can be observed as an underlying failure to cooperate.

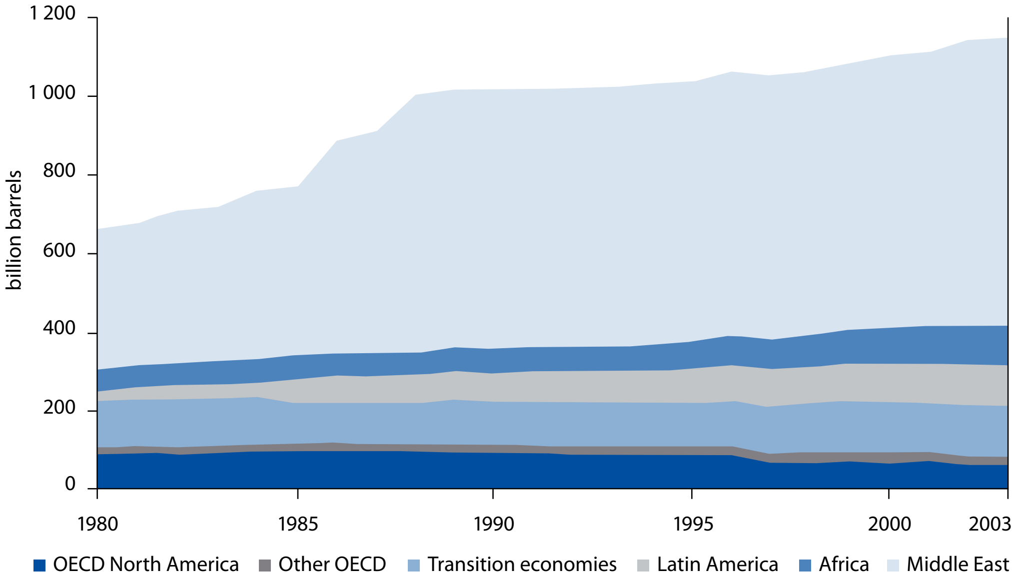
***The active management of risk requires an entirely new approach to security of supply.***

In the short- and medium term when dependencies on imported oil are still growing, energy security is going to be difficult to obtain. Traditional energy risk management instruments will not suffice in an environment of competing nations and where the playing field is in flux. Moreover, they were never meant to provide security for a longer period of time. Current energy risk management instruments in OECD countries were designed for short interruptions of supply, while the longer-term security of supply was guaranteed by foreign direct investments, the frail integration of producer countries in the international market, and US foreign and security policy. Current energy policies also cannot alleviate the impact of sustained higher oil prices on the economy. Energy security in the past three decades relied on the hegemonic powers of the United States and its willingness to share its energy security with its most important allies. China does not seem to be convinced that it will be allowed to share in the energy security of the market economies, particularly in an energy market that is expected to be tight in the coming decades. Distrust among major consumers could then easily translate in competing systems of rule setting.

The new post-Cold War era offers ample room for the world's dominant powers to compete for control of and access to oil and gas. Unless a new energy strategy approach is initiated that can help rival powers to escape the prisoner's dilemma of oil and gas consumption, this geopolitical rivalry will continue.

## Annex

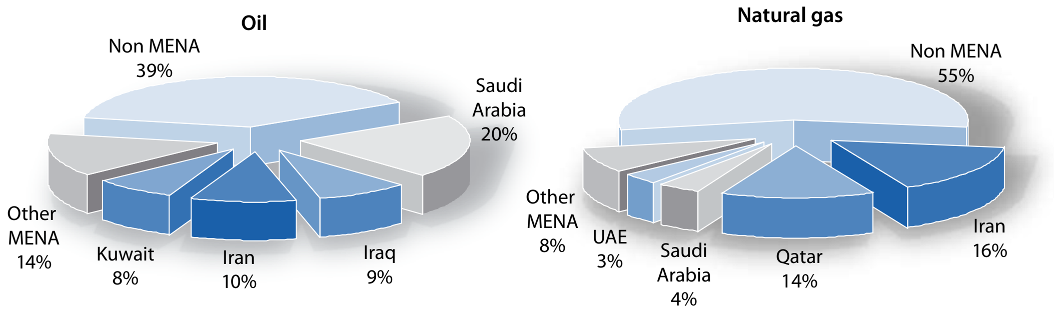
**Figure A1. Development and distribution of world oil reserves**




Source: International Energy Agency (2004)

Notes: There is some difference in the data shown here and those reported by BP, United States Geological Survey (USGS), OPEC, and the Oil and Gas Journal. This difference results from definitions of proven reserves and the method of data collection.

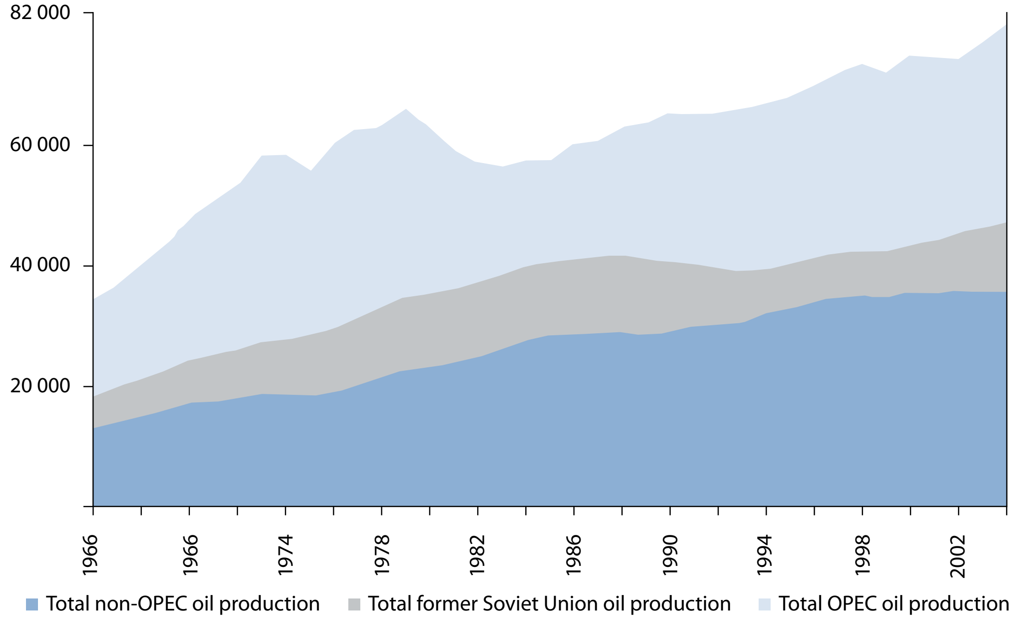
**Figure A2. World proven oil and gas reserves**




Source: International Energy Agency (2005)

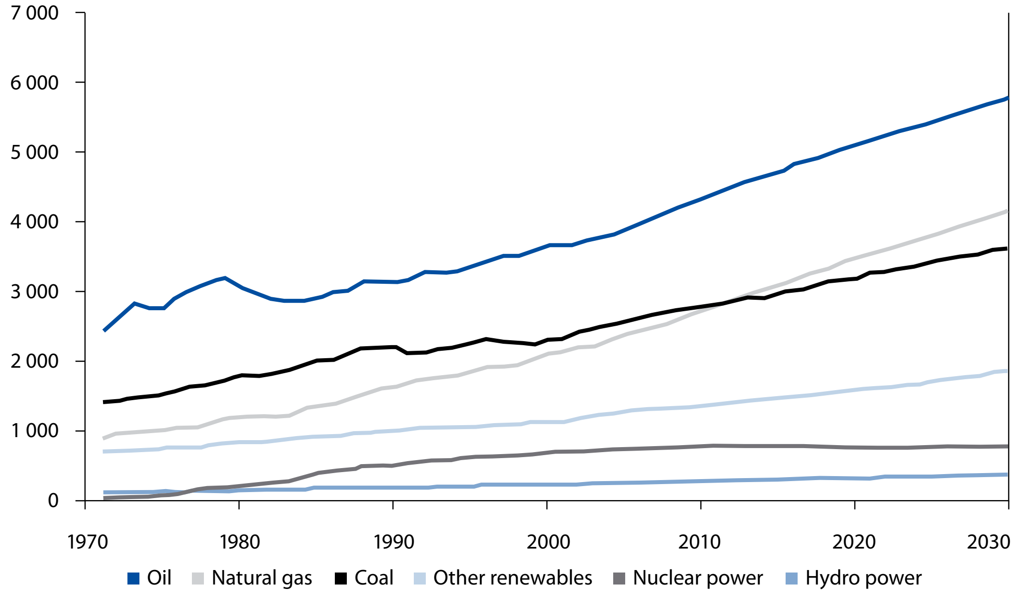
Notes: MENA ≡ Middle East North Africa

**Figure A3. World crude oil production (in thousands of barrels per day), 1965-2004**



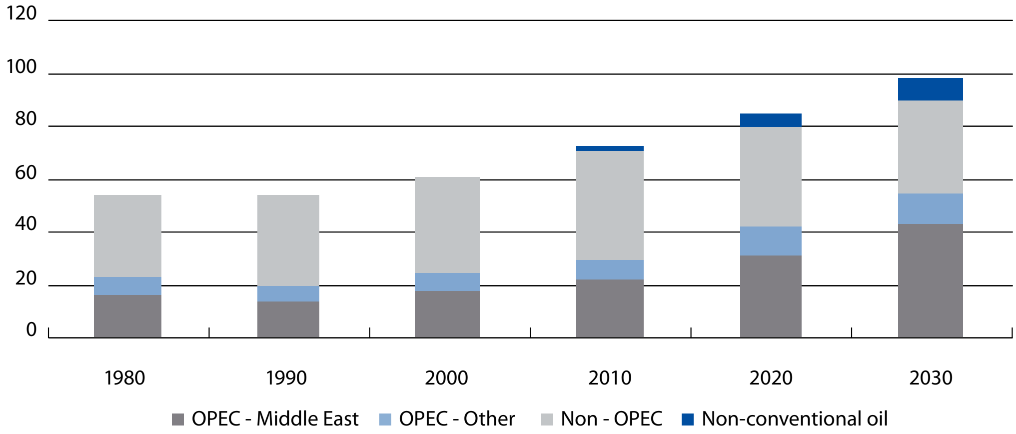

Source: BP (2005)

**Figure A4. World primary energy demand (in million tonnes of oil equivalent)**



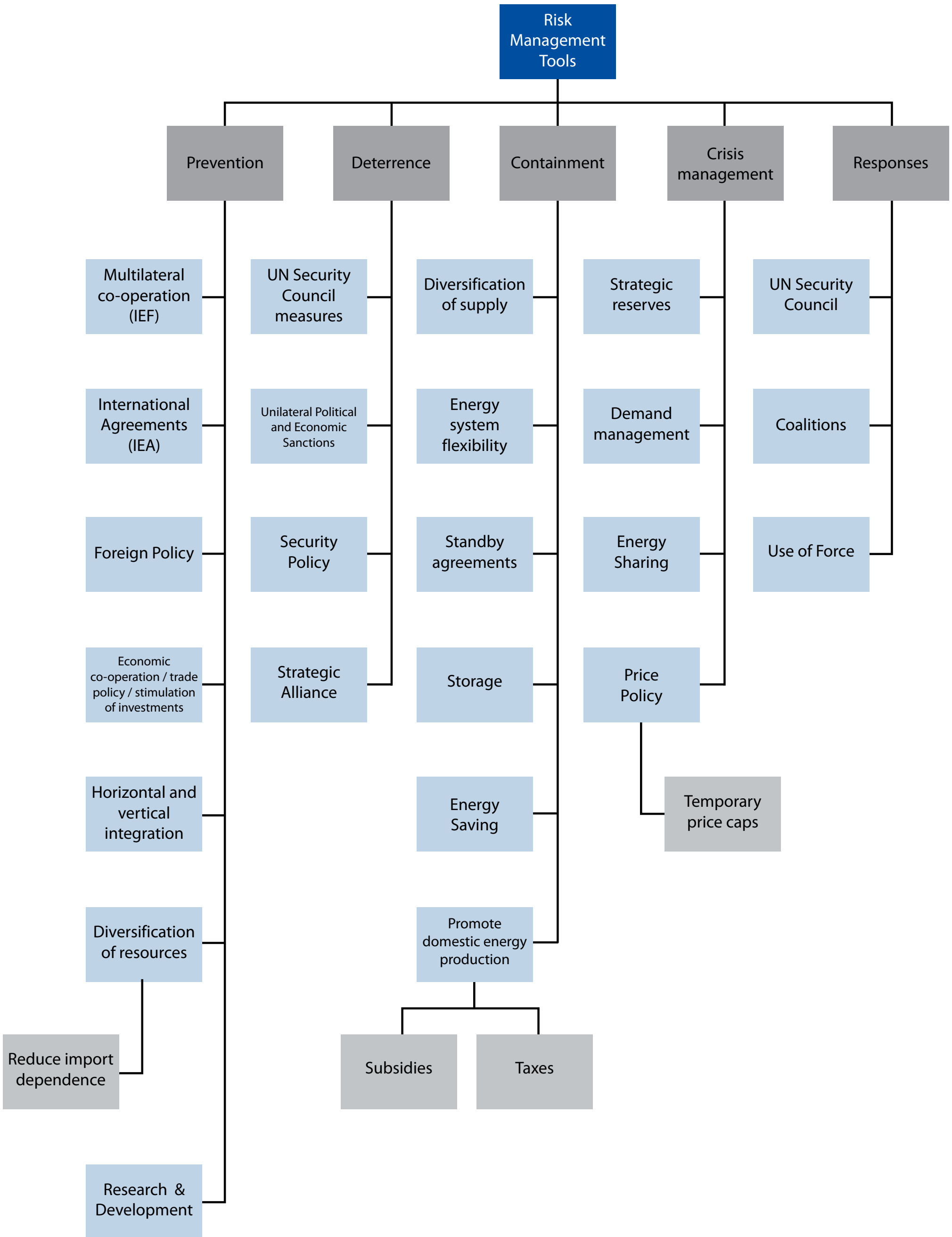

Source: International Energy Agency (2004)

**Figure A5. World oil production (in million barrels per day) – past, present, and future**




Source: International Energy Agency (2003)

**Figure A6. Energy risk management tools**




Source: Based on CIEP 2004

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## ABSTRACT

***Many people believe we must quickly wean ourselves from fossil fuels to save the planet from environmental catastrophe, wars and economic collapse.*** *However, we have the technological capability to use fossil fuels without emitting climate-threatening greenhouse gases or other pollutants. The natural transition from conventional oil and gas to unconventional oil, unconventional gas and coal for producing electricity, hydrogen and cleaner-burning fuels will decrease energy dependence on politically unstable regions. In addition, our vast fossil fuel resources, perhaps especially coal, are likely to remain among the cheapest sources of clean energy for the next century and perhaps longer, which is critical for the economic and social development of the world's poorer countries. By buying time for increasing energy efficiency, developing renewable energy technologies and making nuclear power more attractive, fossil fuels will play a key role in humanity's quest for a sustainable energy system.*



**Mark Jaccard** (jaccard@sfu.ca) has been a Professor in the School of Resource and Environmental Management at Simon Fraser University, Vancouver, since 1986 – interrupted from 1992-97 while he served as Chair and CEO of the British Columbia Utilities Commission.

# Fossil fuels and clean, plentiful energy in the 21st century: the example of coal

***Mark Jaccard***

## 1. Introduction

Many people believe we must quickly wean ourselves from fossil fuels – oil, natural gas, and coal – to save the planet from environmental catastrophe, wars and economic collapse. In this paper, I argue that this view is misguided. I present, instead, evidence to support the hypothesis that fossil fuels can play an integral part of an energy system that can be characterised as sustainable.[1]

For one thing, we have the technological capability to use fossil fuels without emitting climate-threatening greenhouse gases or other pollutants. Also, while we may be reaching limitations in the search for conventional oil and natural gas, the resulting market-driven transition from conventional oil and gas to unconventional oil, unconventional gas and coal for producing electricity, hydrogen, and cleaner-burning fuels will decrease energy dependence on politically unstable regions.

In this paper, I elaborate on this hypothesis by focusing especially on the prospects for coal, the most widely dispersed and easily accessible of the fossil fuel resources. In Section 2, I present a definition of energy system sustainability. In Section 3, I show why our current energy system is not sustainable. In Section 4, I explain how fossil fuels, in particular coal, can meet our energy needs without significant environmental harm. In the interests of brevity, I focus on greenhouse gas emissions from the use of coal to produce clean forms of secondary energy, namely electricity and hydrogen. I also provide rough cost estimates. This is the largest section of the paper. In Section 5, I present a multi-criteria approach to compare a fossil fuel like coal to its energy supply competitors: renewable energy and nuclear power. In section 6, I discuss the policy implications and present the conclusions.

## 2. Defining energy system sustainability

I apply a simple definition of energy system sustainability. To be sustainable, an energy system must meet two conditions.

- First, the energy system must have good prospects for enduring indefinitely in terms of the type and level of energy services it provides. Moreover, given the significant energy use that will be required to improve human well-being in much of the developing world, the size of the global energy system would ideally grow substantially over this century. A sustainable global energy system must be able to provide this expanded level of energy services indefinitely.

- Second, extraction, transformation, transport, and consumption of energy must be benign to people and ecosystems. Flows of the energy system's material and energy by-products must correspond with the ability of land, air, and water to absorb and recycle them without significant negative disruption. In this sense, both the known, cumulative impacts of the energy system must be negligible and any extraordinary risks it poses must be extremely unlikely – and ones from which the system could recover within a reasonable period of time, perhaps aided by rehabilitation efforts. In sum, a sustainable global energy system must have low impacts and low risks.

1 What I present here is a short version of the more detailed arguments and evidence in my recent book *Sustainable Fossil Fuels: The Unusual Suspect in the Quest for Clean and Enduring Energy* (2006).

Both of these conditions are inherent in most working definitions of sustainability. If the system cannot endure, perhaps because some irreplaceable input is exhausted, it cannot be sustainable. If the system is ultimately toxic to humans and the environment, then it also will not endure, this time not because of resource exhaustion but because of disruption and destruction of natural systems and harm to humans.

***It is commonly assumed that the way we consume the earth's fossil fuels must certainly be unsustainable.***

It is commonly assumed that the way we consume the earth's fossil fuels must certainly be unsustainable given that fossil fuels are a rich and irreplaceable endowment produced from millennia of biological and geological processes. Consumption of them today leaves nothing for the future, and the alternatives will be difficult to develop and much more expensive. This seems like a safe assumption. But is it?

## 3. The global energy mix: what is it and where is it headed?

To determine if our energy system is sustainable, we need to estimate where it is headed. I reviewed several forecasts of the long-term evolution of the global energy system and from these selected two mainstream scenarios to guide my 'current-trends estimate'. The scenarios I used are from the 1992 Intergovernmental Panel on Climate Change (scenario IS92a) – as reported in Leggett *et al.* (1992) – and the 2001 World Energy Assessment (scenario B) – as reported in Goldemberg and Johansson (2004). Both of these scenarios share many assumptions, but they also differ in certain respects. Both assume similar trends for income growth: a global level of gross world product rising from $32 trillion in 2000 to above $200 trillion (in 2000 prices) in 2100. Both assume similar trends for energy use: rising from 430 exajoules (EJ) to about 1,500 EJ in 2100. Both assume a global population above 11 billion in 2100. They both show a stagnation of large hydropower as land use conflicts intensify, a decline in conventional oil as its supplies are exhausted, and a healthy growth rate for biomass (for electricity generation and production of biofuels) and other renewables such as solar, wind, and small hydro. In meeting the huge increase in energy demand, however, scenario B relies on a dramatic expansion of nuclear and natural gas while the scenario IS92a suggests that coal will be more dominant. My scenario takes a median position between these contrasting views.

Relative to the two scenarios discussed above, I project a somewhat lower population in 2100 of 10.5 billion, a value recently suggested by the United Nations and other population forecasters. My current-trends projection has global economic output increase (in constant prices) from $32 trillion in 2000 to $80 trillion in 2050 and $230 trillion in 2100. This implies an average global economic growth rate of 2 percent per year, similar to the average growth rates of recent decades, and results in global economic output that is seven times the current level. Dividing global world product by the smaller population in my current trends means that average income (GDP/POP) grows from about $5,000 per capita in 2000 to $8,500 and $22,000 in 2050 and 2100.[2] The average income of $22,000 is comparable to current levels in industrialised countries. This is a global average; I make no specific assumption about the relative incomes between developing and industrialised countries other than to include some narrowing of the disparity in my estimated energy uses in different parts of the world.

I assume that global primary energy intensity (E/GDP) will continue the downward trend of the past five decades, although its rate of decline will be slower in the first half of the century as developing

2 I call global economic output 'GDP', although a more accurate term is global world product.

countries expand their more energy-intensive sectors, and then more rapid as these countries adopt more sophisticated technologies and shift to a greater role for the services sector. Primary energy intensity falls from 13.6 (megajoules) MJ per dollar of gross world product in 2000 to 9.6 in 2050 and 6 in 2100. This represents an annual rate of decrease of 0.69 percent from 2000 to 2050 and 0.93 percent from 2050 to 2100. The 0.93 percent is close to the rate of decrease that occurred during the 15 years following the oil price shocks of the late 1970s and early 1980s.

As in the past, increases in population and especially economic output swamp declines in energy intensity so that total primary energy use grows from 429 EJ in 2000 to 770 in 2050 and 1,390 in 2100, more than a three-fold increase over the next 100 years. For comparison, the global energy system grew 16-fold over the past century. On a per person basis, this translates into an evolution from 70 GJ per capita in 2000 to 80 and then 130 in 2050 and 2100 – a doubling of per capita energy use in 100 years. It is important not to get too fixed on specific numbers. Whether the future size of the system is 860 EJ (a doubling) or 1,720 EJ (a quadrupling), most observers would agree that the system is likely to be significantly larger in 100 years. That information is sufficient for assessing system sustainability.

***As in the past, increases in population and especially economic output will swamp declines in energy intensity.***

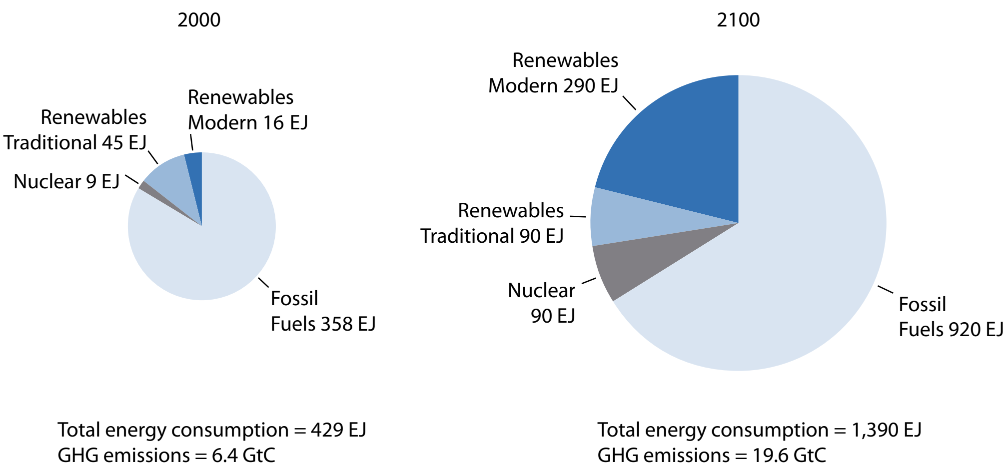
In setting my current-trends values for the relative contribution of primary forms of energy, I struggled with several major uncertainties. While some experts believe that production of oil and gas will drop off significantly in the next few decades because of supply constraints, others believe that advancing technological capabilities will enable us to sustain output and perhaps expand it. My current-trends assumption has oil and gas declining after 2050, albeit not as dramatically as some analysts predict.[3]

There is also much uncertainty about the relative prospects for nuclear and coal in meeting the widening gap between expanding energy use and stagnant oil and gas output. My current-trends scenario has nuclear and coal both growing significantly although coal's share grows the most, reaching 47 percent of total primary energy by 2100. This is because coal is often less expensive for making electricity and for producing the liquid and gaseous fuels that might replace declining oil and natural gas stocks. Remember that my projection sustains the general character and trends of the current energy system, which means that there are no major policy initiatives to achieve environmental or security objectives. As for renewables, my current-trends projection assumes an increase from 61 EJ in 2000 to 380 EJ by 2100, with most of this increase coming from modern uses of renewables such as wind and solar power and the conversion of biomass into gaseous and liquid fuels and electricity.

For assessing sustainability in this paper, my current-trends projection shows only energy-related $CO_2$ emissions, which are estimated to account for at least 60 percent of the climate change effect – ignoring other greenhouse gas (GHG) emissions such as nitrous oxides and methane. Figure 1 shows the resulting primary energy use and GHG emissions. Energy-related GHG emissions are projected to increase from 6.4 gigatonnes of carbon (GtC) per year in 2000 to 19.6 GtC in 2100. This substantial increase is consistent with many of the scenarios generated by the Intergovernmental Panel on Climate Change (IPCC) and other organisations.

3 That fossil fuels are plentiful – certainly in economic terms – is discussed in greater detail in Jaccard (2006, Chapter 5).

**Figure 1. Current-trends primary energy and GHG emissions**




My current-trends case would generate cumulative $CO_2$ emissions in the 100 years between 2000 and 2100 of about 1,200 GtC. For reference, the total anthropogenic $CO_2$ emissions from 1860 to 1995 are estimated at 360 GtC, of which 240 GtC were from fossil fuel combustion and 120 GtC from deforestation and other forms of land use change. According to the current models of carbon cycling between the atmosphere and the earth, the $CO_2$ emissions from my current-trends case would result in 2100 in a $CO_2$ concentration in the the earth's atmosphere of over 650 parts per million by volume (ppmv) compared to the pre-industrial concentration of about 280 ppmv, and this concentration would keep increasing rapidly into the following century. Climate scientists suggest that concentrations above 450 ppmv could substantially affect the earth's climate.

## 4. The scope for zero-emission use of fossil fuels: the case of coal

***My current-trends projection confirms today's wisdom that our energy system is unsustainable.***

My current-trends projection confirms today's conventional wisdom that our energy system is unsustainable: combustion of the world's still-plentiful fossil fuels causes a continuous rise in atmospheric greenhouse gas emissions, which is just what scientists are warning us is unsustainable. However, there is also a growing awareness that abolishing fossil fuels is not necessarily the only or indeed even the best way of reducing GHG emissions. In this section, I summarise the latest evidence on how we might benefit from fossil fuels without emitting greenhouse gases into the atmosphere – what are referred to as 'zero-emission' fossil fuel technologies.

The body of literature on preventing carbon emissions from fossil fuel use seems to double every year, making it precarious to say anything definitive about which paths are more likely to emerge when the inevitable technological shake-out occurs.[4] I provide here an overview of the major technological options that are likely to remain relevant in the years to come. Because coal is considered to be the most plentiful fossil fuel, but also the least desirable in terms of cleanliness of use, I focus below on options that can use coal as the primary energy source.

First, I must clarify the terminology. Although these options are generally referred to as 'zero emission', this is not entirely accurate. The emission prevention techniques that are currently under

4 For an overview of the options see Intergovernmental Panel on Climate Change (2005); Anderson and Newell (2004); International Energy Agency (2004); and http://www.fossil.energy.gov

consideration and whose costs are seen as reasonable all allow at least some escape of $CO_2$ into the atmosphere. A more precise term, therefore, would be 'near-zero-emission' processes. I stick with the term zero emission for simplicity and to signify that if any of these processes were to become the global norm, the effect would be a profound reduction in $CO_2$ emissions that would reverse the trend of rising atmospheric concentrations.

Capturing carbon as a solid or as $CO_2$ gas is one thing. Disposing of it is quite another. I focus first on processes for capturing carbon, then turn to the carbon storage question, and finish the section with a look at costs. Consistent with most current views, I focus on processes involved in capturing and storing carbon in the form of $CO_2$.

### 4.1 Carbon capture

Some commentators have suggested that the challenge of preventing $CO_2$ emissions from fossil fuel combustion is fundamentally different from the previous emission reduction challenges that the industry has dealt with – by virtue of the fact that $CO_2$ is an inescapable by-product of fossil fuel combustion. But academic and industry researchers seem unimpressed with this apparently daunting task, and have tackled this new challenge no differently than their predecessors solved earlier problems in reducing $SO_2$, particulates, $NO_x$ and other emissions.

***Academic and industry researchers have tackled carbon capture no differently than their predecessors addressed $SO_2$, particulates, $NO_x$ and other emissions.***

Indeed, one of the most promising approaches is to install yet another process for purging an unwanted emission from the post-combustion flue gases of fossil fuel electricity generation plants. Using existing technologies, it is possible to react the flue gas with a solvent that attracts the $CO_2$. The solvent then releases a stream of pure $CO_2$ in a separate stage, and finally is recycled back into the flue gas to repeat the process. The residual flue gas (mostly $N_2$, $O_2$ and $H_2O$) is released into the atmosphere. Some $CO_2$ escapes along with this gas.

This '$CO_2$ scrubbing' technique can be integrated into new coal-fired power plants, and even retrofitted into existing plants if there is enough room. The energy required to run the capture process, however, would decrease the efficiency of a typical plant by 14 percent. To reduce this energy penalty, researchers are exploring ways to increase the efficiency of the scrubbing process by raising the $CO_2$ concentration in the flue gas from its typical level of 5-15 percent. This is achieved by increasing the oxygen content and pressure of the air fed into the combustion chamber through an air separation unit. Each option progressively increases the concentration of $CO_2$ and thus the efficiency of the chemical extraction process, but is only viable if the extra costs of concentrating oxygen are compensated by lower costs of $CO_2$ extraction. At an extreme, pure oxygen could be fed into the combustion chamber, resulting in a flue gas rich in $CO_2$ and water vapour. The latter could then be condensed in order to isolate the $CO_2$-rich gas stream. Because of the energy requirements of the air separation unit, this approach would decrease the efficiency of the coal plant by 11 percent.

Thermal power stations and some types of large industrial plants are stationary sources of $CO_2$ emissions for which this post-combustion capture approach would be relatively easy to implement. When it comes to smaller-scale fossil fuel combustion, however, the technological challenge is daunting. Carbon capture implies that equipment like home furnaces and personal vehicles would be fitted with miniature versions of the elaborate processes involved in $CO_2$ extraction, concentration and disposal in a coal power plant. This seems unlikely, although technological surprises cannot be rule out.

For total emission prevention, the more likely scenario is a substantial increase in the end-use role of electricity and hydrogen and a commensurate reduction in the end-use combustion of refined petroleum products (heating oil, transport fuels, butane, and propane) and perhaps even natural gas. Recognition of this has generated considerable interest in technologies and processes that produce from fossil fuels these two key forms of secondary energy while capturing $CO_2$ and other emissions.

Hydrogen has long been produced for industrial use, as a feedstock for ammonia production in fertiliser plants, but also for production of higher fraction fuels in oil refineries and, more recently, for the production of synthetic oil at oil sands plants in western Canada. Although hydrogen can be produced using any form of energy, most current production is based on the catalytic reaction of natural gas (mostly methane – $CH_4$) with steam – called 'steam methane reforming'. Steam and methane are combined in a reactor at temperatures between 750 and 900°C where they react to form a synthesis gas comprised mostly of carbon monoxide (CO) and $H_2$. This gas is cooled and then combined with steam to provoke a water-gas shift reaction that splits the water to make even more $H_2$ while the oxygen combines with the CO to produce $CO_2$. The resulting gas mixture rich in $CO_2$ and $H_2$ is then split into separate gas streams using chemical solvents. Because there has been little concern in the past for capturing pure $CO_2$, the practice thus far has been to separate the $H_2$ but leave the $CO_2$ with other fuel gases for combustion, which means that all of the carbon in the natural gas eventually ends up as emissions of $CO_2$ and CO to the atmosphere.

If coal is the energy source instead of natural gas, and if the $CO_2$ is to be captured, some extra steps are required, but again these involve conventional technologies. Since coal has very little hydrogen, water is the major source of hydrogen in coal-based processes; coal provides the necessary energy for separating the hydrogen in water from oxygen.

The first step is coal gasification – subjecting the coal to oxygen and steam under pressure. This is the process developed in Germany in the 1920s and used today in South Africa to produce synthetic liquid fuels from coal, called *Fischer-Tropsch liquids*. Gasification produces a CO-rich synthesis gas comprised mainly of CO and $H_2$. The gas then enters a gas cleaning unit that extracts sulphur, mercury and other potentially toxic compounds (depending on the properties of the source coal) using solvents and other processes (an alternative configuration involves delaying some gas cleaning until after the next stage). Next, the gas is reacted with steam in the same water-gas shift reaction described for steam methane reforming, producing a synthesis gas rich in hydrogen and $CO_2$. A solvent, such as amine, is then used to capture $CO_2$ from the synthesis gas, leaving pure $H_2$ as the output. Researchers are trying to develop membranes that filter the $CO_2$ instead of capturing it with solvents; this could reduce the energy and material costs of separation.

***Producing hydrogen from coal requires considerable energy, especially for generating the steam used in the coal gasification and the water-gas shift reaction.***

Producing hydrogen from coal requires considerable energy, especially for generating the steam used in the coal gasification and the water-gas shift reaction. The first-law efficiency of the coal input to the hydrogen output is about 65 percent.[5] Production of hydrogen from natural gas using steam methane reforming can achieve efficiencies above 80 percent, but this must be traded off against the higher cost of natural gas as both a hydrogen feedstock and energy source. Coal and water as the combined energy-hydrogen source are cheaper than natural gas and less risky with respect to price fluctuations and long-run price outlook.

5 First-law energy efficiency is measured by the ratio of the energy input to the useful energy output of a device. Although this is clearly a key aspect of energy efficiency, energy analysts point to the importance of second-law efficiency, which is measured by the ratio of the energy input of a device to the minimum amount of energy theoretically needed to perform a task. The differences and links between first-law and second-law efficiency are described in more detail and illustrated in Jaccard (2006, Chapter 4) in the context of discussing the role of energy-efficiency improvements in creating an enduring and sustainable energy system.

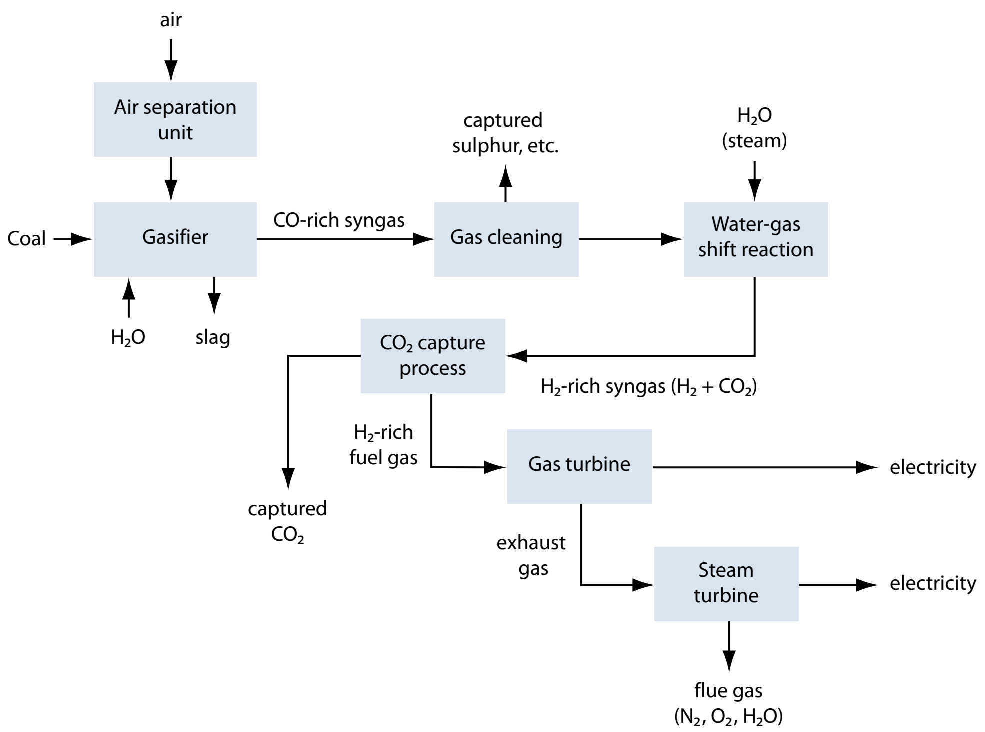
This coal gasification process can capture as much as 99 percent of sulphur and other pollutants, some of which can be processed into commercial chemicals. The slag residue from the gasifier can be used as a harmless material feedstock in road construction and perhaps other civil works.

While hydrogen has an important role as an industrial feedstock, it is rarely called upon to provide energy. Indeed, the development of hydrogen as a major source of secondary energy is hindered by the chicken and egg problem that faces all revolutionary changes in technology – hydrogen-using technologies need major expansion of hydrogen production and distribution facilities to justify their widespread dissemination, and *vice versa*. For this reason, most industry observers expect that coal gasification with carbon capture will first establish a market in electricity generation, a form of secondary energy that already has an established end-use market and delivery system.

The technological configuration that has captured the most attention is the integrated gasification combined cycle (IGCC) with carbon capture. As explained above, coal is gasified to produce a synthesis gas (labelled 'syngas' in Figure 2 below), but this time the hydrogen resulting from separation is combusted in a combined cycle unit (gas turbine and steam turbine) to produce electricity.

***The technological configuration that captured most attention is the integrated gasification combined cycle with carbon capture.***

**Figure 2. IGCC to produce electricity with carbon capture**




While its key technological components have all been in commercial operation for different applications, a single large IGCC plant has not yet been constructed; without penalties for $CO_2$ emissions, electricity companies had no motive to absorb the higher capital costs of an IGCC. To address this concern, the US government launched its *FutureGen* initiative in 2003 – a $1 billion IGCC plant that would generate electricity (275 MW) but also serve as a laboratory for producing hydrogen from coal and for carbon capture and storage technologies. Since then, several governments have launched initiatives to build demonstration IGCC plants and some major electricity companies have announced plans to build large commercial IGCC plants for electricity production.

In presenting these major options, I have deliberately kept things simple. In each case only one form of secondary energy is produced: electricity or hydrogen. The gasification literature, however, is full of increasingly complex configurations in which a fossil fuel input (and biomass in some cases) is gasified into synthesis gas, which is then converted into not just electricity and hydrogen, but an array of synthetic fuels such as methanol, *Fischer-Tropsch liquids* (synthetic gasoline and diesel) and dimethyl ether, and perhaps even into various synthetic chemicals such as acetic acid, methyl acetate, ethylene, and propylene. These so-called poly-generation plants could be financially attractive because of their ability to generate value from so many of the process by-products and to achieve higher energy efficiency from using all available waste heat.

In terms of input energy source, the processes for zero-emission production of hydrogen and electricity could equally use natural gas or oil as the energy input instead of coal. Given their higher hydrogen content and greater energy density, these fuels can be more efficiently converted into hydrogen and electricity, but they are more expensive inputs than coal. Capital costs will also be different from one form of energy to another, including the equipment for controlling other pollutants. The choice of fuel will depend, therefore, on the interplay of these various factors, and will vary from one locale to another.

Biomass is also a potential fuel for energy conversion plants with carbon capture. In concert with carbon capture and storage, the use of biomass as input fuel creates a process with negative GHG emissions: extracting carbon from the atmosphere in photosynthesis to produce biomass, gasifying the biomass to produce synthesis gas, separating $CO_2$ from the synthesis gas and producing electricity or hydrogen from the hydrogen-rich gas, and then storing the $CO_2$. For some people this sounds too much like science fiction – a way for humans in future to manage the climate of the planet by increasing and decreasing the amount of $CO_2$ in the atmosphere. But technologically, this simply reflects our current capabilities.

Regardless of the input fuel or technology for carbon capture, this vision of zero-emission use of fossil fuels depends on whether the captured carbon can be permanently and safely prevented from reaching the atmosphere. Carbon storage is another field whose literature seems to double every year.

### 4.2 Carbon storage

***For several decades some industries have been required to safely store or convert into marketable products various solid and gaseous wastes …***

For several decades, some industries have been required to safely store or convert into marketable products various solid and gaseous wastes. Particulates that are removed by electro-static precipitators and other collection systems (fly ash) find uses as material in structural fill, as dewatering and bulking agents, as road base materials, and as a feedstock in cement and concrete. In the case of sulphur, the conventional practice involves desulphurisation processes that recover sulphur in solid form (surface solids storage), which can have a market value for various processes and products. Recently declining prices in sulphur markets, however, have led to acid gas injection deep into geological formations – these acid gases are hydrogen sulphide ($H_2S$), $CO_2$, and other compounds that are mixed with natural gas in its reservoir and must be separated in order to produce marketable natural gas.

If our energy system is to continue to rely on fossil fuels while evolving into a zero-emission system, almost all carbon from fossil fuel use must be captured and stored. This means that we could conceivably require permanent storage capacity for the over 6,000 gigatonnes of carbon (GtC) in the estimated fossil fuel resource base. A carbon sink is the term used for a medium in which carbon is currently stored or potentially can be stored. The three major sinks that have been identified for carbon storage (or sequestration) are surface storage, ocean storage, and geological storage.

Surface storage of carbon can be achieved with natural and industrial processes. Living and dead biomass on the planet is already a major carbon sink. Forestry and agricultural carbon management can increase carbon storage in plants and soil by increasing or modifying vegetative cover and by altering tilling practices. By itself, however, this form of sequestration cannot prevent the build-up of greenhouse gases in the atmosphere because the mining of fossil fuels continually introduces to the earth's surface and atmosphere carbon that had been stored for millennia in sedimentary layers.

Another possibility for surface storage is for humans to extract elemental carbon from oil and natural gas directly and store it as solid carbon bonded with other elements to produce carbonate rocks. This may ultimately turn out to be the solution, but considerable research and development is required before we can know if this can be achieved at a reasonable cost on a large enough scale.

Ocean storage was initially seen as the most promising means of storing carbon. The oceans are already a major carbon sink, but their capacity to hold carbon can be augmented by pumping $CO_2$ into ocean depths from where it would not resurface because of its physical properties relative to seawater. At ocean depths below 800 metres, $CO_2$ changes from gas to liquid and below 3,000 metres it would have negative buoyancy relative to seawater, meaning that it would sink to the ocean floor. The potential storage capacity of this option far exceeds the carbon in the earth's estimated fossil fuel resources. However, the option raises environmental concerns about how acidity changes caused by increased $CO_2$ might affect deep ocean life forms. It is also expected that increased concentrations of $CO_2$ in the atmosphere will naturally increase the rate of $CO_2$ uptake in aquatic biomass, but an endeavour to manage this process is likely to be more difficult to control than land-based strategies.

***… resulting in accumulated experience in transporting $CO_2$ and injecting it into underground geological structures.***

Geological storage has garnered the most attention in recent years. For several decades, the fossil fuel industry has had experience in transporting $CO_2$ and injecting it into underground geological structures. In more than 70 sites worldwide, $CO_2$ is injected into oil reservoirs to increase pressure as part of enhanced oil recovery (about 20-30 million tonnes annually). $CO_2$ injection is also a means for enhanced natural gas recovery and for dislodging methane from deep coal deposits as part of coal-bed methane production. Finally, $CO_2$ is injected into sedimentary layers as part of acid gas injection.

A highly relevant demonstration is provided by the recent development of a major enhanced oil recovery project in western Canada. Since 2000, a plant in North Dakota has been shipping $CO_2$ to Saskatchewan for injection into an aging oil field to increase its yield by 30 percent. The North Dakota plant is a coal gasification facility that produces a hydrogen-rich gas for industrial uses and a stream of $CO_2$ as a by-product. Instead of being vented to the atmosphere, 20 million tonnes of the $CO_2$ are being shipped over the next 30 years to the Canadian field in a 320 kilometre pressurised pipeline. Industry, governments, and researchers are closely monitoring the project as it integrates all of the essential components of a zero-emission fossil fuel system – coal gasification, production of a hydrogen-rich fuel, capture of pure $CO_2$ in the gasification process, a long $CO_2$ pipeline, and geological storage of the $CO_2$.

This and other economically attractive projects indicate the feasibility of a concerted effort to sequester $CO_2$ in depleted oil and gas reservoirs. However, current and future depleted reservoirs have a combined carbon storage capacity of only 300-600 GtC, not nearly enough to contain all carbon from fossil fuels if these were to continue to dominate the global energy system through this century and beyond. Other research has widened the search for suitable geological storage sites to include the much more plentiful deep saline aquifers which underlie sedimentary basins at depths greater than 800 metres – far deeper than typical fresh water aquifers, which are found at 300 metres and less.

Contrary to the common understanding of the word aquifer, saline aquifers are not underground bodies of water, but rather porous rock infiltrated with highly saline water (oil and gas reservoirs are also usually in aquifers). Depending on pressure, porosity and other conditions, the pores of deep saline aquifers are capable of absorbing large quantities of $CO_2$, which would have a liquid-like density at these pressures. Researchers note the serendipitous association between fossil fuel deposits and deep saline aquifers, as they are co-located in sedimentary basins around the globe. While aquifers that are capped by an impermeable sedimentary layer are ideal, this is not essential for long-term storage. If injected far enough from the reservoir boundary, the $CO_2$ may eventually either dissolve into the aquifer water (hydrodynamic trapping) or precipitate as a solid carbonate mineral by reacting with the surrounding rock (mineral trapping). If dissolved into the aquifer water, the flow rates are such that in a million years most $CO_2$ would not have travelled more than 10-20 kilometres from the injection site. Efforts to estimate the total $CO_2$ storage capacity of deep saline aquifers are still crude, but the capacity is known to be huge. While initial estimates ranged from 3,000 to 10,000 GtC, of which two thirds are onshore and one third offshore, more recent analyses is converging around the middle of the range. Conveniently, this matches the planet's estimated carbon endowment in fossil fuels.

***From its experience in enhanced oil and gas recovery, the petroleum industry is familiar with the properties of hydrocarbon saline aquifers, and with the dynamic properties of injected $CO_2$.***

From its experience in enhanced oil and gas recovery, the petroleum industry is familiar with the properties of hydrocarbon saline aquifers, and with the dynamic properties of injected $CO_2$. But prior to the recent concern about climate change, there had been little interest in $CO_2$ sequestration in saline aquifers. Norway's implementation of a carbon tax of $55 per tonne of $CO_2$ in the early 1990s motivated the *Sleipne*r project in 1996. This is a project to inject $CO_2$ into a deep saline aquifer below the North Sea, not for enhanced oil or gas recovery, but simply to avoid the carbon tax. In this case, the carbon source is a reservoir of natural gas about 300 metres below the sea floor whose high $CO_2$ content must be reduced to meet market specifications. A process on the offshore platform uses a chemical solvent to separate $CO_2$ from the natural gas and then inject it into a saline aquifer 1,000 metres below the sea floor. The solvent is continually recycled in the process, and the cleaned natural gas is shipped by pipeline on the sea floor to northern Europe.[6]

Researchers, industry staff, and government officials now closely monitor the existing projects in which $CO_2$ is being geologically sequestered. Several new projects are in the planning stages or under development in Norway, Algeria, Australia, the United Kingdom and the United Sates.

Geological sequestration also requires the transport of $CO_2$, but there is extensive commercial experience since 1970 with long distance $CO_2$ pipelines, some of which extend more than 300 kilometres. The United States and Canada now have over 3,000 kilometres of pipelines carrying $CO_2$ from various sources for injection as part of enhanced oil recovery projects, resulting in the sequestration of about 50 million tonnes annually. These have operated without major concerns or incidents.

The generally positive views of energy technologists and earth scientists towards carbon capture and storage is important, but policy advisors know that no matter how low the risks of a particular technology, public perception is critical. Advocates of the zero-emission use of fossil fuels need to educate the public about the types of risks and their potential magnitude as well as engaging them in the planning and siting process of capture, transport, and storage facilities.

6 For an illustration of the process see:
http://www.statoilnorge.no/STATOILCOM/SVG00990.NSF/web/sleipneren?opendocument.

### 4.3 The future cost of carbon capture, transport, and storage

In the last decade, a great deal has been written on the projected costs of fossil fuel-derived energy with carbon capture and storage. While initial estimates varied substantially, the range has narrowed in the last few years as experts compare assumptions and share new information in conferences and international processes. A key document reflecting this work is the IPCC report on carbon capture and storage, which synthesises the extensive literature of recent years (Intergovernmental Panel on Climate Change 2005).

Carbon capture and storage cost estimates are constructed from individual estimates for the three separate components: capture, transport, and storage. Capture represents about 90 percent of the costs in most estimates.

Estimates have been generated for carbon capture in coal IGCC plants and natural gas combined cycle plants as well as for prospective coal and biomass poly-generation plants producing electricity, hydrogen, and synthetic fuels. These estimates vary in part because of different assumptions about fuel input costs (natural gas and coal), technology costs, regulatory costs, and the value of energy outputs (electricity, hydrogen, synthetic fuels, and process heat). They range from $75 to $150 per tonne of carbon ($21 to $42 per tonne of $CO_2$).

Because of the years of industry experience, there is little range in the estimates for the costs of $CO_2$ transport. Assuming a pipeline distance of 100-200 kilometres, the cost would be $14-$18/tC ($4-$5/t $CO_2$).

Sequestration costs can be negative or positive depending on whether the $CO_2$ has value for enhanced oil and gas recovery. The sequestration cost estimates therefore range from -$20 to +$30/tC (-$6 to +$9/t $CO_2$).

***Carbon capture and storage would add 2-3 $-cents per kWh to the cost of electricity produced from an advanced coal plant.***

When all three components are combined, the total estimated cost ranges from $70-$200/tC abated ($20-$56/t $CO_2$). One way of interpreting these numbers is to convert them into estimates of their effect on the production cost of electricity and hydrogen. In the case of electricity generation, carbon capture and storage would add 2-3 $-cents per kWh to the cost of electricity from an advanced coal plant, increasing its total production cost to 6-9 $-cents/kWh (assuming that sulphur, fine particulates, and other emissions are also captured). In the case of hydrogen production, carbon capture, transport and storage would add about $2-4 per gigajoule over the current cost of producing hydrogen from natural gas reforming (when the natural gas price is at $3/gigajoule).

When the objective is to shift to a clean energy system over a long time period, these costs do not present an overwhelming barrier. Electricity prices currently vary by at least 3 $-cents/kWh from one jurisdiction to the next as a result of regional resource endowments and historical investment choices (hydropower, nuclear, coal, natural gas, renewables). Indeed, the move towards market prices in some jurisdictions has been associated with short-run price fluctuations far exceeding 3 $-cents/kWh.

But whether or not our current preference for fossil fuels should be sustained as we shift towards a cleaner energy system depends on how this primary energy option compares to others. I now turn to this task by conducting an evaluation that includes cost information in conjunction with the other real-world considerations that might influence our choice of energy alternative, such as international politics, divisions between industrialised and developing countries, regional and local politics, and public perceptions of risk. I especially focus on coal, although the analysis applies to all fossil fuels.

## 5. A multi-criteria assessment of coal *vs*. alternative non-fossil fuel options

In this section, I compare fossil fuels, efficiency, nuclear, and renewables on the basis of their performance against three criteria: projected financial cost, extreme event risk, and geopolitical risk.

### 5.1 Projected financial cost

The cost of energy efficiency is controversial, with some advocates arguing that reducing energy use by 30-75 percent in industrialised countries is profitable at current prices. In part, advocates build their case on the presumption that there are easy to remove barriers to energy efficiency – a hypothesis critically reviewed, for example, by Schleich (this volume). Indeed, a substantial body of research suggests that this analysis overestimates technically achievable efficiency gains, underestimates risks associated with new efficient technologies with lengthy payback periods, underestimates welfare costs to consumers of adopting technologies and behaviours that are not perfect substitutes for current practices, overlooks cost decreases to supply technologies that make efficiency comparatively more expensive, and overlooks new profit seeking practices and consumer preferences that by increasing energy demand partly offset efficiency gains.

***It is increasingly recognised by independent energy analysts that only a fraction of the so-called profitable energy efficiency actions are likely to be economically beneficial.***

Thus, it is increasingly recognised by independent energy analysts that only a fraction of the so-called profitable energy efficiency actions are likely to be economically beneficial on the basis of financial costs alone (excluding externalities). Beyond this amount, some additional energy efficiency will cost only a modest amount, so effort to realise some of this may become financially justified. But only if the development of clean secondary energy leads to significantly higher energy prices will a substantial increase in the rate of energy efficiency improvement occur. Is this likely to happen?

The energy and environment literature is rife with estimates for future energy supply costs, much of it driven by the intense focus on reducing $CO_2$ emissions. I have reviewed several studies in the process of developing my own set of numbers for the costs of producing electricity, hydrogen, low-emission synthetic fuels, and biofuels.[7] My cost estimates are based on these studies, but also incorporate my reading of the particular constraints and opportunities facing each option over the course of this century – resource constraints, land-use constraints, regulatory constraints, infrastructure costs, and potential cost reductions due to economies of learning and economies of scale. Adjustments such as these are necessary because most cost estimates are focused on the technologies and resources that are seen to be most plausible for energy supply investments over the next 20–50 years. To produce a crude estimate that extends out 100 years, additional assumptions about these long-term constraints and opportunities are required. I explain the key assumptions behind each of my numbers.

Table 1 presents my estimates for the cost of generating electricity from alternative supply sources over the coming century. The values are in $-cents per kWh in prices of 2000. Confidence in the

7 Key studies include the following: Goldemberg (2000); Goldemberg and Johansson (2004); Intergovernmental Panel on Climate Change (2001); Intergovernmental Panel on Climate Change (2005); Gale and Kaya (2003); and Sims *et al. (*2003).

values is obviously higher for the earlier decades of the century. The range for each estimate indicates both the increase in uncertainty further into the future and the likelihood of movement as various constraints and opportunities come into play over time. These costs are assumed to reflect the costs for each option were it to experience large-scale development – which requires consideration of both cost-reducing and cost-increasing aspects.

**Table 1. Projected electricity cost ($-cents per kWh in 2000 prices)**

| Coal PC post-combustion | Coal IGCC | Natural gas CCGT | Nuclear | Hydro | Wind | Biomass | Solar-PV |
|---|---|---|---|---|---|---|---|
| 6–7 | 5½ – 6½ | 5½ – 6½ | 6–10 | 6–8 | 6–8 | 6–8 | 15–20 |

Notes: PC = pulverized coal; IGCC = integrated gasification combined cycle; CCGT = combined cycle gas turbine; PV = photovoltaic. Assumed input prices are coal $1.5–3/GJ, natural gas $5–7/GJ, and biomass $2–5/GJ.

All three fossil fuel technologies include the full cost of carbon capture, transport, and storage – reducing carbon emissions from each source by about 90 percent. They also include desulphurisation, low nitrous oxide emissions, and capture of particulates in the case of coal combustion. The two coal options are combustion of pulverised coal for a standard steam turbine with post-combustion capture of $CO_2$ and other emissions, and coal gasification with $CO_2$ capture from the resulting synthesis gas, which then feeds a combined cycle gas turbine. Some studies show natural gas as the cheapest fossil fuel option for generating zero-emission electricity, but my cost estimate reflects the transition over the course of the century from conventional natural gas towards higher cost unconventional sources (matching, perhaps with a lag of a few decades, that of oil) as well as the effect of the more recent trend for international trade in liquefied natural gas to bring natural gas prices upward into line with oil prices on a per unit of energy basis. Given the large current supplies, the cost of coal is unlikely to increase significantly over the course of the century, although it will experience short-term fluctuations whenever price instability affects a key substitute such as oil or natural gas.

The wider cost estimate for nuclear power of 6–10 $-cents/kWh reflects the diversity in how countries develop this technology, disputes about its full costs, and uncertainty about its future costs. My estimates are intended to include the full costs of siting new facilities, treating and permanently storing all nuclear waste, and operation of international institutions and monitoring mechanisms to ensure a safe worldwide expansion of the technology. Some experts argue that inclusion of all these costs will push the estimate into the higher end of my range and perhaps beyond.

The table presents four renewable alternatives for electricity generation – hydro, wind, biomass and solar PV. The wide range in the cost estimates for each renewable reflects the uncertainty as to how large-scale development will affect the countervailing factors causing cost reductions and cost increases. Renewables advocates focus on the economies of scale and economies of learning that will lower costs as renewables achieve a growing share of the global energy system. Sceptics caution, however, that there will also be upward cost pressures if renewables were to become the dominant source of energy. For hydropower, windpower and geothermal among others, development occurs first at the most favourable sites and then proceeds to less favourable, higher cost sites. The low energy density of most renewables means that wide-scale expansion will increasingly confront competition for land with non-energy uses, as in the case of biomass. Because many renewables provide only intermittent energy, the additional costs of energy storage must be included as renewables provide a larger share of energy supply. This can lead to substantially higher costs unless research and development realises significant gains in reducing the costs of non-hydro energy storage.

***The low energy density of most renewables means that wide-scale expansion will increasingly confront competition for land with non-energy uses.***

Table 2 presents my estimates for the cost of producing hydrogen from alternative supply sources over the coming century. As with electricity, these cost estimates reflect the cost of an option was it to experience large-scale development – which requires consideration of both cost-reducing and cost-increasing aspects. The range for each estimate indicates both the increase in uncertainty further into the future and the likelihood of upward or downward change as various constraints and opportunities come into play over time. The wider range of the cost estimates compared to those for electricity reflects the lack of experience with large-scale hydrogen production.

**Table 2. Projected hydrogen cost ($ per GJ in 2000 prices)**

| Coal gasification | Natural gas steam-methane reforming | Nuclear electrolysis of $H_2O$ | Wind/hydro electrolysis of $H_2O$ | Biomass gasification |
|---|---|---|---|---|
| 8–10 | 8–10 | 18–25 | 18–25 | 10–15 |

Notes: Assumed input prices are coal $1.5–3/GJ, natural gas $5–7/GJ, and biomass $2–5/GJ. For electrolysis, see Table 1 for assumed electricity prices from each source. GJ of hydrogen based on 'higher heating value.'

Unlike in the case of electricity, there are significant cost differences. Producing hydrogen via gasification or steam reforming is substantially less expensive than via electrolysis of water using electricity. Unless there is a major breakthrough in electrolysis processes, the gasification of coal and the steam methane reforming of natural gas – both with carbon capture, transport, and storage – offer the least costly means of producing hydrogen. Biomass gasification offers the lowest cost method of producing hydrogen from renewables, but it still has higher costs than coal gasification because of capital cost differences and land competition were this option to become the dominant means of producing hydrogen. Other candidate processes for hydrogen production, such as the thermal splitting of water, are excluded from the table as their costs will not be competitive without a major technological breakthrough.

***If hydrogen is to play a significant role in the global energy system, it is likely to be especially important as a transportation fuel, initially in large urban areas.***

If hydrogen is to play a significant role in the global energy system, it is likely to be especially important as a transportation fuel, initially in large urban areas. Given all of the uncertainties about long-term hydrogen transport and storage capabilities, and the resulting costs, the estimated cost of shifting to hydrogen for the services provided by personal vehicles is highly uncertain. This requires a set of cost estimates for fuel production, fuel delivery, vehicle engine platforms, and the efficiencies at each link in the chain. Some analysts suggest that even in the long-run the costs of fuelling personal vehicles with hydrogen will result in double the energy service cost – on a person-kilometre-travelled basis – compared to gasoline and diesel. Others suggest that within a few decades these costs could be quite comparable (see, for example, Ogden *et al.* 2004). Again, if this latter case is true, the prospects for reduced energy use due to efficiency and mode switching away from personal vehicles will be diminished accordingly.

Stepping back to compare all of energy supply costs, there are some situations in which the competing sources of supply are similar in cost. This suggests that other criteria will play a role in our choice of energy option. I focus below on how each option compares in terms of extreme event risk and geopolitical risk.

### 5.2 Extreme event risk

Both energy efficiency and renewables appear to have a comparatively clean slate when it comes to extreme event risk. Even the risks of failure by large hydro dams are well understood by experts and there is considerable public confidence in this expertise.

Nuclear power is especially vulnerable to the tendency for the public to put extra weight on catastrophic outcomes even though these have extremely low probabilities of occurrence. This can seem irrational to nuclear advocates, but it is consistent with a rational risk-averse strategy. Some analysts suggest, moreover, that nuclear power faces an additional burden in that the type of extreme event it is associated with is particularly frightening to many people. The unseen radiation exposure associated with a catastrophic nuclear accident signifies potential damage to the human genetic code and possible mutations in future generations. Dread of this type of extreme event is profound, even among well-informed and well-educated people, and this represents a serious handicap for nuclear relative to its competitors, especially for the siting of new plants. In the United States, for example, even if the federal government strongly supports the establishment of nuclear power facilities at new locations, local authorities have considerable control over site permitting and opposition groups have numerous legal and public relations means at their disposal.

Because of the potentially frightening character of a nuclear catastrophe, there is also a fear that nuclear facilities are ideal targets for terrorist attack. This possibility can appear to increase the probability of occurrence for what is otherwise an extremely unlikely event.

Fossil fuel use can be associated with various types of extreme events, although none of these appear to be at the same level of significance for the public and decision makers as the risks of a major nuclear accident. There have been marine oil spills, refinery explosions, pipeline explosions, and coal mining accidents (slides, mine collapse or explosion). However, the risks are mostly local and well understood, and can be diminished by efforts to tighten safety standards and to mitigate impacts in the aftermath of an accident. While an emerging risk from fossil fuel combustion is the possibility of runaway climate change from accumulated greenhouse gases, this risk does not apply to the zero-emission fossil fuel option.

As I noted above, geological storage of $CO_2$ is in its early stages, making it precarious to anticipate how the risks of large-scale development might be perceived by the public one or two decades from now. However, $CO_2$ has been injected underground for decades as part of enhanced oil recovery and acid gas injection. Localised risks from a significant leak do not appear to be of a different magnitude from the kind of risk the public faces every day from oil and gas pipelines, petroleum refineries, gas processing plants, enhanced oil and gas recovery, transport by truck, rail and ship, and even the use of oil and gas inside public and private buildings. The industry has a good safety record, but major accidents occur from time to time, and these do not lead to major shifts in opinion against the use of fossil fuels. Slow leaks of $CO_2$ could affect the achievement of greenhouse gas reduction objectives, but experts suggest that these slow leaks can be offset by a modest quantity of biomass gasification with carbon capture and storage.

### 5.3 Geopolitical risk

It is often assumed that renewables are like efficiency in that as domestic energy alternatives neither poses geopolitical risk. While this is true for efficiency, the apparent immunity of renewables from geopolitical risk might simply reflect their small share of the global energy system. Would that change if renewables were to dominate? In a renewables energy future, would each country become autarkic, meeting virtually all of its energy needs from indigenous renewable resources in a small-is-beautiful future? Or, would some countries have substantial advantages that enabled them to profit by exporting renewables-based electricity, hydrogen, and synthetic fuels to countries less favourably endowed?

***It is often assumed that renewables are like efficiency in that as domestic energy alternatives neither poses geopolitical risk.***

Although some advocates claim that the development of renewables would result in uniform energy costs between countries and the end of significant energy trade, the evidence suggests otherwise. Renewable resource endowments on the planet are as geographically heterogeneous as fossil fuel resources. Perhaps Mongolia would export wind-based electricity to China. Perhaps Middle-East countries, their conventional petroleum resources declining, would cover large areas of desert with PV arrays, exporting electricity directly or using it to produce hydrogen for export via pipeline and tanker. Perhaps biomass-rich countries would produce electricity and hydrogen and synthetic fuels for export. Under such heterogeneity of resource endowments and interdependence from trade, it seems plausible that renewable energy could be vulnerable to exploitation as a pawn of geopolitics just as water, another vital renewable resource, is today.

The geopolitical risks of nuclear power, in contrast, are widely agreed upon. Several times over the past decades, the dissemination of nuclear technology, ostensibly for domestic power production, has been associated with diversion to nuclear weapons development. Israel, India, and Pakistan cached weapons production under their domestic nuclear power programmes. Iraq tried to do this in the 1980s until Israeli fighter jets destroyed its main facility. North Korea and Iran are contemporary threats. Dominant powers in the world are wary that disgruntled or ambitious governments in unstable regions may try to develop nuclear weapons in order to improve their bargaining power, and that even terrorist organisations might try this.

***Geopolitical risk presents a substantial barrier to the global dissemination of nuclear power, especially to poorer regions of the planet.***

This risk presents a substantial barrier to the global dissemination of nuclear power, perhaps especially to the poorer regions of the planet where electricity demands should grow the fastest. Use of nuclear power may increase in OECD countries, if there is sufficient demand, if it can out-compete other energy sources (in competitive markets), and if local populations permit the siting of new plants. It can also grow in countries like Russia, India, and China – although the United States and other global powers are likely to be concerned about safeguarding measures if the nuclear industry grows to dominant levels in these energy systems. But its development in the Middle East, Africa, and parts of Asia is less likely to be acceptable to the United States and the other major powers for some time yet.

Some would argue, however, that the geopolitical risk of global dissemination of nuclear energy is small compared to the risk of reliance on petroleum imports – meaning that the geopolitical criterion actually works in favour of nuclear power. This was the rationale behind the French and Japanese nuclear programmes in the 1980s. Political instability in the oil-rich Middle East is correlated with periods of oil price instability and threats to economic growth: the Arab-Israeli war and oil embargo in 1973, the Iranian revolution in 1979, the Iraqi invasion of Kuwait and subsequent expulsion by NATO in 1991, and the Anglo-American invasion of Iraq in 2003.

With its extensive petroleum resources, Russia is less exposed to international oil market turbulence. There is, however, considerable concern in the United States, Europe, Japan and increasingly China and India that the geopolitical risks of oil will intensify, perhaps rapidly, over the coming decades as global dependence on OPEC and especially Middle-East oil increases. Oil resources in the United States, China, and Europe (North Sea) are being depleted while oil imports by industrialised countries and many developing countries like China are increasing rapidly. Both the United States and China are projected to experience a substantial growth in oil import dependence over the next decades if current trends continue.

While some people lump all fossil fuels together with oil when discussing geopolitical risk, others see a sharp difference. As it grows in significance, natural gas has achieved comparable status to oil in some respects, and this may include geopolitical risk. Europe feels increasingly that its natural gas supplies from Russia are insecure. One response is to increasingly rely on liquefied natural gas, which allows for supply from anywhere in the world.

Coal seems to pose virtually no geopolitical risks, either currently or in the foreseeable future. This fossil fuel is distributed widely around the planet, with key countries like the United States, Russia, and China being particularly well endowed, and India also owning substantial resources.

The evaluation of the geopolitical risks of fossil fuels must be understood in its full dynamic. While conventional oil provides the quintessential example of geopolitical risk, switching away from all fossil fuels makes little sense if the goal is to reduce this risk. Coal and natural gas are plentiful in many regions of the world. Moreover, major deposits of unconventional oil, ultra heavy oil and oil shale, are located far from the Middle East.

***The evaluation of the geopolitical risks of fossil fuels must be understood in its full dynamic.***

### 5.4 Multi-criteria comparison of the energy options

If these three criteria are dependable indicators of the key factors to consider when evaluating our primary energy options, they show that no option is superior on all counts. The choice is not obvious. One might conclude that we can and should pursue all four options with equal vigour. But if history is any guide, this is rarely a dependable approach – and the world rarely unfolds this way anyway. There are usually winners and losers, or at least options that fare better even though all are pursued to some extent. In this sub-section, I compare the options in terms of these criteria in order to generate my own assessment of the path that humanity is likely to follow if its goal is to achieve a clean and enduring energy system.

I summarise each energy option's performance against the evaluative criteria in Table 3. Energy efficiency and renewables are generally free of extreme event risk and geopolitical risk. Some efficiency and renewables are economic relative to zero-emission fossil fuels and nuclear, but their costs rise if more ambitious growth is pursued in too short a timeframe. Greater use of renewables, especially if rushed during the next few decades, will entail higher costs because renewables are particularly associated with new technologies that need more R&D and that have not yet benefited from the economies of scale and economies of learning that result from widespread commercialisation. As commercialisation progresses, the competitive position of renewables could improve, but this depends on whether exhaustion of the most favourable sites occurs faster than innovation and commercialisation can lower costs. The eventual cost of large-scale energy storage is a big uncertainty for the intermittent renewables like wind and solar, which could lead to much higher costs as their market share grows.

**Table 3. Multi-criteria comparison of energy options**

| | Projected financial cost | Extreme event risk to environment and humans | Geopolitical risk |
|---|---|---|---|
| **Efficiency** | Some competitive.<br>Costs rise steeply for dramatic reductions. | No risk. | No risk. |
| **Nuclear** | Slightly higher cost. | High perceived risk. | High risk. |
| **Renewables** | Some competitive,<br>some higher cost.<br>High costs if dramatic expansion in short time period. | No risk. | No risk yet.<br>Moderate risk possible with larger scale. |
| **Fossil fuels** | Competitive. Slightly higher cost with carbon capture and storage. | Moderate to low risk. | Oil perceived high risk.<br>Coal – low risk. |

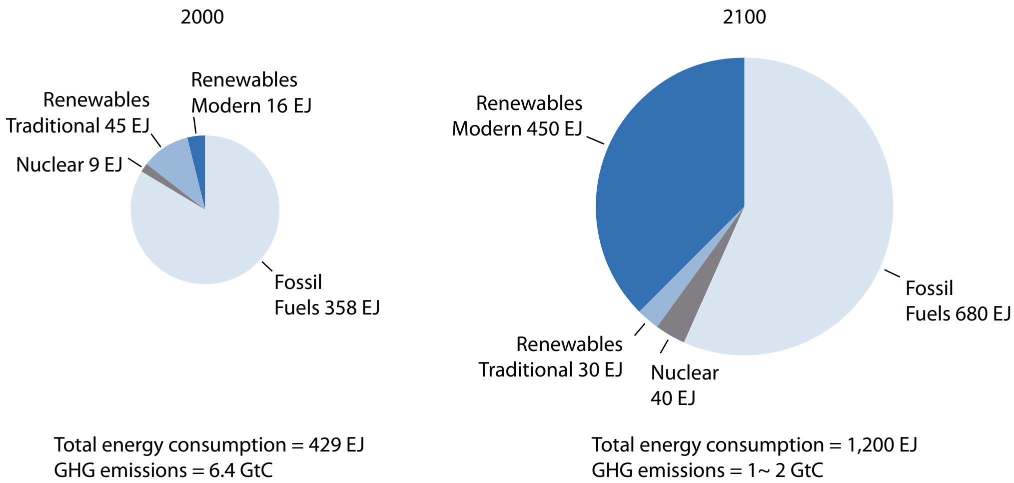
Zero-emission fossil fuels should remain economically competitive, given the plentiful resource base, the opportunity to substitute among fossil fuels with modest increases in production costs, and the reasonable cost of producing hydrogen, electricity and synthetic fuels in zero-emission processes. Conventional and unconventional oil may also play a role in the zero-emission production of electricity and hydrogen depending on the growth of these reserves as energy prices rise. With a growing role for coal, unconventional oil and unconventional natural gas, the geopolitical risk associated specifically with crude oil should diminish for fossil fuels as a whole. Extreme event risk should not be great, although there is still some uncertainty about the local risks of carbon storage in geological formations.

***My multi-criteria comparison suggests that nuclear power has a low chance of pushing aside fossil fuels and renewables in order to dominate the global energy system …***

This multi-criteria comparison suggests that nuclear power has a low chance of pushing aside fossil fuels and renewables in order to dominate the global energy system. Given its negative scores in the areas of extreme event risk and geopolitical risk, nuclear probably needs to be substantially cheaper than the alternatives if it is to have a chance of playing a dominant role in the global energy system for the foreseeable future. It does not have this cost advantage today and appears unlikely to achieve it during the next 50 years unless fossil fuels are deliberately abandoned while efficiency and renewables are pursued too aggressively. The best hope for nuclear is if large, relatively stable countries like China and India make the industry the centrepiece of their national energy strategies, but even expansion in these two countries would be insufficient for nuclear to realise a dramatic increase in its share of the global energy system.

To recall from Figure 1, in my current-trends projection nuclear grows tenfold over this century, from 9 to 90 EJ. On the basis of this multi-criteria comparison, I revise this downward in my sustainable energy projection – pictured in Figure 3 – to 40 EJ, which still represents a five-fold expansion, attaining 2,000 plants worldwide in comparison to the current 430. Most of this expansion would occur in the latter half of the century, keeping the share of nuclear in total electricity generation not far below its current 17 percent market share.

**Figure 3. The sustainable fossil fuel future**




Regardless of whether one favours renewables, nuclear power, or fossil fuels, most people agree in principle that energy efficiency has highly desirable attributes and should be pursued. There are, however, several challenges to the achievement of rapidly declining primary energy intensity (the ratio of primary energy to world economic output), which is the goal of our energy efficiency efforts.

First, a rapid decline in energy intensity is not always possible or desirable. In my current-trends projection, energy intensity declines by 0.8 percent annually during the century and still the global energy system grows to more than three times its current size. Yet global energy intensity was constant between 1850 and 1950, and only declined at an average annual rate of 0.7 percent during the last several decades, a period with recurrent expectations of rising energy prices and widespread government and utility energy efficiency efforts. Even if the rate of intensity decline could somehow be sustained through the century at the high rate of 1.2 percent annually, the global demand for primary energy would still grow to 920 EJ, more than double its current level.

Second, economic growth in developing countries can require a lot of energy for the steel, cement and other heavy industries whose output is required to construct buildings, factories and infrastructure. Growing energy demand from final consumers will cause strong upward pressure on energy intensity, again especially in developing countries where the increasing demand for heating and air conditioning of larger living spaces, all sorts of appliances, and greater personal mobility will strongly correlate with rising incomes. The rising energy demand associated with China's rapid economic growth of the past two decades illustrates this link.

Third, an energy system dominated by conventional oil and natural gas is able to take advantage of the high energy density and high conversion efficiency of these two primary forms of energy. As that system evolves towards unconventional oil, unconventional natural gas, coal, and renewables with storage, energy production and conversion activities will consume more energy. Oil sands extraction requires significant inputs. Zero-emission conversion of coal to electricity has a lower efficiency than conventional, emitting technologies. Offshore windfarms require long transmission lines that lose energy as a function of distance. The conversion processes required for providing energy storage alongside intermittent renewables will also use of lot of energy. Our exhaustion of the highest quality energy endowment and our demand for cleaner secondary energy will create, for global energy intensity indicators, an upward push to counter the normal downward push resulting from technologies becoming more energy efficient.

***… while an energy system dominated by conventional oil and gas is able to take advantage of high energy density and high conversion efficiency of these two primary forms of energy.***

Fourth, energy efficiency is a double-edged sword in that efficiency improvements lower the operating cost of energy services, which can result in a rebound in the demand for the service or some related service. Efficient light bulbs lower the cost of lighting, which may not increase the demand for interior lighting but may surface as increased demand for decorative and security lighting. Rebound also occurs because of the harder-to-measure connection between improvements in energy productivity and the invention of new energy using services and devices – and example being the rapid spread of backyard patio heaters in wealthier northern countries. Some research suggests that this phenomenon will be a significant counterweight to energy efficiency efforts.

These factors make it difficult for policies in favour of energy efficiency to make great gains in accelerating the normal tendency for energy intensity to decline gradually. Thus, under most scenarios of population and economic growth, the global energy system in 2100 is unlikely to be much below 1,200 EJ. In the absence of dramatically higher energy production costs, the only way to achieve this outcome would be via higher energy taxes and forceful energy efficiency regulations. Governments have not been able to sustain these types of policies in the past, and this would be especially difficult to justify if zero-emission energy supply were not particularly expensive.

For my sustainable energy projection in Figure 3, I assume that the global energy system in 2100 will require 1,200 EJ of primary energy instead of the 1,390 EJ of my earlier current-trends projection

(Figure 1). This will require an average decline in the energy intensity of the global economy of about 1 percent per year through the century. The primary energy system therefore increases by almost threefold, which is still a dramatic slowing of growth compared to the 16-fold expansion during the previous century.

Given the limitations of nuclear power and energy efficiency, I conclude that renewables and zero-emission fossil fuels will especially compete for dominance over the coming century. Renewables may appear to many people to be more attractive in terms of both cleanliness and endurance, but zero-emission fossil fuels are likely to have a cost advantage in most circumstances as well as the additional advantage that they currently dominate the global energy system. Even with rapid growth, renewables would be hard pressed to overtake fossil fuels by the end of the century given the small base they must start from in what will remain a rapidly growing global energy system. There would be a greater possibility if renewables were significantly cheaper than zero-emission fossil fuels, thereby motivating business and consumers to switch as soon as they had the chance. Instead, the evidence suggests that zero-emission fossil fuels will remain economically competitive with renewables because of the abundance of exploitable reserves of unconventional oil, unconventional natural gas, and especially coal – which will impede the ability of renewables to replace them quickly. Even if those who emphasise the global significance of 'peak oil' are correct, and conventional oil production soon begins an inexorable decline, this should have no significance for the competitive position of fossil fuels relative to renewables in the early decades of this century. Conventional oil is but a small component of the aggregate fossil fuel resource, and its potential fossil fuel substitutes may be more expensive per unit of fuel delivered, but not greatly so. Also, a more rapid expansion of renewables will more quickly confront the problems of energy storage and land use conflicts instead of allowing research and development the time to produce innovations that could address these challenges and reduce costs. In these circumstances, an effort to push the market share of renewables substantially beyond the already rapid growth in my current-trends projection is likely to raise the total costs of the energy system with no appreciable benefit in terms of the key trade-off criteria for choosing among energy options. It is difficult to envision the political will for such an effort.

***With environmental policies raising the cost of electricity from fossil fuels, renewables will find opportunities to compete.***

Since greenhouse gas emissions, especially carbon emissions, have a dominant place in current discussions about energy sustainability, I assess in greater detail how energy options and specific technology choices could affect the evolution of these emissions. Coal-fired electricity plants produced almost one third of anthropogenic carbon emissions in 2000, and this share grows dramatically in my current-trends projection. In the next decade or so, efforts to increase the role of wind, hydropower, and natural gas in electricity generation can only slow slightly the growth of carbon emissions relative to the current-trends projection. However, on a 10-50 year timeframe, carbon capture and storage technologies will pass from the demonstration stage to commercial dissemination – provided there are policies to motivate the installation of these higher cost technologies and processes. Once the technology is well-proven, it becomes much easier for governments in the middle decades of the century to enact more forceful policies that lead to universal compliance with carbon capture and storage requirements at coal-fired and perhaps natural gas-fired electricity generators. With these policies raising the cost of electricity from fossil fuels, renewables will find opportunities to compete. But even the high growth rate I envision for renewables will not sweep away fossil fuel dependency over the course of the century.

For the transport of people and goods – the other great source of carbon emissions – the picture is more complicated. It is important to assess not just the end-use emissions of the transport mode (personal vehicle, public transport, ships, trains and planes) but also emissions that occur upstream in the production of the electricity, hydrogen or hydrocarbon fuels used in the mode of transport. This is why some analysts argue that gasoline combusted in efficient internal combustion engines will still be desirable because the life-cycle emissions will be less than those of electric vehicles recharged from a fossil fuel-based electric grid or hydrogen fuel cell vehicles using hydrogen produced from fossil fuels (both in energy systems that lack carbon capture and storage). The case for efficient internal combustion engines is even stronger if some of the hydrocarbons it uses are produced from biomass.

***As for the transport of people and goods, the case for efficient internal combustion engines is even stronger if some of the hydrocarbons it uses are produced from biomass.***

However, because my clean energy future does not allow the use of fossil fuels without carbon capture and storage, I can focus on the relative viability of only those major technology-energy alternatives for transport energy that have close to zero life-cycle emissions. If the global carbon constraint is severe, biomass may garner an exclusive role in the production of liquid fuels for air travel (depending on the willingness to accept hydrogen combustion for air transport). But for other applications, the alternatives for substantially cleaner transport energy appear to be equally viable at this point. One alternative is super-efficient internal combustion engines that combust lower emission hydrocarbon fuels like natural gas or synthetic fuels from biomass and fossil fuel feedstocks (the latter with partial carbon capture and storage) rather than gasoline. But if global mobility trends continue as I project them to, this alternative cannot be dominant because it will not satisfy my sustainability requirements for greenhouse gas emissions and local air pollutants.

A second alternative is hydrogen fuel cells with the hydrogen mostly produced by gasification of fossil fuels with carbon capture and storage, which is the cheapest zero-emission way of producing hydrogen for the foreseeable future.

A third alternative is the wide-scale adoption of efficient plug-in hybrid engines that substantially increase the role of electricity in fuelling mobility of goods and people. This alternative could be superior under two conditions. For one thing, carbon and/or local pollution constraints require end-use technologies that are virtually zero-emission (thus ruling out the reliance on stand-alone internal combustion engines). For another, hydrogen production costs, hydrogen storage problems, and/or high fuel cell costs offset the benefits of more efficient hydrogen production directly from fossil fuels (as opposed to producing electricity) and the efficient hydrogen fuel cell engines. In this case, there is a chance for market dominance by high efficiency plug-in hybrid engines fuelled primarily by expanded production of zero-emission electricity from fossil fuels and renewables (see, for example, Hoffert *et al.* 2002 and Ogden *et al.* 2004).

What is important from a primary energy perspective, however, is that zero-emission fossil fuels have a good prospect for playing a significant role in all three of these technology-energy alternatives for transport of people and goods. If this assessment proves to be correct, fossil fuels would continue to dominate both electricity generation (currently the domain of coal and natural gas) and transport fuels (currently the domain of oil). This technology-energy evolution at the secondary energy level would occur in step with an evolution at the primary energy level from conventional oil, conventional natural gas, and coal in the current system to unconventional oil, unconventional natural gas and yet more coal as the century progressed. If it turns out that potential fossil fuel reserves are more limited than current assessments indicate, then growing energy demand will lead to gradually rising fossil fuel prices and eventually open the door to a more rapid growth of renewables in the later decades of the century – as well as greater opportunities for energy efficiency and perhaps nuclear.

In spite of these competitive challenges for renewables, I project that their output in a sustainable energy future exceeds that of my current-trends projection – even though this is a scenario in which they already experience extremely high growth rates through the century. While the current-trends projection has renewables reaching 380 EJ by 2100, I now project that with a strong push to a cleaner energy system they can reach 480 EJ by 2100. This means that in my sustainable energy future in Figure 3 the contribution in 2100 from renewables alone exceeds today's entire global energy system of 429 EJ in 2000.

## 6. Overview and policy implications

In this paper, I describe the technologies that would permit humanity to continue to use fossil fuels even while radically reducing the global energy system's GHG emissions over the next 50 to 100 years. I estimate the likely costs of producing zero-emission energy from fossil fuels and then compare these with the projected costs of meeting our energy needs from nuclear power and renewables in the decades to come. But to make a more realistic comparison of our energy options, to this cost information I then add an assessment of the extreme event risks and geopolitical risks associated with each supply option.

My resulting multi-criteria comparison of our energy options suggests that both nuclear power and energy efficiency are constrained in their potential over this century to deal with the rapidly rising demand for energy services. Renewables and zero-emission fossil fuels, especially coal in the latter case, are likely to compete for dominance of the global energy system. While the market share of renewables will grow significantly, these are unlikely to unseat fossil fuels, even as these are required to reduce substantially their GHG emissions.

***The general lesson is that broad assumptions about the undesirability of fossil fuels need to be re-evaluated.***

The general lesson is that broad assumptions about the undesirability of fossil fuels need to be re-evaluated. Fossil fuels are plentiful. We can use them with minimal environmental impacts if we want to. If we recognise that the end we seek is a clean and enduring energy system, not a particular form of energy or a particular amount of energy efficiency, fossil fuels may end up sustaining a much more important role in the energy system than many people – perhaps especially environmentalists – believe they would or should.

From a policy perspective, this means that our policies for clean energy should not be biased against or in favour of any particular form of energy, should not require a minimum production of renewable energy or nuclear power or a minimum amount of energy efficiency, or set a target for abolishing fossil fuels. Instead, our policies should focus explicitly on our specific environmental objectives. In the case of the climate change risk, this means that our policies should levy a fee for GHG emissions or set a regulated emissions cap that is enforced by penalties, and these should be set to attain levels of GHG emissions reduction consistent with the environmental imperatives that scientists are arguing for.

This does not mean that other policies are ruled out completely. In some cases, the inadequacy of market responses to price signals may require particular technology focused policies. But even such policies should be as flexible as possible while sticking to the specific environmental concern. An example is the California vehicle emissions standards. These do not mandate vehicle energy efficiency, although energy efficiency may be one way for manufacturers to achieve the emissions targets. These standards also do not require a particular form of energy (ethanol, electricity or hydrogen) or a particular technology (battery-electric car, plug-in hybrid, hydrogen fuel cell). They simply require that personal vehicles reduce their emissions and that vehicles whose emissions are zero or almost zero must gain a growing share of the market, and manufacturers must meet these requirements collectively or face individual penalties.

If societies forgo the temptation to see the world in terms of good guys and bad guys, they will design policies that focus directly on their environmental objectives. If they do so, many people anxious about our unsustainable energy system will be surprised to discover that fossil fuels may very well be our friend rather than our foe.

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## ABSTRACT

***EU energy policies have changed focus in the last few years with a view to substantially reducing energy import dependency and greenhouse gas emissions.*** *The EU Commission has played a leading role in defining the new orientations. The implementation of the EU policy objectives approved by the Council of March 2007 will require a substantial expansion of energy investments. However, the degree of uncertainty affecting investment decisions remains high, notably in relation to the pricing of $CO_2$ and high energy-price volatility. To make the necessary investment in low-carbon technologies happen, energy policies need to establish a credible long-term framework that reduces uncertainties.*

**Juan Alario** (j.alario@eib.org) is Associate Director in the Projects Directorate of the EIB. The views expressed are strictly personal.

# EU policy objectives and energy investment decisions

## 1. Introduction

*Juan Alario*

This paper analyses the implications of the EU policy objectives on energy investment decisions from an investor's angle. Investors are confronted with changing policy objectives, unclear definition of the objectives, and debates among policy makers on the importance of different objectives and the ways to achieve them. This introduces substantial uncertainties in a context where the achievement of policy objectives, like those related to security of supply and climate change, has substantial implications for investment decisions.

Government policies play a role in all economic activities. In the energy sector this role is very significant. Energy is traditionally considered a fundamental service because economic activity is significantly affected if energy services are not of good quality – in terms of both availability and affordability. Therefore, governments have traditionally intervened in energy matters. In liberalised markets, government policies influence investment decisions in different ways. The regulatory framework, the general policy objectives, and investors' perception of the soundness and stability of policies are key considerations in energy investment decisions. Outside the energy sector, government energy policies also play a significant role, particularly with the aim of improving energy efficiency or favouring or penalising the use of certain energy sources.

Section 2 presents the developments of the EU energy policy and the most recent EU energy objectives. The latest IEA World Energy Outlook (IEA 2006) confirms that the 'reference' world energy scenario is environmentally unsustainable, as energy related $CO_2$ emissions will increase substantially in coming years (by 55 percent in 2030 compared to 2004). This implies that it is necessary to curb $CO_2$ emissions at world level. The need to substantially decrease greenhouse gas (GHG) emissions and oil and gas dependency of the EU has triggered a revision of the energy policies in the EU. The recent energy policy for Europe, which was adopted by the European Council of March 2007, defines ambitious energy objectives at EU level. Achieving these objectives will require more government intervention and a coordinated approach at EU level.

Section 3 analyses the energy investment outlook in the EU, taking into account future energy demand growth and the need to replace or renovate facilities reaching the end of their lifespan. The objectives adopted by the European Council of March 2007 have substantial implications for energy investments. The energy efficiency objectives will significantly reduce the needs of investment in the energy sector, but will imply significant investments in the energy-consuming sectors. The objectives concerning renewable energy will imply a substantial increase of investment in renewable energy and less investment in imports and use of fossil fuels.

In the final section of the paper, the different factors that influence the investment decision are analysed. The key factors that influence the profitability of energy investments are policy and regulation, as well as energy prices. The current context is very challenging for energy investors because of significant uncertainties related to the revision of energy policies in Europe and increased volatility of the energy markets. Most of the issues raised for the energy sector are relevant to energy-intensive industries too, such as metallurgical industries, petrochemical or cement factories.

## 2. The energy policy objectives of the EU

### 2.1 The changing focus of EU energy policy objectives

A feature of the development of the energy policy in EU countries and in other countries is that the importance of the three main objectives (that is, security of supply, limiting environmental impacts, and competitiveness) has varied over time (Finon 1994).

***The oil crisis in 1973 led to a substantial reinforcement of public intervention in energy matters.***

After the first oil crisis of 1973, security of supply was the main objective. The emphasis was on reducing energy import dependency, in particular on oil imports. The oil crisis led to a substantial reinforcement of public intervention in energy matters. Governments led the response to the crisis, as they, directly or indirectly, controlled the energy sector. Therefore, the response to the crisis was essentially national. The European Commission developed a role of 'benchmarking' and 'peer review' process of national energy policies at European level by establishing common energy objectives.[1] However, these objectives reflected the sum of the national objectives rather than common EU objectives.

The results of the policies were spectacular. In just over ten years, the level of energy dependency of the EU-12 decreased substantially, from 65 percent in 1973 to around 45 percent in 1986; oil import dependency fell from 62 percent to 33 percent in 1986. This was achieved largely by reducing the use of oil in power generation, which declined from 42 percent to 16 percent in the same period. In addition, the energy intensity of the economy decreased by some 22 percent in 1973-86. While the changes were impressive, their costs were high in many countries. The cost of the nuclear programmes in some countries turned out to be very high, such as in Spain and in the United Kingdom.[2] Substantial over-capacities were created in the electricity and refining sectors as a result of optimistic assumptions about energy demand growth, which took many years to absorb.

The oil price collapse of 1985 led to a change of priorities of energy policies in Europe and to less public intervention. The policy objective of lowering energy supply costs ('competitiveness') became the most important one. The main instrument used was the gradual introduction of competition in the energy sector. The control of the sector by governments decreased and a process of deregulation was initiated in the electricity and gas sectors.

Since the end of the 1980s, a number of EU countries developed policies aiming at introducing competition in the electricity and gas markets, a process pioneered by the United Kingdom. This trend reflected a similar one elsewhere in the world. The Commission supported the liberalisation of national energy markets with a view to creating an internal EU energy market. Creating this market became the long-term objective intended to give new impetus to an EU energy policy. After a long process of negotiation, both Directives aiming at a gradual opening of the electricity market (Directive 96/92/EC) and the gas market (Directive 98/30/EC) were approved in December 1996 (electricity) and June 1998 (gas). Differences across countries in regulatory frameworks, 'national styles' and the dominance of incumbents have dramatically influenced both the development of the newly liberalised energy markets and the business strategies of energy companies (Finon and Midttun 2004). Because of this and the limited interconnection capacity between EU member states,

1 The Treaty of Rome does not include specific provisions for the energy sector, although coal and nuclear are at the origin of the process of European integration. The different attempts to create a common energy policy have not achieved substantial results up until now. However, common energy strategies have been developed in certain areas, using the Treaty provisions.

2 For instance, the last two nuclear power stations commissioned in Spain attained cost levels higher than €3,500/kW (Alario 2001).

significant barriers to enter national electricity and gas markets continue to exist in most member states. This is well documented in the annual reports of the Commission on the implementation of the gas and electricity internal markets (European Commission 2005).

Since the early 1980s, another trend has been at work: policies to reduce the negative environmental impacts of energy activities. The energy sector is the main contributor to air pollution. Initially, policy measures focussed on reducing the 'traditional' sources of air pollution such as emissions of $SO_2$, NOx, and dust. This was reflected in the introduction of tighter emission standards for new installations, a gradual reduction of emissions from existing installations, and the development and use of less polluting forms of energy, notably natural gas and renewable energy. Later, fighting climate change gradually became an important energy policy objective due to the increasing scientific evidence that human activity, particularly energy production and consumption, leads to an increase in the concentration of GHG and, thus, global warming. The importance attached to climate change has increased in the last few years together with policy makers' acceptance that it is necessary to substantially reducing GHG emissions (in the past the objective was just stabilising or slightly decreasing GHG emissions).

Towards the mid-1980s, the decline in EU energy dependency discussed above came to an end and dependency started to slowly increase again, reviving the debate on security of supply. A key milestone of this debate was the Commission's Green Paper on security of energy supply (European Commission 2000). However, few concrete policy measures followed from this, largely because energy markets functioned smoothly and oil prices were relatively low. Since 2003, the energy security debate has gained new momentum due to rapidly increasing oil prices and efforts by the main energy-exporting countries to strengthen state control over energy resources and to restrict the entry of foreign energy companies.

Several EU countries, such as the United Kingdom, have started reviewing their energy policies with the aim of reinforcing their climate change and security of supply objectives. The European Commission has been very proactive by launching a debate at the EU level on energy policy. The clear need for a coordinated EU approach to address climate change and security of supply issues gives the EU institutions an unprecedented opportunity to develop a common energy policy.

***Recent years have again seen an intensive debate on the goals and instruments of energy policy.***

Indeed, in recent years, there has been an intensive debate on the goals and instruments of energy policy – a debate that will continue in the future. But what seems to become clear already is that the period of limited government intervention in energy matters, which started in the mid-1980s, is coming to an end. This is because the objectives of significantly reducing GHG emissions and improving security of supply requires much more government intervention in energy matters. Indeed, some have observed that the conditions of the energy market have changed so fundamentally around the year 2000 to give rise to a new energy paradigm (Helm 2005). Around the turn of the century, a set of events began to take place in the energy markets that put the conventional wisdom of the 1980s and 1990s under considerable stress. "These events combined with 'new' concerns, notably the issues of security of supply and of climate change. …this shift in external circumstances, combined with new knowledge about climate change, cannot be adequately addressed within the existing paradigm of privatization, liberalization and competition. Though these policies continue to contribute both to the context and the outcomes, they are no longer sufficient" (Helm 2005, p 2).

In a way, EU energy policies have come back to the situation of the first and second oil crises. However, in contrast to the previous period, EU countries' energy sectors are now open to competition and not directly controlled by governments. Therefore, there will be new forms of intervention (market and non-market instruments) to achieve key policy objectives.

*EU institutions should play a leading role in defining energy policies to ensure the achievement of the key objectives in the most effective way.*

The EU Commission policy is defined in the Green paper "Energy" published in 2006; followed by the so-called "Energy package" of January 2007, which includes among others, the communication of the EU Commission "An Energy Policy for Europe". The latter presents the key energy objectives of the EU proposed by the Commission. After some hesitations, the Council adopted the key objectives proposed by the Commission at the European Council of March 2007. Through these different initiatives (presented in the different papers included in the "Energy Package"), the Commission has been able to play a leading role in the definition of EU energy policies. The key issues at stake clearly justify that the EU institutions play such a role to ensure the achievement of the key objectives in the most effective way.

The climate change objectives are presented in a clear and quantitative way in the Commission's communication. The Commission proposed to commit now to achieve at least a 20 percent reduction of GHG emissions by 2020 compared to 1990, regardless of the decisions at the international level. This objective has been adopted at the European Council of March 2007. The Commission sees this as a concrete contribution to the objective in international negotiations of achieving a 30 percent reduction in GHG emissions by developed countries by the same date. This means that EU countries would commit to 30 percent reduction if developed countries adopt this objective. In addition, to limit adverse effects of climate change, global GHG emissions have to be reduced by up to 50 percent compared with 1990 by 2050, implying reductions in industrialised countries of 60-80 percent by the same year.

Regarding security of energy supply, the focus is on limiting the security threats related to the increasing dependence on imported oil and gas. The objectives in this area are multidimensional. The two key objectives are to reduce the dependence on imported oil and gas and to further diversify imports. On the latter, it is explicitly stated that "it remains important for the EU to promote diversity with regard to source, suppliers, transport routes and transport methods" (European Commission 2007a). The growing dependence on imported oil and gas carries political and economic risk, which the policy aims to mitigate. The Commission does not give quantitative targets on security of supply, as it does for climate change objectives.

Finally, in the Commission's communication, the competitiveness objective has different aspects. Obviously, the aim is to achieve lower energy costs, but other objectives are also pursued, such as reducing the exposure to "the effects of price volatility and price rises on international energy markets, as well as dealing with the consequences of the progressive concentration of hydrocarbons reserves in few hands"(Commission 2007a). This is related to the objective of import diversification under the security of supply objective. Another related objective is to contribute to growth and jobs in Europe by leading the rapidly growing market for low-carbon energy technologies, notably renewable energies.

The objectives related to increasing energy efficiency or renewable energy sources are discussed in the next sub-section. This is because these objectives are considered instruments or means to achieve the policy objectives.

### 2.2 The EU energy mix and its role in achieving energy objectives

The recent papers on the EU energy policy do not analyse clearly enough the energy mix coherent with the objectives proposed. This is not surprising because the energy mix to achieve the objectives is less clear than it appeared in the previous crisis.

With the oil price collapse of 1985, gas became a low-cost and environmentally competitive option to cover energy demand, particularly for electricity production. Gas resources were considered abundant and from relatively diversified origins. The gas competitiveness was based on the general perception that oil and gas prices will remain relatively low in the long run. For all these advantages and in a context of a liberalised energy market, gas became the fastest growing energy source (only surpassed by renewable energy) in the EU and in many other parts of the world.

However, the view on gas has changed since early 2000. For one thing, the substantial rise of oil prices since end-2003 has dramatically reduced the competitiveness of gas in power generation. At present, without taking into account a price for $CO_2$ emissions, electricity from a coal-fired power station is cheaper than electricity produced in a combined-cycle gas turbine power station (CCGT) using gas (see Section 4). This explains that at a world level, coal consumption is now increasing faster than gas, particularly in Asia. For another, for the EU, gas now raises substantial security of supply concerns, contrary to the previous situation. This is related to the growing EU dependence on imported gas.

These factors should normally lead to the expansion of coal for power generation in Europe. However, this is happening to a very limited extent at present due to the climate change policies. Latest EU forecasts (European Commission 2006c) suggest that in a business-as-usual scenario, gas demand in the EU is expected to continue to grow relatively fast up to around 2010, stabilise thereafter, and decline by 2030. An eventual increase of coal consumption would increase $CO_2$ emissions, unless it is combined with carbon capture and storage (CCS), and would thus contradict climate change objectives. This explains why there is no agreement at the EU level on the role of gas and coal in the energy mix. Some EU countries are in favour of a revitalising coal, particularly those with a long tradition in coal mining, such as Poland and other new member states.

At present, nuclear covers about 15 percent of total energy consumption and over 30 percent of electricity production of the EU. In principle, nuclear power is a good option to achieve key EU energy policy objectives. In practice, nuclear power faces public opposition in many countries, reflecting concerns about nuclear safety, notably related to nuclear waste and decommissioning. Again, there is no consensus at the EU level on the future role of nuclear; with some countries fiercely against and others in favour.

***Increasing energy efficiency and the share of renewables in Europe's energy mix are the two key options to achieve security of supply and climate change objectives.***

In this context, energy efficiency and renewable energy are the two key options to achieve the objectives of security of supply and climate change, where there is agreement at the EU level. Reflecting this, the European Council of March 2007 endorsed a binding target of 20 percent of renewable energies in overall EU energy consumption. In light of these new EU energy targets, national energy plans are to be prepared for endorsement at the EU level, reflecting the burden sharing that still needs to be agreed on by member states. Furthermore, the European Council stressed the need to increase energy efficiency in the EU, so as to achieve the objective of saving 20 percent of energy consumption compared to projections for 2020.

In principle, the achievement of these objectives should result in a reduction of 20 percent of $CO_2$ emissions from the energy sector, everything being equal. However, achieving these objectives will not be easy. In the baseline energy price scenario of the Commission (European Commission 2006c), the renewable energy target should lead to a significant increase in the cost of energy (see Section 3).[3] The case for public policies to support the expansion of renewable energies largely rest on the notion that financial support to R&D activities and to the deployment of these technologies

3 In this scenario, the price of oil rises from $45/bbl in 2010 to $58/bbl in 2030.

in the early market penetration phase will lower the costs of such technologies in the medium to long term. Effectively, market expansion of some of these technologies, such as wind, has resulted in significant cost declines through scale and learning effects – a topic covered in greater detail by Kolev and Riess (this volume). However, future cost developments, as for any new technology, are very difficult to forecast. Concerning the energy efficiency target, in principle it can be achieved without raising the cost of energy under the current energy price scenario. However, as Schleich (this volume) and Sorrell *et al*. (2004) argue, there are substantial barriers to boosting energy efficiency (imperfect information on energy efficiency possibilities, hidden costs, split incentives, and others). Some of these barriers require a policy intervention, whereas others do not.

Therefore, it seems necessary to have more options to achieve the EU objectives to limit the risk of relying practically exclusively on energy efficiency and renewable energy. The Commission proposal to develop carbon capture and storage (CCS) appears as a relatively uncontroversial alternative to renewable energy sources, particularly in a transitional period until low-carbon technologies are fully developed. CCS allows using fossil fuels for electricity production without producing substantial amounts of $CO_2$ and it can contribute to opening a potentially economically viable route to the mass production of hydrogen (coal gasification or gas reforming). However, CCS technologies are only expected to be commercially available by 2020 and the cost of $CO_2$ abatement with CCS is high at present, but R&D activities might – as it is the case for renewable energy and energy efficiency – considerably reduce their costs in the medium term. The Commission proposes (European Commission 2006a) to support the construction and operation of up to 12 demonstration power generation plants including CCS by 2015 and to provide a clear perspective of when coal-and gas-fired plants will need to install $CO_2$ capture and storage. On the basis of the existing information, the Commission believes that by 2020 all new coal-fired plants should be fitted with $CO_2$ capture and storage and existing plants should then progressively follow the same approach.

## 3. Energy investment outlook

***The information available on the historical development of EU energy investments is very limited.***

The information available on the historical development of EU energy investments is very limited. During the period 1970-86, EU-7 energy investments followed a cyclical pattern (Alario 1988).[4] More specifically, investments increased by over 40 percent after 1973, and by an additional 20 percent after the second oil crisis. A considerable part of this investment occurred in the electricity sector, mainly as a result of the construction of new power stations – overwhelmingly nuclear – to replace oil-fired electricity generation. Investment in oil and gas production, notably in the North Sea, was another important contribution to the investment boom in this period. At the same time, investments in refineries decreased substantially. Since the mid-1980s, energy investment declined and since the mid-1990s investments remained relatively constant in real terms (see Table 1). The energy investment trend since the mid-1980s is explained by the substantial overcapacities in the power sector, which – in turn – are due to the earlier investment boom and gradually declining growth of energy demand. Given these overcapacities, there has been a limited need for additional energy investments in the last 20 years.

For 2006, the level of gross fixed capital formation (GFCF) in the energy sectors of the EU-25 can be estimated at €80 billion per year (own estimate based on the information presented in Table 1). But the information available is unreliable.[5] This figure is equivalent to 6 percent of overall GFCF.

4 The seven countries are: Germany, France, Italy, the Netherlands, Belgium, the United Kingdom and Denmark.

5 In the Eurostat statistics, the countries that report energy sector investment account for 72 percent of EU-25 GDP and 70 percent of gross fixed capital formation.

The electricity and gas sectors have accounted for most of the investment (around 80 percent) in recent years, followed by oil, gas and coal production (10 percent) and oil refining and distribution. Investment in renewable energy has rapidly increased in recent years and now accounts most likely for €15 billion, which is about 20 percent of the total energy sector investment.[6] Energy efficiency investments are difficult to estimate and are not presented in the statistics.

**Table 1. EU-25 gross fixed capital formation in the energy sector, 1995-2004**

| | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|
| | Billions of euros (1995 prices and exchange rates) unless otherwise indicated | | | | | |
| Energy sub-sector | | | | | | |
| Electricity, gas, and water supply | 63.0 | 56.6 | 57.7 | 59.5 | 61.2 | 61.0 |
| Mining and quarrying of energy producing materials | 10.8 | 6.4 | 7.9 | 8.9 | 8.2 | 7.0 |
| Manufacture of coke, refined petroleum products and nuclear fuel | 6.2 | 5.5 | 4.8 | 4.5 | 5.3 | 5.2 |
| Total | 80.0 | 68.5 | 70.4 | 72.9 | 74.7 | 73.2 |
| Memorandum items | | | | | | |
| In % of GDP | 1.6 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| In % of GFCF | 8.0 | 5.5 | 5.7 | 6.0 | 6.1 | 5.9 |

Source: Eurostat and own calculations
Notes: Mining and quarrying includes extraction of crude oil and natural gas.

***Investment needs in the energy sector depend on demand growth and the replacement of the capital stock that reaches the end of its economic life.***

Investment needs in the energy sector depend on demand growth and the replacement of existing capital stock reaching the end of its economic life. Total energy demand growth will continue to decrease in the medium to long term. In the baseline scenario, the Commission forecasts total energy consumption to be 15 percent higher in 2030 than in 2000 (European Commission 2006c). The fastest expanding energy sources are forecasted to be renewable energies (+242 percent in 2030 compared to 2000), electricity (+51 percent) and gas (+38 percent). These three energy sources will concentrate most of the investments in coming years. The rest of the energy sources are expected to decline or remain constant (nuclear -11 percent; coal -4 percent; oil +1 percent).

As gas import dependency is expected to increase from over 50 percent to 84 percent in 2030 in the baseline scenario, gas imports are expected to expand by 72 percent in the period to 2030. This implies that the capacity of gas import infrastructures will need to be expanded to enable additional gas imports. In addition, new gas import capacity may be needed to diversify import routes and methods of gas imports, notably in favour of LNG import terminals as they offer more flexibility than pipelines.

However, this baseline scenario is environmentally unsustainable ($CO_2$ emissions increase) and the dependence on imported oil and gas will increase substantially. Therefore, as indicated before, the EU energy policy aims at changing this scenario to reduce $CO_2$ emissions and import dependency. This will significantly influence the investment needs. Renewable expansion is targeted to be faster

6 Own estimate.

than in the baseline scenario (the objective is 20 percent of total energy consumption in 2020 while the forecast is 10.4 percent in the baseline scenario) and energy efficiency policies are envisaged to reduce energy demand growth. If successful, the energy efficiency objective (-20 percent by 2020) would imply that by 2020 the EU primary consumption would be slightly lower than today (European Commission 2006e).

***If EU energy efficiency objectives are achieved, electricity demand growth will be significantly lower than foreseen so far.***

If the objectives of the Commission are achieved, electricity demand growth will be significantly lower than in the baseline (0.6 percent per year in 2000-20). Similarly, gas consumption will expand at a rate of 0.5 percent per year in the same period, which will result in a lower gas import dependency than in the baseline scenario. The main impact of these objectives will be in the power sector with a pronounced rise in renewable electricity and a fall in fossil fuel-based electricity (Commission 2006d). More specifically, the use of coal and lignite in power generation is envisaged to drop by 50 percent by 2020 and to further decline thereafter. Gas expansion in the power sector is foreseen to be much slower than in the baseline scenario (+20 percent increase in 2020 compared to 2000). In part, this increase is related to the expansion of combined heat and power (CHP) plants, where gas is the preferred fuel. In line with these trends, the electricity capacity using fossil fuels is forecasted to halve by 2020. However, the Commission's scenario foresees an increase in biomass-fired power generation capacity equivalent to the decrease of the capacity using coal or lignite. It should be noted that, with some adaptations, biomass can be used in combination with coal or lignite in existing or new coal-fired power stations.

A significant part of the existing capital stock in the energy sector will need to be decommissioned in the next 20 years. Most of this will be in the power sector and very little in the gas sector, where the infrastructure is relatively modern in most EU countries.

A substantial share of the existing electricity capacity came on stream in 1980-85. Therefore, decommissioning of this capacity will reach a peak in 2020-25, based on an average lifespan of 40 years (see Figure 1). Concerning electricity grids, replacement needs to pick up by 2020-30 for high voltage grids (CESI 2005) and renovation of existing medium-low voltage grids will also be significant in the period to 2030. Electricity companies have substantial flexibility as to the decommissioning of existing power stations. They can accelerate or delay these investments depending on market circumstances. In the current context, characterised by substantial uncertainties, they have tended to delay decommissioning of existing power stations. This became quite apparent in the approach they adopted in order to meet the stricter pollution emission limits imposed by the Large Combustion Plan Directive. Most companies have opted to install additional anti-pollution equipment in existing power stations, rather than decommissioning them and building new, more efficient ones. This concerns mainly existing coal power stations, as those using gas and oil are practically not affected by this regulation.[7]

Moreover, investments in the electricity grid have been relatively low in the past, for different reasons. This is highlighted by the European Commission (2006b), which indicates that progress in the development of energy networks, notably electricity grids, has been insufficient.

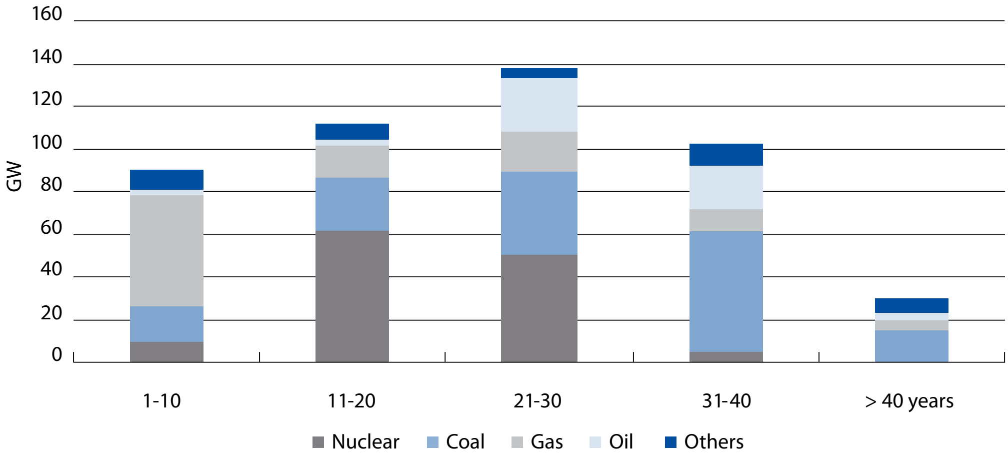
In its baseline scenario, the European Commission (2007c) has projected the cumulative energy investment needs for the period 2005-30. As Table 2 shows, they are estimated at €1,790 billion,

7 Power stations using gas are usually modern, and oil power stations are usually used in isolated areas (islands for instance) and there is thus limited need for additional investment in most EU countries, with the notable exception of Italy.

implying annual investment of about €72 billion, which is slightly less than the annual average in the past ten years. Around 77 percent of this investment would be needed in the electricity sector, out of which two-thirds for electricity generation. The gas sector (gas production, import facilities, and transport) comes next, accounting for 12.3 percent of the total. Investment in renewable energy sources is projected to amount to almost 23 percent of total investment. Most of this (some 80 percent) is for renewable electricity production.

***Investment in renewable energy sources is projected to amount to almost 23 percent of total investment.***

**Figure 1. Age structure of EU-25 electricity generating capacity**




Source: Güldner (2007).

**Table 2. EU-27 cumulative energy investment needs, 2005-30**

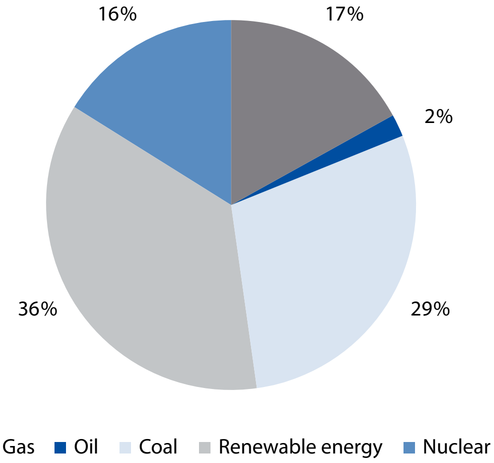
| Energy sub-sector | Billions of euros | % of total |
|---|---|---|
| Oil (development, exploration, refining) | 90 | 5.1 |
| Gas (exploration, development, distribution) | 221 | 12.3 |
| Coal (mining, shipping) | 24 | 1.3 |
| Renewables (heating, transport) | 78 | 4.4 |
| Electricity | 1.377 | 76.9 |
| Generation | 897 | 50.0 |
| Gas | 148 | 8.3 |
| Oil | 19 | 1.0 |
| Coal | 261 | 14.6 |
| Renewables | 327 | 18.3 |
| Nuclear | 141 | 7.9 |
| Transmission | 116 | 6.5 |
| Distribution | 364 | 20.3 |
| TOTAL | 1,790 | 100.0 |

Source: European Commission (2007c)
Notes: This is the Commission's baseline scenario, i.e., not the policy scenario resulting in a 20 percent reduction in GHG emissions, a 20 percent share of renewable energy, and a 20 percent decline in energy consumption targeted to result from energy efficiency measures.

*Electricity sector investments will not only account for the bulk of energy sector investment, but they will also play a key role in achieving EU energy objectives.*

Electricity sector investments will not only account for the bulk of energy sector investment, but will also play a key role in achieving the energy objectives of the EU – as in the past. In the baseline scenario, total investments in electricity are estimated at €900 billion in the period to 2030. As Figure 2 illustrates, renewable energy sources are projected to account for 36 percent of this investment, followed by coal-fired generation (29 percent), gas (17 percent), and nuclear (16 percent).

**Figure 2. Sectoral breakdown of EU-27 cumulative electricity sector investments, 2005-30**




Source: Commission (2007c)

As discussed above, although informative, the baseline scenario is not in line with the EU objectives agreed on at the European Council of March 2007. To meet these objectives, additional investments in energy efficiency and renewable energies will be needed. Successfully implemented energy efficiency policies will reduce the investment needs in the energy sector, as they will decrease energy demand growth. However, they will require investments in the energy-consuming sectors. These investments are hard to quantify, but they may be similar to the investments avoided in the energy sector. This is because many of the measures to increase energy efficiency called for under the Commission's Action Plan for Energy Efficiency (European Commission 2006e) are capital intensive. Measures concern, in particular, the development of CHP and those aimed at raising energy efficiency in buildings and transport – areas where the Commission identified most of the energy efficiency potential.

The aim for renewable energy is to double – relative to the baseline scenario – its share in total energy consumption by 2020. This implies a significant increase in investments in this field. However, biomass is expected to cover a substantial part of the renewable energy expansion, and using biomass as a fuel in electricity generation might not require substantial investments in the energy sector, as biomass can be used in existing coal and lignite power stations. The investment in renewable energy will also depend on progress in reducing their cost through innovation and scale effects. From the impact assessment study carried out by the Commission (2007b), meeting the 20 percent renewable energy target by 2020 will require investments in renewable energy of the order of €600-670 billion in 2005-20. This is a significant increase in relation to the baseline scenario (2.5 times in yearly investments).

The investment needs in conventional power stations (leaving aside renewable energy) are difficult to forecast. As mentioned above, meeting the EU climate change objective is bound to lead to an accelerated replacement and modernisation of existing power stations. Therefore, it is reasonable to assume that the new capacity to be built in the years to come will increase significantly. However, depending on the technologies chosen, building new capacity will have very different investment implications. There are three possible options: CCGT using gas, coal-fired power stations, and – in some countries – nuclear power stations. These options have very different investment costs: about €600/kW for a CCGT using gas, €1,200/kW for a new coal power station, and around 1,800 €/kW for nuclear power stations.[8] Which option each EU country will favour depends on security of supply considerations and the national GHG emissions target. If coal and gas power stations were to be CCS-equipped, the cost of investing in these two options would dramatically increase. At present, the cost of CCS might double the initial investment outlays in a new plant depending on the technology used, but CCS costs are expected to decrease in coming years.

To conclude, achieving EU energy policy objectives will require a substantial expansion of energy related investments (in the energy sector and in the other sectors). Most of the expansion will take place in the period to 2020. The investment expenditure needed for the expansion depends on a variety of factors. In the long run, cost could decline as a result of R&D efforts and with a greater market penetration of new technologies. This being said, a fast implementation of investments might create bottlenecks in the industries producing energy equipment and in biomass production, which might put upward pressure on prices and thus investment expenditure and other expenditures (e.g. biomass cost). All in all, it seems that the European Union is heading for another cyclical energy investment boom – similar to the ones after the two energy crises in the 1970s. However, the duration of this investment boom may be much longer than earlier ones. Equally important, while the scope of the investment required to achieve EU policy objectives can be estimated, the exact timing and composition cannot – mainly because of uncertainties about the options chosen and specifics of the policy priorities EU and its members intend to pursue to achieve these objectives. The next section sheds more light on this issue.

***There is a risk that fast implementation of investments will create bottlenecks in biomass production and in industries producing energy equipment.***

## 4. Energy investment decisions in an uncertain environment

### 4.1 Taxonomy of investment risks

In this section, different factors influencing the investment decision in the energy sector will be analysed, with particular emphasis on policy and regulatory factors. The decision to invest results from an analysis of expected developments in key variables influencing the profitability of the investment under consideration. Changes in policies, regulations, energy prices, technology, and administrative and environmental procedures are traditional risks affecting energy investments. Moreover, risks stem from limited experience with the functioning of newly liberalised electricity and gas markets. Therefore, the investment environment seems particularly challenging at present. Broadly distinguishing between economic, political, and legal risks, Table 3 gives a non-exhaustive list of risks facing energy sector investments.

8 The investment cost of new nuclear power stations in the EU is very uncertain and will vary depending on the country and the technology. The cost quoted corresponds to the new nuclear power station in Finland, which is presently under construction. However, this power station is experiencing cost overruns (covered by the provider of the equipment, Areva) and delays.

**Table 3. Taxonomy of risks facing energy sector investments**

| | |
|---|---|
| **Economic risk** | |
| Market risk | Inadequate price and/or demand to cover investment and production costs<br>Increase in input cost |
| Construction risk | Cost overruns<br>Project completion delays |
| Operation risk | Insufficient reserves<br>Unsatisfactory plant performance<br>Lack of capacity of operating entities<br>Cost of environmental degradation |
| Macroeconomic risk | Abrupt depreciation or appreciation of exchange rates<br>Changes in inflation and interest rates |
| **Political risk** | |
| Regulatory risk | Changes in price controls and environmental obligations<br>Cumbersome administrative procedures |
| Transfer-of-profit risk | Foreign exchange convertibility<br>Restrictions on transferring funds |
| Expropriation and nationalisation risk | Changing title of ownership of the assets |
| **Legal risk** | |
| Documentation or contract risk | Terms and validity of contracts, such as purchase/supply, credit facilities, lending agreements and security/collateral agreements |
| Jurisdictional risk | Choice of jurisdiction<br>Enforcement risk<br>Lack of a dispute-settlement mechanism |
| **Force majeure risk** | |
| | Natural disaster<br>Civil unrest<br>Strikes |

Source: Sullivan and Blythe (2006)

***Governments influence all key variables of the investment decision: from demand expansion to support of certain energy sources and the penalisation of others.***

Governments influence all key variables of the investment decision: from demand expansion (energy efficiency policies) to support of certain energy sources and the penalisation of others by modifying energy prices through taxes and subsidies. The review of the EU energy policies taking place at present creates uncertainties and a wait-and-see attitude of market players.

Energy policies should be formulated with a view to influencing investment decisions and operational behaviour of the companies in the most effective way. Stern (2006, p.325) indicates that the "three essential elements for an effective policy framework are credibility (belief that the policy will endure, and be enforced); flexibility (the ability to change the policy in response to new information and changing circumstances); and predictability (setting out the circumstances and procedures under which the policy will change)".

If uncertainties are high, as at present, companies may be slow in responding to price signals. Responses would likely be gradual and may not achieve deep structural change needed to reach a more efficient outcome (Blyth and Hamilton 2006). However, if the policy framework provides certainty for a large enough period, investments can be stimulated, as shown – for instance – by the experience with feed-in tariffs in a number of countries (see Finon, this volume).

By comparison to a planning system, now policy makers need to become more precise about their policies and adapt policy instruments to changing circumstances, in order to avoid raising the cost of capital by creating policy and regulatory uncertainty.

In liberalised energy markets, market-based instruments – such as the EU Emissions Trading Scheme (ETS) – have greater potential than non-market based instruments to achieve the objectives in an efficient way. However, market participants might react too slowly to price signals for different reasons. As a result, a combination of market and non-market instruments will be used. Governments will adapt the instruments depending on the results.

In the following sub-section, traditional price risks will be briefly analysed. Other traditional risks are related to possible delays and cost overruns due to administrative and environmental procedures and public opposition. Additionally, in an environment of fast technological progress in the years to come, the risk will rise that equipment will become obsolete much faster than anticipated.

### 4.2 Traditional price risks

Energy companies face a range of risks and uncertainties when making an investment decision. In competitive markets energy price risk is a traditional risk.

***In competitive markets, energy price risk is a traditional risk.***

It is normal practice to define scenarios for long-term energy prices. These scenarios reflect the 'vision' of institutions and market players of long-term developments. The substantial rise of oil prices since end-2003, which initially was seen as a short-term phenomenon, was gradually perceived as a sign of the end of the period of low oil prices that had been prevailing since the mid-1980s. Higher energy prices now projected on the basis of this reassessment reflect a more pessimistic view on oil resources and the price elasticity of oil demand. The new energy scenarios considered at present (IEA 2006 and European Commission 2006c) not only show higher energy prices, but also a substantial change in relative energy prices. European gas prices are assumed to remain linked to oil prices. The ratio between coal prices, on the one hand, and oil and gas prices on the other hand has decreased substantially and thus coal competitiveness has improved under the current scenarios.

The upward revision of oil and gas price scenarios implies that, other things remaining equal, the profitability of investments in oil and gas production, energy savings (except for coal), renewable energy sources, nuclear energy, and equipment to use coal (such as power stations and boilers) has increased. By contrast, the profitability of investments related to the use of oil and gas has decreased, notably for power stations using these fuels. Investment in the transmission and distribution of electricity, gas and oil should be largely unaffected. However, the profitability of such investment might be affected indirectly, as higher energy prices might lower the use of transmission and transport infrastructures – gas and oil pipelines, for instance – thereby depressing transmission and transport prices. The profitability of refinery investments is also not directly affected by the level of oil prices, but by price differentials between different types of crude oil and petroleum products (heavy *vs*. light crude and low-sulphur *vs*. high-sulphur fuel, for instance). These changes in the profitability of energy investments have already influenced investment trends in recent years, as shown – in particular – by the rapid expansion of coal in power generation.

There is considerable debate on the possibility to forecast long-term energy prices. Stirling (1994) argues that for most energy investment decisions, it is not possible to assign probabilities to alternative future developments. Other analysts – Awerbuch and Berger (2003), for instance – consider that historical variability provides a good guide for the future. Nonetheless, they add: "This is not to say, however, that certain fundamental changes in the future, such as significant market restructuring or radical new technologies, could not create 'surprises' by altering historical patterns" (Awerbuch and Berger 2003, p.17). This has indeed happened in the oil market, which has gone through several phases, characterised by different energy price levels.

In any case, there is considerable uncertainty about future energy price developments and oil price volatility has increased since the oil price drop in early 1986 (Regnier 2007). Therefore, the best way to mitigate energy price risks seems to be to diversify the portfolio of energy assets. Generally, energy companies diversify their portfolios to cover against different risks (political, energy prices, and others). Assets poorly diversified (concentrated on a single source) will benefit the most from diversification –and *vice versa*. The portfolio theory has been applied to electricity systems in order to analyse the portfolio benefits of different diversification strategies to protect against energy price risks. This approach, pioneered by Awerbuch, is presented in detail in Awerbuch and Yang (this volume).

### 4.3 Risks due to unclear climate change policies

Concern about climate change, particularly deep cuts of GHG emissions, is a relatively new feature of the energy policies in Europe, gaining prominence just after the turn of the century. Compared to other environmental impacts, it so far lacks policy credibility. As Stern (2006, p.25) pointed out, climate change is "the market failure on the greatest scale the world has seen".

***To substantially reduce policy uncertainty, policy makers need to clearly communicate on the post-2012 approach addressing climate change ...***

To eliminate – or substantially reduce – policy uncertainty, policy makers need to clearly communicate on the post-2012 ambition and approach. This uncertainty is a barrier to investment and leads companies to choose investment strategies that are sub-optimal from society's viewpoint as they fail to achieve climate change objectives (see Sullivan and Blyth 2006, for instance).

There is no doubt that after 2012 a system to reduce emissions will continue, but there is uncertainty about emissions targets and the instruments to enforce the regulatory mechanism. In part, this is related to the international commitments on GHG emission reductions. In essence, EU policy makers might consider a strong policy to combat climate change that is not accompanied by sufficient international support detrimental to the international competitiveness of EU economies. If this policy is left to national governments alone, they have incentives to review objectives *ex post* if costs become high in a certain period. The EU institutions can thus provide a certain degree of independence in policy implementation by monitoring and enforcing objectives and instruments set at EU level.

Policy makers might not accept targets that lead to high $CO_2$ prices. On the other hand, only relatively high $CO_2$ prices that prevail long enough will promote the development of new low-carbon technologies. This, in turn, will stimulate cost reductions in low-carbon technologies. This virtuous cycle will lower $CO_2$ prices in the long run.

Efforts to develop a clear and predictable long-term climate change policy are further complicated by a possible conflict between climate change objectives and security of supply objectives. This is notably the case for coal. The natural reaction of markets to higher oil and gas prices is to diversify away from such fuels. Coal appears to be the easiest way to achieve this diversification.

However, an increasing use of coal raises $CO_2$ emissions – at least in the short- and medium term. The conflict between the use of coal and climate change objectives will disappear only in the long run as and when CCS technologies have reached commercial maturity. But it is also true that a credible long-term climate change policy spurs the development of clean coal technologies, notably CCS. As a result, while there is a conflict between security of supply and climate change objectives over the medium term, this conflict eventually subsides – or even disappears in the long run. One can turn this argument around: uncertain climate change policies today delay investments that would strengthen security of supply tomorrow.

***… which would also be good for security of supply reasons, as uncertain climate change policies today delay investments that would strengthen security of supply tomorrow.***

It is worth noting that there is a complex relationship between the energy price risk discussed in the previous sub-section and the $CO_2$ price risk discussed here (IFRI 2006). This relationship depends on the emission target, energy prices, economic growth, and the development of low-carbon technologies. To illustrate, everything else being equal, an increase in gas prices makes coal more competitive in power generation and thus increases $CO_2$ emissions. As a result, for a given $CO_2$ emission target, the $CO_2$ price rises. The investment implication of all this depends on whether or not the investment is covered by the EU ETS.

For investments covered by the EU ETS, the $CO_2$ price will be influenced by changes in energy prices. To some extent, this limits the risks of the investments that contribute to achieving the GHG emission target. However, for the sectors outside the EU ETS, the viability of the investments contributing to reduce GHG emissions is substantially exposed to energy price volatility risks. Everything else being equal, the profitability of these investments (in energy efficiency, for instance) drops with a decline in fossil fuel prices. To ensure an acceptable profitability of investments outside the EU ETS, governments should put in place a mechanism to make up for this impact, for instance, using taxes or subsidies to compensate for changes in energy prices.

### 4.4 The case of investments in power generation

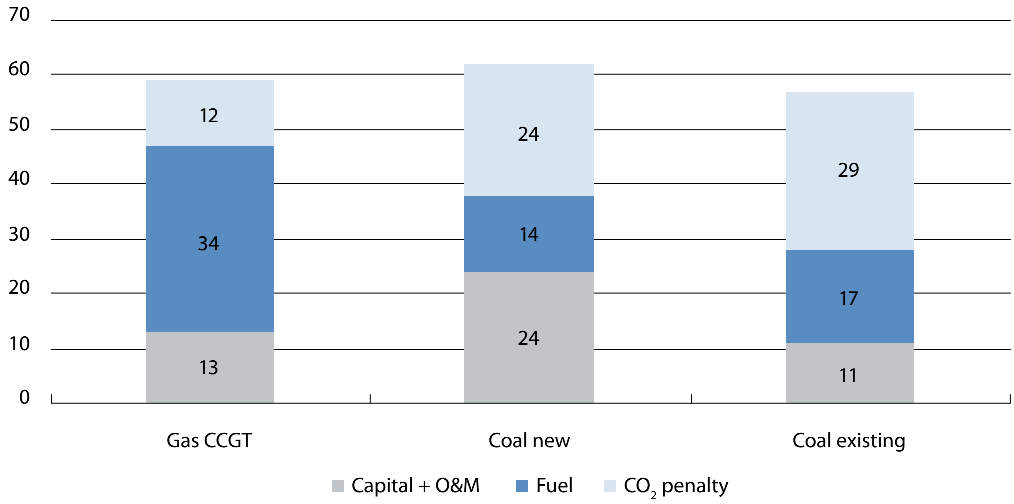
In this sub-section, we will briefly analyse the case of investments in power generation in the EU. As argued above, the power sector will play a key role in implementing EU policy objectives and it is projected to account for the bulk of total energy investments. In principle, this analysis requires a country-by-country (or group of countries) approach because the EU electricity market is not yet well integrated due to limited interconnection capacity. However, to illustrate the impact of uncertainty on investment decisions, it is pertinent to look at a 'typical' EU country, which we do in what follows.

Leaving aside nuclear, which is a realistic option in only a few countries and depends in any event on political decision, electricity companies can generally choose between three possible options to invest in new generation capacity: renewable electricity, CCGT using gas, and coal-fired power stations. As for renewable electricity, member states will establish national renewable energy targets to contribute to meeting the EU renewable energy target. Therefore, renewable energy capacity expansion will be largely determined by policy decisions (financial support schemes). For the rest of the electricity capacity needs, the choice is between gas-fired CCGT and coal power plants. Another option in the medium term is to delay as much as possible the decommissioning of existing plants. This concerns mainly coal power stations, as they will be the first to reach the end of their life.

Figure 3 presents the costs of electricity for the gas and the coal options, based on average EU investment and operating and maintenance (O&M) costs and on the EU energy price scenarios. Under these scenarios, the cost of electricity in a new, modern coal power station is significantly lower (over 20 percent) than in a new CCGT using gas; this is for a real discount rate of 5 percent.

In practice, a more refined comparison accounts for the cost of access to gas and coal, which vary depending on the country and location of the power station.

**Figure 3. Electricity production cost (in €/MWh)**




Source: Own calculations

Notes: Estimates for a typical location in the EU; 5 percent real discount rate; €30/t $CO_2$; $55/t coal; gas baseline price scenario IEA (2006).

Introducing a $CO_2$ price in the calculation significantly affects this comparison. Both alternatives have similar costs for a $CO_2$ price of around 25 €/t $CO_2$. Coal is cheaper than the gas option for $CO_2$ prices below €25/t $CO_2$ and *vice versa*.

The cost of electricity in an existing coal power station is normally substantially lower than in a new one, considering as sunk the existing investment in the plant. However, introducing a $CO_2$ price affects existing coal power stations more than new ones because the former are less energy efficient than the latter (typically, the efficiency of existing plants is more than 20 percent below new ones). Existing coal-fired power stations would cease to be competitive with new ones at a $CO_2$ price of around €50/t $CO_2$ . But as argued above, at that price, gas-fired CCGT plants would clearly be the most economic choice. It should also be pointed out that there are substantial variations in terms of cost and energy efficiency of the existing plants. Therefore, the $CO_2$ price range that makes the generating cost of an existing coal power station equal to the cost of a new one is wide and for the less efficient plant can be less than €20/t $CO_2$.

***Because of low $CO_2$ prices, there are currently no incentives to replace existing coal power stations with new, more efficient ones.***

The objective of the EU to achieve at least a 20 percent reduction in $CO_2$ emissions by 2020 will put a substantial constraint on the GHG emissions from the power sector. Indeed, the Commission's scenarios suggest that meeting the $CO_2$ emissions target would result in a substantial decrease of the use of coal in power generation. This implies that the $CO_2$ price would have to increase to levels ensuring that inefficient existing coal power stations are decommissioned or modernised. It is difficult to estimate the level of $CO_2$ prices compatible with this objective, but under our cost estimates it may be around €30/t $CO_2$. At present, the $CO_2$ price in the EU ETS system is much lower than this figure and there are substantial uncertainties on its future development. Therefore, there are currently no incentives to replace existing coal power stations by more efficient ones. But even if these incentives were sufficiently strong: should existing coal power stations be replaced by new coal power plants or by gas-fired plants?

This is difficult to say. If the renewable and energy efficiency objectives are achieved (20 percent in both cases by 2020) the current $CO_2$ reduction target for 2020 (-20 percent) could be easily achieved and thus the $CO_2$ price may remain at moderate levels, everything else remaining equal. This will favour the coal power plant option, at least in the period up to 2020. By contrast, if the renewable energy/energy efficiency targets are not achieved and the expectations are to keep a relatively tight emission target, the $CO_2$ price would tend to become much higher than at present. In this case, the gas-fired plant option would be favoured. However, a new power station commissioned in 2010-15 will still be in operation up to 2040 at least. Therefore, it is necessary to analyse long-term scenarios.

***Possible investment in new coal-fired electricity generation faces the risk that the cost of carbon storage and capture turn out to be much higher than currently expected.***

In the long run, it is very likely that coal power stations will need to be equipped with CCS, if the objective of substantially reducing $CO_2$ emissions is pursued (the objective is to cut $CO_2$ by 60-80 percent by 2050 in industrialised countries). However, CCS technologies are expected to be commercially available by 2020. At present, CCS costs (including transport and storage) around €35-€65/t $CO_2$ (own estimates based on different sources). Looking beyond that time horizon, CCS cost could possibly decline to €25-€35/t $CO_2$ for suitable locations (own estimates based on different sources). However, this is far from certain, as for any new technological development. It follows that investments in coal-fired electricity generation face the considerable long-term risk that CCS cost turn out to be much higher than currently expected. Gas-fired plants are significantly less exposed to the risk related to CCS technologies, as they emit substantially less $CO_2$ than coal-fired plants.

In addition, the result of the comparison between the gas and coal options is very sensitive to the energy price assumptions. An increase in energy prices by 20 percent increases the electricity costs (without environmental externality costs) of the gas option by 15 percent, while the increase is less than 8 percent in the case of a new coal-fired power station.

All in all, the dilemma for electricity companies is that a new modern coal power station is exposed to substantial $CO_2$ price risk and related CCS risks. By contrast, a gas-fired plant is substantially less exposed to the $CO_2$ price risk, but it is exposed to the gas price risk.

Confronted with all these risks and policy uncertainties, electricity companies will tend to limit investments. There is also a risk that they develop investment programmes that are not compatible with the objectives of the EU energy policy. Electricity companies will have to diversify their portfolio of power stations particularly towards portfolios that limit their exposure to $CO_2$ and energy price risks.

## 5. Conclusions

The oil price increase since 2003 has triggered a revision of energy policies in the EU with a view to reducing energy import dependency and GHG emissions. Previous policies – adopted in the 1980s – focussed on the liberalisation and privatisation of energy markets, with limited scope for government intervention in energy matters. These policies do not seem to be able to address climate change and security of supply challenges. New forms of government intervention and more intervention will be needed to change energy trends. In order to achieve the energy policy objectives, governments should create strong and credible incentives to influence market players. Currently, there is considerable policy uncertainty, with policy makers debating the objectives and the adequate policy instruments to address them. The key objectives of the EU policy cannot be achieved in an effective way without a coordinated approach at EU level. This is a historical opportunity for the EU institutions to play an important role in the energy policy.

*Increasing energy efficiency and expanding renewable energy are crucial for achieving EU energy policy objectives.*

Increasing energy efficiency and expanding renewable energy are crucial for achieving EU energy policy objectives. In the long run, the use of coal and gas will only be compatible with the climate change objectives if CCS technologies are available at a reasonable cost, but CCS technologies are still in the demonstration phase. EU policies will support fast technological progress and penetration of low-carbon technologies. The future role of nuclear power is uncertain at this stage.

Energy investments in the EU have remained at relatively low levels during the last two decades, as a result of overcapacities created after the two energy crises in the 1970s and a gradual reduction of the energy demand growth. Most of the energy investment went to the power sector, around 80 percent of the total. In the European Commission's baseline energy scenario up to 2030, energy investments would remain at the current level. However, this baseline scenario would lead to an increase in $CO_2$ emissions and import dependency. The aim of the EU policy is to prevent this increase. The energy objectives of the EU are very ambitious, particularly the objective of reducing $CO_2$ emissions by at least 20 percent by 2020 and further reductions later. This will require a substantial increase in energy investments, mostly in the power sector, particularly in renewable electricity generation. At the same time, there is likely to be an accelerated replacement of the old inefficient power stations by modern ones. The period 2010-20 is critical, as many long-life investments will be decided then.

Market players need clarity on policy objectives and on the instruments to achieve them. Policy and regulatory uncertainty increase the risk premium companies have to account for when considering investments. In a context of highly volatile energy markets and a fundamental review of energy policies, the degree of uncertainty affecting investment decisions has increased. More importantly, with the pricing of $CO_2$, another significant uncertainty has been added to traditional energy investment risks.

Climate change policies are relatively new and it takes time to establish credibility. These policies will have a substantial impact on energy investment decisions. The uncertainty related to the development of the EU ETS post 2012, and climate change policies in general, limits investments in low-carbon solutions and energy investments in general. This is because major energy investments need a predictable long-term framework so that investors can properly assess risks and returns.

All these uncertainties prevent the realisation of the investment needed to achieve EU policy objectives. However, once a clear policy framework is put in place, energy companies will launch substantial investment programmes. This may lead to tensions in the sectors supplying energy equipment and services, particularly low-carbon technologies. Some companies that adopt a strategic behaviour by taking risks in advance of concrete policy developments may benefit from the situation. More importantly, confronted with high uncertainty, companies will tend to better diversify their portfolio of assets in order to manage risks, notably $CO_2$ and energy price risks.

Finally, a brief analysis of current investment challenges in the EU electricity sector was carried out. At present, electricity companies face the following dilemma: on the one hand, they currently have limited incentives to rapidly reduce $CO_2$ emissions; on the other hand, before too long, they will have to substantially reduce $CO_2$ emissions if the policy necessary to achieve EU $CO_2$ targets is implemented. In these circumstances, companies are reluctant to invest and there is a high risk that the investment they do carry out is incompatible with the EU's ambitious $CO_2$ reduction targets.

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## ABSTRACT

***This paper discusses three main approaches for analysing oil prices: non-structural models, the supply-demand framework, and the informal approach.*** *Each approach emphasises a certain set of drivers of oil prices. While non-structural models rest on the theory of exhaustible resources, the supply-demand framework uses behavioural equations that link oil demand and supply to its various determinants. The informal approach focuses on the specifics of oil market history in explaining oil prices. Although all approaches provide useful insights on how the world oil market functions, they suffer from major limitations especially when used for long-term projections. Thus, pushing hard for policies based on such projections defeats the purpose of such models and may result in misguided policies.*



**Bassam Fattouh** (bf11@soas.ac.uk) is Reader in Finance and Management in the School of Oriental and African Studies (SOAS), University of London, and Senior Research Fellow at the Oxford Institute for Energy Studies (OIES).

# The drivers of oil prices: the usefulness and limitations of non-structural models, supply-demand frameworks, and informal approaches

***Bassam Fattouh***

## 1. Introduction

Understanding oil price behaviour has received special attention in the current environment of rapidly rising prices and marked increase in oil price volatility. It is widely believed that high oil prices can slow down economic growth, cause inflationary pressures and create global imbalances. Volatile oil prices can also increase uncertainty and discourage much needed investment in the oil sector. High oil prices and tight market conditions have also raised fears about oil scarcity and concerns about energy security in many oil importing countries.

Some observers argue that the oil market has undergone structural transformations that have placed oil prices on a new high path. The adherents of this view point to the erosion of spare capacity in the entire oil supply chain, the emergence of new large consumers – mainly China (and India to a lesser extent), the new geopolitical uncertainties in the Middle East following the US invasion of Iraq, and the re-emergence of oil nationalism in many oil-producing countries. Others interpret the recent oil price movements in terms of the cyclical behaviour of commodity prices. Like all raw materials, the rise in oil price stimulates oil production and slows oil demand growth. This would cause oil prices to go down which, in turn, would stimulate demand and increase the oil price. These different views about the oil market clearly reflect divergent expectations about the future evolution of oil prices (Stevens 2005).

Oil price behaviour has been analysed using three main approaches: the economics of exhaustible resources, the supply-demand framework, and the informal approach. Most analyses based on the theory of exhaustible resources conclude that oil prices must exhibit an upward trend (see Krautkraemer 1998 for a review). The insights from this literature have resulted in the derivation of non-structural models of oil price behaviour that do not explicitly model the supply and demand for oil and other factors affecting them (see for instance Pindyck 1999 and Dufour *et al.* 2006). In contrast, in the supply-demand framework, the oil market is modelled using behavioural equations that link oil demand and supply to its various determinants, mainly GDP growth, oil prices, and reserves (Bacon 1991 and Dees *et al*. 2007). And then, the informal approach is usually used to identify economic, geopolitical, and incidental factors that affect demand and supply and hence oil price movements within specific contexts and episodes of oil market history.

These different approaches are frequently used to make projections about oil prices and/or global demand and supply either for the short term or for the very long-term horizon, often over twenty years. Various players such as governments, central banks, and international oil companies rely on these projections for planning energy policy, evaluating investment decisions and analysing the impact of various supply and demand shocks hitting the oil market. Although the above frameworks are useful in improving our understanding of how the different elements of the oil market function, any attempt to use these models to predict oil prices or project oil market conditions in years to come would certainly result in errors. It is not only that these models cannot adequately capture the various shocks that can influence the oil market. But equally important, these long-term projections and long-run oil price forecasts are highly sensitive to the assumptions of the underlying model.

This paper is divided into five sections. In Section 2, we discuss oil price behaviour within the context of the economics of exhaustible resources. In section 3, we discuss the main building blocks of the supply-demand framework and discuss the limitations of using this approach for making projections. In section 4, we use the informal approach to discuss the main factors that may have affected oil prices in the current context and whether the influence of these factors is transitory or permanent. Rather than listing a wide catalogue of potential factors, we focus our analysis on four: the erosion of spare capacity, the role of OPEC, speculation, and inventories. Section 5 concludes.

## 2. The exhaustible-resources framework

There is a very wide theoretical research that deals with oil price behaviour within the theory of exhaustible resources (see Krautkraemer 1998). An important characteristic of an exhaustible – that is, non-renewable – resource is that it is not replaceable or replaced at a very slow rate such that once it is used or extracted, the resource is no longer available for use or extraction within a reasonable time horizon. Another important characteristic is that the supply of the non-renewable resource is limited relative to demand. Oil has both these features and thus is treated in this literature as a classic example of a non-renewable resource.

The essential implications of exhaustibility are twofold. First, oil production and consumption in one period affect production and consumption in future periods. Thus, the oil market should be analysed within a dynamic context. Second, oil as a non-renewable resource should command a resource rent. Thus, unlike standard goods, the market price for non-renewable resource is not equalised with the marginal cost. This positive premium, also called the scarcity rent, is the reward the resource holder gets for having kept her stock up until today.

Hotelling's pioneering work (1931), which forms the basis of the literature on exhaustible resources, is mainly concerned with the following question: given demand and the initial stock of the non-renewable resource, how much of the resource should be extracted every period so as to maximise the profit of the owner of the resource? Hotelling proposes a very intuitive and powerful theory to address this question. Assuming no extraction costs and given a market price per unit of the resource and a risk-free real interest rate on investment in the economy (*r*), Hotelling shows that in a competitive market, the optimum extraction path would be such that the price of the non-renewable resource (the price of oil in our context) will rise over time at a rate equal to the interest rate *r*. This theory has also an important implication on the exhaustibility of the resource. Specifically, as the price of the resource keeps rising, demand is slowly choked off and eventually when the price reaches very high levels, the demand for the resource disappears. This point occurs when the exhaustion of the resource is complete.[1]

***The theory of exhaustible resources has had a bearing on many economists' view of oil price behaviour.***

The theory of exhaustible resources has had a bearing on many energy economists' view of oil price behaviour. Most analysts using this theory conclude that the oil price must rise over time. Empirically, this meant that oil prices must exhibit an upward trend (Berck 1995). This gradually rising price trend continued to dominate forecasting models even in the 1980s and 1990s. In a sense this is surprising – not only because these decades witnessed many occasions of sharp oil price falls, but also because most empirical studies have shown that mineral prices have been trend-less over time (see Krautkraemer 1998). As argued by Lynch (2002):

" …for many years, nearly every oil price forecast called for such a trend; as the forecasts proved erroneous, the trend was retained but applied to the new lower point … the combination of these theoretical arguments with the oil price shock of 1979 gave credence to these rising price forecasts, and it has proven difficult to convince casual observers that although prices might rise, it is neither inevitable nor preordained by either economic law or geology" (pp.374-375).

1 It is important to note that by following the optimum extraction path, the owner of the resource maximises the discounted income stream accruing from extracting the resource over time.

Pindyck (1999) is an interesting example on how the Hotelling model has been used to construct forecasting models of energy prices. He suggests that rather than using structural models that take into account a wide array of factors – including supply and demand factors, OPEC and non-OPEC behaviour, technological advances and regulatory factors – it might be preferable to use simple non-structural models that examine the stochastic behaviour of oil prices. Non-structural models are quite flexible and allow oil prices to be modelled as a geometric Brownian motion or mean reverting process, or a related process with jumps. Using a simple Hotelling model, Pindyck (1999) shows that oil prices revert to an unobservable trending long-run marginal cost with a fluctuating level and slope over time. The forecasting performance of his model is highly mixed and especially poor for the period 1974-85 where there was wide variation in oil prices. But Pindyck (1999) argues that "putting aside the forecasting performance over the past two decades, the model captures in a non-structural framework what basic theory tells us should be driving price movements" (p. 22).

***Many oil price forecasting models are based on the theory of exhaustible resources.***

Since the pioneering work of Hotelling (1931), the theory of non-renewable resources has developed further and a number of simplifying assumptions has been relaxed to make models of non-renewable resources more realistic. More recent models allow for extraction cost to be a function of cumulative production, introduce perfect substitutes for the non-renewable resource, permit marginal extraction to vary over time, and allow for varying demand and monopolistic market conditions. Reflecting these modifications, oil prices may trend downward or follow a U-shaped path (Slade 1982; Moazzami and Anderson 1994). For instance, Khanna (2001) finds that the price trajectory can be decreasing, increasing, increasing first and then decreasing depending on whether the growth in demand is higher than the growth in marginal cost of extraction.

In any event, although the Hotelling model predicts the net price to rise exponentially, it does not imply that the market price paid by the consumer (known as the user cost) has to rise. The user cost is the sum of the scarcity rent and marginal extraction cost and the price trajectory will depend on the interaction between these two variables. If extraction costs fall faster than the increase in the scarcity rent, the user cost might decline over a period of time. However, as the resource is extracted, the scarcity rent rises rapidly and eventually dominates the fall in the marginal extraction costs causing the user cost to rise. Khanna (2001) considers six different scenarios in the simulation analysis. The oil price declines in only one of them, but only for a short period of time. Khanna (2001) argues that this scenario fits well with the declining price trend during 1975-85.

Slade (1982) finds that the price of a non-renewable resource exhibits a U-shaped path. Technological change that lowers extraction costs generates a decreasing path but continuous resource depletion with diminishing return to technological innovation will eventually cause the price to shift upward. In his empirical exercise, Slade (1982) finds that the minimum point of the U-path occurs during the sample period (in 1978), indicating that oil prices should have followed an upward trend from the late 1970s onwards. However, oil prices did not trend upward after the 1970s. In fact, more recent empirical studies conclude that non-renewable resource prices have a stochastic trend and that the property of increasing prices for most non-renewables is not clear, reducing "the prediction of price increase from near certainty to maybe" (Berck and Roberts 1996, p. 77). This, however, is not the last word on the issue. In more recent work, Lee *et al.* (2006) find support for characterising natural resource prices as stationary around deterministic trends but with structural breaks.

Despite its main contributions, many economists consider that the literature on exhaustible resources does not provide any insights into the oil price issue. The main criticism is directed towards the foundations of the Hotelling model: the very concept of resource exhaustibility and that of a fixed stock of resources (Adelman 1990; Watkins 1992 and 2006). Rather than assuming a fixed stock, Adelman (1990) suggests that oil reserves should be treated similar to inventories that are continuously depleted through extraction and augmented through exploration and development.[2] Thus, according to this view the issue is not one of exhaustibility, but investment in accumulating inventories and costs involved in finding new reserves. An important implication of this view is that there is no such thing as a scarcity rent, and models based on such a concept do not provide an accurate description of prices in the real world.

Between these two extreme positions, Mabro (1991) argues that when oil is perceived to be plentiful, Adelman's main argument holds. However, when oil is perceived to be in limited supply, Hotelling's basic proposition that current prices might be influenced by price expectations might be useful. Mabro (1991) argues that the cycle of perceptions will fluctuate depending on oil price behaviour – among other factors. Specifically, an increase in oil prices will stimulate exploration and development, thus shifting perception towards abundance. This might cause prices to fall, thereby leading to an increase in demand and, eventually, a shift in perception towards scarcity.

In our view, Hotelling's original model was not intended to and did not provide a framework for predicting prices or analysing the time series properties of prices of exhaustible resource, aspects that the recent literature tends to emphasise. Furthermore, the application of Hotelling's model to the entire oil industry reduces its usefulness especially when there is no clear idea about the size of reserves and what should be included in the reserve base. As Watkins (2006) argues, the application of Hotelling's model to the oil industry "distorts Hotelling's insightful work, work directed more at the firm level where the focus is on a deposit of known, fixed quantity" (p. 512).

## 3. The demand-supply framework

***The most widely used approach to modelling the oil market is the demand-supply framework.***

The most widely used approach to modelling the oil market is the supply-demand framework (Bacon 1991 and Dees *et al*. 2007). After all, it is the interaction between demand and supply for oil that ultimately determines the oil price in the long run. However, the special features of the oil market make the modelling exercise quite complex due to various types of uncertainties. Some of them are due to unknown future events such as geopolitical factors, supply disruptions, environmental disasters, and technological breakthroughs. Other uncertainties arise due to the lack of knowledge about factors such as the long-run price and income elasticity of demand, the response of non-OPEC supply, and above all OPEC behaviour.

### 3.1 The demand for oil

The starting point of most structural models is the demand-for-oil equation, which is modelled as a function of world economic activity and oil prices. The hypotheses presented are straightforward: higher economic activity should be associated with higher oil demand while higher oil prices should be associated with lower demand for oil. The bulk of the empirical literature has focused on estimating the price elasticity and income elasticity of demand both in the short run and the long run and across a large number of countries.

#### 3.1.1 Price elasticity of crude oil demand

The relationship between the demand for crude oil and its price is usually examined by estimating the price elasticity of demand. Suffice it to refer here to a few recent studies to show the wide variation in estimated price elasticity. As Table 1 shows, estimates for the short-run and long-run price elasticity

2 The reserves issue will be discussed in more detail in Section 3.2.

of demand range from 0 to -0.64. Despite this wide variation, it is possible to draw some general conclusions regarding the link between demand and price. First, changes in oil prices have a small and usually insignificant effect on demand for crude oil, especially in the short run. Second, the long-run price elasticity of demand is higher than the short-run elasticity due to substitution and energy conservation, but the elasticity is still quite low.

***Changes in oil prices have a small and usually insignificant effect on demand for crude oil, especially in the short run.***

**Table 1. Recent estimates of the price elasticity of crude oil demand**

| | Short-run estimates | Long-run estimates | Sample |
|---|---|---|---|
| Dahl (1993) | -0.05 to -0.09 | -0.13 to -0.26 | Developing countries |
| Pesaran *et al*. (1998) | -0.03 | 0.0 to -0.48 | Asian countries |
| Gately and Huntington (2002) | -0.05 | -0.64 | OECD |
| | -0.03 | -0.18 | Non-OECD |
| | | -0.12 | Fast growing non-OECD |
| Cooper (2003) | 0.001 to -0.11 | 0.038 to -0.56 | 23 countries |
| Brook *et al.* (2004) | | -0.6 | OECD |
| | | -0.2 | China |
| | | -0.2 | Rest of the world |
| Griffin and Schulman (2005) | | -0.36 | OECD |
| Krichene (2006) | -0.02 to -0.03 | -0.03 to -0.08 | Various countries |

Some recent studies have modelled an asymmetric response of demand to a change in crude oil prices. For instance, Gately and Huntington (2002) argue that the short-run price elasticity depends on whether prices rise or fall. Specifically, an increase in oil prices could reduce oil demand, but that a subsequent drop in oil prices would reverse the decline in demand is not necessarily true. The increase in price may induce investment in more energy-efficient equipment, thereby reducing demand for oil – and this decrease in demand would not be reversed by a subsequent drop in prices. Gately and Huntington also hypothesise that the demand response to an all-time price peak is different from the response to a price recovery from a low point. When testing their hypothesis, the authors indeed find that price elasticities are significantly different across price falls and prices increases and that the most elastic demand response is due to new price peaks.

Despite the attractiveness of this explanation, Griffin and Schulman (2005) argue that the asymmetric model has the unintended consequence of creating price volatility, thus shifting inward the intercept of the demand-for-oil equation. The authors note that this is observationally equivalent to a shift in the intercept due to an energy-saving technical change. Griffin and Schulman (2005) conjecture that the findings of Gately and Huntington (2002) might capture energy-saving technical change rather than an asymmetric response of oil demand to changing oil prices. Thus, Griffin and Schulman (2005) opt for a fixed effects model of oil demand in which time dummies account explicitly for technical change. Using a panel of OECD countries, the authors find that the hypothesis of price symmetry cannot be rejected after controlling for technical change.

### 3.1.2 Income elasticity of crude oil demand

Similar to price elasticities, estimates for the income elasticity of crude oil demand vary widely according to the method used, the period under study, and the country sample (for instance, developing countries or OECD countries). As can be seen from Table 2, which summarises some recent findings, estimates range from as low as 0.2 to estimates larger than one. Despite this range, it is possible to draw some general conclusions. First, oil demand is more responsive to income than prices. Second, the long-run income elasticity of oil demand is higher than the short-run income elasticity. Third, there is large heterogeneity in estimated income elasticity across countries and/or regions, with developing countries exhibiting higher income elasticity than OECD countries. Finally, in OECD countries, the responsiveness of oil demand to income has been declining over time.

**Table 2. Recent estimates of the income elasticity of crude oil demand**

| | Long-run | Sample |
|---|---|---|
| Ibrahim and Hurst (1990) | >1.0 | Developing countries |
| Dahl (1993) | 0.79 to1.40 | Developing countries |
| Pesaran *et al.*(1998) | 1.0 to 1.2 | Asian countries |
| Gately and Huntington (2002) | 0.56 | OECD |
| | 0.53 | Non-OECD |
| | 0.95 | Fast growing non-OECD |
| Brook *et al.*(2004) | 0.4 | OECD |
| | 0.7 | China |
| | 0.6 | Rest of the world |
| Krichene (2006) | 0.54 to 0.90 | Various countries |

### 3.1.3 Elasticity of gasoline demand

***There is large heterogeneity in estimated income elasticity across countries and/or regions, with developing countries exhibiting higher income elasticity than OECD countries.***

Rather than examining crude oil demand, many studies have looked at various finished petroleum products, gasoline in particular (see Dahl and Sterner 1991, Dahl and Duggan 1996, and Graham and Glaister 2002 for surveys). Despite its retreat in most other sectors, crude oil and petroleum products (gasoline, diesel oil, and jet fuel) remain the dominant fuel in the transport sector.

It would go far beyond the purpose of this paper to review this literature. Suffice it here to offer insights from the meta-study by Espey (1998), which covers a wide array of studies published between 1966 and 1997. First, empirical studies suggest that short-run price elasticity estimates for gasoline demand range from 0 to -1.36, with a mean of -0.26, while long-term price elasticity estimates range from 0 to -2.72, with a mean of -0.58. Short-run income elasticity range from 0 to 2.91, with a mean of 0.47, while long run income elasticity range from 0.05 to 2.73, with a mean of 0.88. Second, the author finds that the estimated elasticities are highly sensitive to the behavioural model underlying demand. In this respect, his results indicate that the exclusion of vehicle ownership as an explanatory variable would bias upwards estimates of short-run and long-run income elasticity. Third, he finds that estimates using US data are very different from those using data sets that include other OECD and European countries. This is not surprising since the dependence on cars is higher in the United States than in other countries, largely because the population density and reliance on public transport in this country is relatively low. That being said, the price elasticity of gasoline demand in OECD countries is still very low. This is in large part due to high taxes that most OECD governments impose on oil products, which weaken the link between international oil prices and gasoline demand. Since taxes represent a large percentage of the price paid by consumers for gasoline, a rise in international crude oil prices would increase gasoline prices by only a fraction of the increase.

### 3.1.4 Demand projections

The relationship between oil demand, prices, and income has been used extensively to project global or regional oil demand. Table 3 – which summarises often used projections – shows that demand projections differ considerably. A number of points are worth emphasising. First, the projections are highly sensitive to underlying economic growth assumption. Second, they are highly sensitive to the income and price elasticity used. Third, they are sensitive to the oil price path chosen. To appreciate the sensitivity of the results to some of these assumptions, it is useful to know that in the IMF (2005) projection a change in economic growth by ± 0.5 percentage points changes projected oil demand by around ± 4 percent. And then, a hypothetical oil price shock at the beginning of the projection period can cause oil demand to decline by almost 6 percent compared to the baseline projection. Fourth, there is the issue of endogeneity of prices and income. Most studies implicitly assume that the price is exogenous – probably set by OPEC, but as will be argued in Section 4 this is not a realistic assumption. Finally, most empirical studies ignore the potential relationship between oil price shocks and growth. An extensive literature on oil price shocks and growth suggests a feedback mechanism in which oil prices can have a large and significant impact on growth (see for instance Jones *et al*. 2004 and Barsky and Kilian 2004 for a review of this literature). However, the insights and results from these writings have not been so far integrated into the empirical literature on the income and price elasticity of oil demand, and these two strands of literature have grown independently from each other.

**Table 3. Projected oil demand (in million barrels per day)**

| | 2003 (actual) | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| IMF (2005) | 79.8 | 92.0 | 102.4 | 113.5 | 125.5 | 138.5 |
| EIA (2006) | 80.0 | 92.0 | 98.0 | 104.0 | 111.0 | 118.0 |
| IEA (2006) | 82.5 | 91.3 | 99.3 | – | – | 116.3 |

Sources: IMF (2005), World Economic Outlook, April 2005, Table 4.5; Energy Information Administration (EIA), International Energy Outlook 2006, Figure 26; International Energy Agency, World Energy Outlook 2006, Table 3.1.

Note: IEA figure in first column refers to 2004 and not 2003.

### 3.2 Non-OPEC oil supply

***Modelling oil supply is much more complex than modelling demand.***

Modelling oil supply is much more complex than modelling demand, reflecting the controversy surrounding the level of reserves and the behaviour of various oil suppliers. As to the latter, it is useful to distinguish between OPEC and non-OPEC suppliers. While it is usually assumed that non-OPEC suppliers behave competitively, OPEC behaviour is much more multifaceted, and there are diverse and competing theories describing its behaviour (see Gately 1984 and Crémer and Salehi-Isfahani 1991 for a review). Although non-OPEC suppliers are fairly diverse – comprising national oil companies, large international oil companies, and smaller, independent firms – empirical studies typically do not distinguish between them, but normally aggregate oil production outside OPEC.

In what follows, we will first review two main approaches that are used to shed light on non-OPEC oil supply: the geophysical approach – also called the Hubbert approach – and economic-based models. We will then briefly turn to hybrid models, which combine elements of the main approaches, and conclude with non-OPEC supply projections. The supply of oil by OPEC will be examined in sub-section 3.3.

#### 3.2.1 The geophysical approach

The geophysical approach, which is mainly based on the work of Hubbert (1956), stresses geophysical factors in determining non-OPEC oil supply. According to this approach, production is governed by historical cumulative production and the size of ultimately recoverable reserves (URR), with the production profile of an oil region following three phases: production increase, stagnant production at a 'peak', and declining production as and when reserves approach depletion. More specifically, assuming that cumulative production follows a specific logistic curve, the annual rate of production during these phases fits a symmetric bell-shaped curve.

Hubbert's approach of modelling oil supply became very popular in the 1970s (mainly because of its success in forecasting annual production of the lower 48 US states), but it has been recently widely criticised (see for instance, Lynch 2002 and Watkins 2006). A major criticism concerns the treatment of URR as a static variable while in reality it is dynamic and has expanded over time due to economic and technological advances. Another weakness is the tendency of the geophysical approach to overestimate the depletion effect. Lynch (2002) reviewed various predictions and finds that most of them have overstated the depletion effect. Thus, far from being symmetrical, the Hubbert curves are skewed to the right, indicating that other factors such as new investments, the discovery of new fields, or a combination of the two prevent – or postpone – the decline in production.

***In geophysical models, the assumptions made about oil reserves are central for forecasting non-OPEC oil supply.***

It is clear from the above that assumptions made about reserves are central in modelling oil production. The issue of reserves, however, is highly contentious and there is substantial disagreement on the size of global reserves. The estimates range from less than 2 trillion barrels of oil equivalent (tboe) (Campbell 1989 and Campbell and Lahererre 1998), to between 2-4 tboe (USGS 2000), and to reserve estimates in excess of 4 tboe (Odell and Rosing 1983 and Shell 2001)[3]. This range arises due to a number of factors, including different estimation methodologies, 'vested interests', and differences in defining reserves and oil (conventional *vs.* unconventional oil).

Regarding the definition of reserves, the World Petroleum Congress and the Society of Petroleum Engineering have adopted a new approach, which introduces elements of probability, allowing a distinction between proved and unproved reserves. Proved reserves are quantities of petroleum (i) that are commercially recoverable from known reservoirs given current economic and regulatory conditions and (ii) for which there is 90-percent probability that the quantities recovered will be equal to, or greater than, estimated proved reserves. Unproved reserves are estimated on the basis of similar geological and engineering data as proved reserves, but because of contractual, economical, regulatory, or technical factors they cannot be treated as proved. Unproved reserves can be divided into probable reserves (unproved reserves with a 50-percent probability that quantities actually recovered will equal or exceed the estimate) and possible reserves (unproved reserves with a 10-percent probability that quantities actually recovered will equal or exceed the estimate).[4]

Identifying the underlying assumption about the size of reserves is important because it forms the basis for projecting oil supply. Pessimists predicted that oil would 'peak' in the 1990s (see Campbell 1989, for instance). The wrongness of such predictions led to a variety of modifications to the underlying model, allowing – for instance – for multimodal rather than unimodal production curves. Other studies based on the USGS data predict the peak in non-OPEC production to occur between 2015 and 2020 (Cavallo 2002). And then, studies using still higher reserve estimates suggest that peak production will take much longer to come. For instance, Odell (1998), who estimates 3 tboe of conventional oil and 3 tboe of unconventional oil, suggests a peak for conventional oil in 2020 and for unconventional oil around the year 2060 (see Ahlbrandt 2006).

It is important to stress that despite regular discussions of a looming oil shortage, the ratio of proved reserves to annual production has increased over the last 30 years, indicating strong growth in reserves. Table 4 shows that while total production increased from 59 million barrels of oil per day (mbd) in 1973 to 77 mbd in 2003, reserves over this period rose by more than 500 billion barrels, suggesting that reserves have become more plentiful compared to 30 years ago (see Watkins 2006 for a more detailed discussion). The bulk of this growth is not due to new discoveries but mainly to reserve

3 This classification is based on Ahlbrandt (2006).

4 For more details see Ahlbrandt (2006) and Seba (1998), for instance.

(or field) growth.[5] For instance, Ahlbrandt (2006) reports that in the last 15 years reserve growth has added 85 percent of reserves in the United States. Studies applied to world reserve growth also show that the contribution of reserve growth of existing fields has been more important than the discovery of new fields.

The reserve growth can be explained by initial conservative estimates and the use of better exploration, development, and drilling technologies. Regarding the latter, Verma (2000) emphasises the importance of enhanced oil recovery where new technologies, such as water flooding and gas injection, have lead to dramatic improvements in recovery rates, increasing from, say, 30 percent of the original oil in place to 50 percent (and more).

**Table 4. World oil reserves, production, and reserve-production ratio**

| | 1973 | 1983 | 1993 | 2003 |
|---|---|---|---|---|
| Reserves (billion barrels) | 635 | 723 | 1,024 | 1,148 |
| Annual production (mbd) | 59 | 57 | 66 | 77 |
| Reserves/annual production (years) | 30 | 35 | 42 | 41 |

Source: Watkins (2006), Table 1.
Note: mbd = million barrels per day

### 3.2.2 Economic-based models

Many have argued that since the Hubbert model is based on the wrong concept of ultimate recoverable reserves, it should not be used for modelling oil supply. The model has also been criticised for its neglect of the role of economic factors and technology.

Economic-based supply models have emphasised that economic factors – for instance, real oil prices and costs, regulatory factors such as the fiscal system and the concession terms, and technology – play an important role in determining investment and hence oil supply. Taking economic factors into account, various studies have attempted to estimate the price elasticity for non-OPEC oil supply. They have shown that the response of non-OPEC production to oil prices is very low, especially in the short run. For one thing, producers do not necessarily increase production when oil prices rise. For another, a price decline does not induce producers to reduce production. For instance, during the 1970s, prices soared and production did not rise as fast. But in the 1980s, prices fell dramatically but production continued to increase, suggesting a negative price elasticity of non-OPEC supply during this period.[6]

***Economic-based supply models have emphasised that economic factors – for instance, real oil prices and costs, regulatory factors, and technology – play an important role in determining oil supply.***

Although the long-run price elasticity is found to be positive, many studies suggest low elasticities. For instance, Krichene (2006) reports a long-run price elasticity for non-OPEC supply of 0.08, and Al Hajji and Huenter (2000) report one of 0.29. Gately (2004) reports a wide band of price elasticity, varying from 0.15 to 0.58 while Dahl and Duggan (1996) estimated a price elasticity of 0.58.

Other more elaborate attempts to estimate oil-supply functions have been made. Watkins and Streifel (1998) estimate a model in which reserve additions are regressed on some inferred price of discovered but undeveloped reserves and a time variable that is meant to capture a range of factors – including the net impact of changes in prospectivity, depletion effects, cost efficiency, and technology. The main purpose of their exercise was to test whether the supply function has been moving outward

5 Reserve growth is defined as an increase in the estimated size of a (oil-)field over time.

6 It is worth noting that economic-based models could also include the notion of an exhaustible resource in which case supply will be determined by inter-temporal optimisation. Specifically, supply will not only depend on current prices, but also on future prices (Crémer and Salehi-Isfahani 1991).

(i.e., expanding) in response to new discoveries and cost-saving technologies or moving inward (i.e., contracting) due to depletion effects. Their results indicate that outside North America, non-OPEC supply has been expanding while in North America it has been contracting. The authors warn that the latter result does not indicate that reserves will not be added in North America, but that the diminishing returns on exploration have not been offset by technological or efficiency advancements. It is clear that in such economic-based models, ultimate recoverable reserves play no role in determining the oil supply and are treated as irrelevant, non-binding constraints (Adelman 1990).

### 3.2.3 Hybrid models

In general, economic models of oil supply that focus on price elasticity were not very successful, not even when applied to non-OPEC production, where producers are assumed to be competitive price takers. This is mainly due to complex interaction between geological factors (reserves, depletion, discovery, etc.), economic factors (oil prices, technical change, etc.), regulatory factors (fiscal system, concession agreements, etc.) and political factors (sanctions, political turmoil, and so on).

***Hybrid models combine geophysical with economic factors to forecast non-OPEC oil supply.***

Against this background, there have been a number of attempts to construct models that combine geophysical with economic factors, referred to as hybrid models (Kaufmann 1995, Moroney and Berg 1999, and Kaufmann and Cleveland 2001). An early attempt was Kaufmann (1991) who in the first step constructed the difference between the actual production curve and the predicted production curve based on Hubbert's model. The difference was then regressed on number of economic and regulatory variables. Moroney and Berg (1999) model oil supply as a function of the stock of reserves, the real price of oil, and dummy variables to account for regulatory factors. They use a partial adjustment model to account for the fact that producers react gradually to changes in the determinants of supply. For the United States, the authors find a wide band of price elasticity estimates ranging from 0.057 to 0.19. Their results also indicate a unitary long-run elasticity of production with respect to lagged reserves.

### 3.2.4 Projections of non-OPEC supply

Given the different models and the wide range of elasticity estimates, it is no surprise that non-OPEC supply projections differ considerably across studies and over time. Table 5 below reports most recent EIA and IEA projections of non-OPEC supply. While the EIA expects a relatively high non-OPEC supply growth, the IEA is more conservative about the potential contribution of non-OPEC suppliers. The large difference in the projections is mainly due to differences in the responsiveness of non-OPEC supply and unconventional oil supply to oil prices and different assumptions as to whether or not non-OPEC oil supply reaches a peak during the projection period. In fact, the large EIA revision in 2006 is partly due to the more optimistic view about the potential of unconventional oil, which could become highly economical if oil prices remain high – as currently projected. The EIA's 2006 International Energy Outlook predicts that unconventional supplies will reach 9.7 mbd in 2025 and 11.5 mbd in 2030. This is a substantial upward revision from the 2005 Outlook, which projected unconventional oil supply to reach 5.7 mbd in 2025.

**Table 5. Projected non-OPEC oil supply (in million barrels per day)**

| | 2010 | 2015 | 2030 |
|---|---|---|---|
| EIA (2006) | 54.4 | 58.6 | 72.6 |
| EIA (2005) | 56.6 | 61.7 | 66.2 |
| IEA (2006) | 53.4 | 55.0 | 57.6 |

Sources: Energy Information Administration (EIA), International Energy Outlook 2005 and 2006. International Energy Agency (IEA), World Energy Outlook 2006.

### 3.3 OPEC oil supply

#### 3.3.1 A plethora of approaches to modelling OPEC supply

Studying the behaviour of OPEC in supplying oil is crucial for understanding the oil market and long-run oil prices. However, OPEC behaviour is very complex to model (see Fattouh 2007a for a recent review). Many conflicting theoretical and empirical interpretations of the nature of OPEC and its influence on world oil markets have been proposed. The debate is not centred on whether OPEC restricts output, but on the reasons behind these restrictions.

Some studies emphasise that OPEC production decisions are made in reference to budgetary needs, which, in turn, depend on the absorptive capacity of members' domestic economies (Teece 1982). Others explain production cuts in the 1970s with the transfer of property rights from international oil companies to governments, with the latter having lower discount rates than the former (Johany 1980 and Mead 1979). And then there are studies that see coordinated actions of OPEC members as a main determinant of output. Within this literature, the view of OPEC behaviour ranges from classic text book cartel, to two-block cartel (Hnyilicza and Pindyck 1976), to clumsy cartel (Adelman 1980), to dominant firm (Salant 1976 and Mabro 1991), to loosely co-operating oligopoly, to residual firm monopolist (Adelman 1982), and – most recently – to bureaucratic cartel (Smith 2005). Finally, some studies suggest that OPEC oscillates between various positions but always acts as a vacillating federation of producers (see for instance Adelman 1982 and Smith 2005). The existing empirical evidence has not helped narrow these different views.

***The view of OPEC behaviour ranges from classic text book cartel, to two-block cartel, to clumsy cartel, to dominant firm, to loosely co-operating oligopoly, to residual firm monopolist, and – most recently – to bureaucratic cartel.***

There has been an extensive debate on the usefulness and limits of the various models. This debate is beyond the scope of this paper. What is important to emphasise though is that each of these theories implies a different OPEC behaviour and hence supply decisions and pricing rule. Let us look at two theories to clarify this point. For one thing, there are models that consider OPEC as a monopoly owner of an exhaustible resource. In these circumstances, the organisation's behaviour is highly predictable: it would choose prices or quantities so that the difference between marginal revenue and marginal extraction cost will increase at the rate of interest (Pindyck 1978). For another, there is the target-revenue theory, which hypothesises that OPEC countries typically respond to a rise in oil price by cutting production and to a fall in prices by expanding output. The underlying intuition behind this theory is simple. Supply decisions are determined by a country's national budget requirements, which are a function of the economy's ability to absorb productive investment. Thus, if many OPEC countries follow such a target-revenue rule, an exogenous increase in oil prices will trigger simultaneous cuts in production in these countries even without any coordination from OPEC members (Teece 1982).

Whatever theory is chosen, modelling OPEC supply creates a serious challenge for the supply-demand framework. Simply put, it is problematic to describe OPEC as a cartel, or oligopoly, while at the same time use a competitive supply-demand framework for analysing the long-run behaviour of oil markets. A standard way to close the model has been to treat OPEC supply decision as a residual often referred to as the 'call on OPEC', which is the hypothetical amount that OPEC needs to produce to close the gap between oil demand and non-OPEC supply. In other words, projections about OPEC supply are not based on behavioural analysis but derived from a simple accounting formula that balances world demand after taking into account various factors. This approach has been widely used to project OPEC supply.[7]

7 The demand-supply framework has also been used to study the impact of various shocks on oil prices. For instance, in the model of Dees *et al.* (2007), a 10-percent increase in OPEC's quota triggers a decrease in the price of oil which, in turn, boosts demand. After a series of oscillations, in which demand and oil price react to each other, the price of oil is simulated to settle some 10 percent below its starting value. Using a similar model, Brook *et al.* (2004) examine the impact of a serious supply disruption on oil prices. In a bad-case scenario, they find that a 7-percent oil supply shock would raise the oil price by around $20 in the first year, but it would fall back to the baseline relatively quickly. These types of exercises are very useful, but they are highly sensitive to the various parameters and the way the model is closed.

Table 6 below shows various projections on the call on OPEC. As can be seen from this table, the projections vary widely (with the difference between the lowest and highest estimate in 2030 reaching around 43 mbd) and even for a given projection the difference between its upper and its lower bound can be substantial, as indicated by the difference of 20 mbd in the EIA projection for 2030.

**Table 6. Projections of OPEC supply (million barrels per day)**

| | 2010 | 2020 | 2025 | 2030 |
|---|---|---|---|---|
| EIA (2006) | 32.9-37.9 | 29.3-43.3 | 29.8-46.9 | 30.9-51.0 |
| IMF (2005) | 30.6-32.7 | 43.5-49.2 | 51.6-61.0 | 61.3-74.4 |
| IEA baseline scenario (2006) | 35.9 | – | – | 56.3 |

Sources: Energy Information Administration (EIA), International Energy Outlook 2006. International Energy Agency (IEA), World Energy Outlook 2006. International Monetary Fund (IMF), World Economic Outlook, April 2005.
Note: Based on 'call-on-OPEC' models

Although calculating OPEC supply as a residual overcomes the problem of modelling OPEC's complex behaviour, this approach suffers from two major limitations: it assumes that OPEC has the incentive to expand output and that the necessary investment to increase capacity materialises.

### 3.3.2 Incentive for OPEC to expand output

***Calculating OPEC supply as a residual suffers from two major limitations: it assumes that OPEC has the incentive to expand output and that the necessary investment to increase capacity materialises.***

The above projections implicitly assume that OPEC has the incentive to increase market share regardless of oil prices. Specifically, there is no analysis whether the projected output path will serve the interests of OPEC. Gately (2004) analyses whether OPEC producers have the incentive to expand oil output and increase their market share. Rather than calculating the OPEC supply as a mere residual, Gately (2004) calculates the OPEC's net present value (NPV) of profits for different choices of OPEC's market share. His main finding is that profits are relatively insensitive to higher output growth. In fact, aggressive plans to expand output can yield a lower payoff than if OPEC decides to maintain its market share. This result is quite intuitive. Given certain assumptions about the model parameters, the increase in the NPV of expected profits from higher output would be more than offset by lower prices as a result of a rapid output expansion. Gately (2004) thus concludes that the projections of rapid increases in OPEC output and market share (such as those summarised in Table 6) are implausible and "are likely to be contrary to OPEC's own best interests" (p.88). He notes that the incentive to increase capacity at a rapid pace might exist only if one assumes a high price elasticity of both world oil demand and non-OPEC supply.[8]

To shed more light on the link between the market share of OPEC and its profitability, we draw on IMF (2005), which suggests that the optimal strategy for OPEC is to maintain its market share between 41 percent and 46 percent. This is well below the shares implied by the projections shown in Table 6. To illustrate, in the IMF baseline scenario, world oil demand is projected to reach around 139 mbd in 2030. For the same year, the upper bound for the 'call on OPEC' is projected at around 74 mbd, implying a market share (54 percent) well above the level that would maximize OPEC profits.

### 3.3.3 The investment problem

Even if OPEC has the incentive to increase market share, the investment needed to attain those shares is substantial and it may not materialise for a number of reasons. There is no scope in this paper to

8 In a separate paper, Gately (2001) reaches the same conclusion regarding Persian Gulf oil producers.

offer a comprehensive assessment of investment bottlenecks in the oil sector, such as that provided by Fattouh and Mabro (2006). Instead, a few general observations are useful to emphasise non-price factors that might prevent OPEC from increasing its capacity in the future. First, unfavourable geopolitical factors and sanctions could create an investment climate that is detrimental to capacity expansion in many OPEC countries. In the past, economic sanctions hindered investment and deferred the development of projects in Libya, Iraq and Iran.

Second, in OPEC countries where the state controls the hydrocarbon sector, the relationship between the government and the national oil company can result in an unfavourable environment for investment. Specifically, given the competing and increasing demands for economic, social, and infrastructure projects, national companies' budgets are likely to be kept tight, preventing them from undertaking investment, acquiring technological capabilities, and enhancing their managerial expertise.

Third, investment is also complicated by another relationship: that between the governments and/or national oil companies and the international oil companies. Many consider that restriction of access to reserves is an important barrier to investment. However, access is not the central issue since such access is effectively restricted only in Saudi Arabia, Mexico and Kuwait, with the latter developing plans to open its sector to foreign investment through Project Kuwait. What matters most is the nature of the relationship between the two parties. Experience has shown that even in countries where access to reserves is allowed, there may be important obstacles that could delay or prevent investment by international oil companies. As markets have tightened, the terms and conditions demanded by the owners have been hardening over time.

***It is more profitable for OPEC to underinvest than to overinvest.***

Finally, many OPEC officials consider that uncertainty about demand for oil constitutes a very important obstacle to investment. This has led OPEC members to call for security of demand in face of concerns about security of supply. Security of demand cannot be achieved in the current market structure, and the idea that uncertainty has to be resolved before making an investment is highly unrealistic. Instead, investment decisions can only be made in the context of uncertainty. As the literature of irreversible investment suggests, uncertainty increases the option value of waiting, that is, delaying the investment until new information about market conditions arrive. For OPEC, the option to wait is very valuable. After all, the decision to wait and not to invest is more profitable than to invest and increase production in the face of falling global demand. In other words, it is more profitable for OPEC to err on the side of under-investing in new capacity as opposed to expanding capacity because forgone oil sales can be compensated by higher oil prices in tight market conditions.

### 3.4 A synthesis of the supply-demand framework

The supply-demand framework explains oil market behaviour in terms of factors that determine demand (income and price) and supply (price, reserves, and OPEC behaviour). Although this approach is useful for gaining a better understanding of the oil market, using this framework to project oil prices is likely to result in mistakes for a number of reasons. First, price projections are highly sensitive to the assumptions made about income and price elasticity of demand, the price elasticity of supply, the role of reserves, and OPEC behaviour – the latter being essential to close models. Second, the above framework cannot capture the impact of unexpected shocks. These shocks are central to understanding the behaviour of oil prices since evidence suggests that shocks can be persistent (Cashin *et al*. 1999). One important implication of shock persistency is that "it is incorrect to view shocks to commodity prices as generally being a temporary phenomenon that largely reflect short-lived variability in supply interacting with relatively unchanging demand" (p.39). Instead, these shocks are long lived, have enduring effects, and – indeed – may shift oil prices to a new path. Third, the above framework does not take into account the geopolitical context and general market conditions in which oil prices are determined. It is true that demand and supply determine the oil price in the long term, but they do so in a specific context. Unfortunately, the supply-demand framework analyses oil prices and makes projections in a 'neutral context'. Considering the specific context in which oil prices evolve is a salient feature of the informal approach to analysing the drivers of oil prices – as we will see next.

## 4. Drivers of oil prices in the current context: an informal approach

***The increase in oil prices and oil price volatility experienced in the last three years led many analysts to argue that factors other than changes in elasticities or reserves influence oil market developments.***

The increase in oil prices, and oil price volatility, experienced in the last three years led many analysts to argue that factors other than changes in elasticities or reserves influence oil market developments – at least in the short run. The list of factors include unexpectedly strong demand (mainly of emerging economies), lack of spare capacity, distributional bottlenecks, OPEC supply response, geopolitical and weather shocks, and an increasing role of speculators and traders in price formation. This section discusses some of these factors – notably the role of OPEC, eroding spare capacity, speculators and traders, and of inventories and the term structure of oil prices – and concludes with an assessment of whether the influence of these factors on the oil market is temporary or permanent.

### 4.1 The pricing power of OPEC

Views about the pricing power of OPEC diverge and have changed over time (Fattouh 2007a). Perceptions range and have been shifting from one extreme, where OPEC is believed to play no role at all in pricing or only a very limited one, to the other extreme where OPEC is seen as a price setter. The shift in perception became very apparent in the events that surrounded the oil price collapse in 1998 and the oil price hike in 2004. In 1998, when the Dubai oil price approached $10 per barrel, many observers claimed that OPEC had lost its ability to defend oil prices and quite a few of them predicted its demise. This view reversed only few months later, however, with many observers arguing that the 1998 price collapse induced greater cooperation among OPEC members, thereby marshalling a new era for the organisation.[9] That said, high oil prices in 2004 gave rise to yet another switch in perception, with doubts about the pricing power of OPEC re-emerging.

Cognisant of variations in the actual, or perceived, pricing power of OPEC over time, it is true that while OPEC has successfully defended the oil price on many occasions, cutting output with a view to stabilising prices has sometimes proved to be unsuccessful. Because of different features, needs, bargaining power, and divergent interests of OPEC members, they usually fail to agree on the allocation of production cuts (see for instance Kohl 2002 and Libecap and Smith 2004). These problems are more acute when the required cuts are large because small OPEC members regularly find it difficult to reduce their production on a pro-rata basis – the usual system adopted by OPEC over the years. In these circumstances, market participants might doubt the credibility of OPEC's decision to cut production and ignore the signal that OPEC is trying to send. This holds especially if there are deep divisions and political rivalries among OPEC members.

Increasing output in the face of growing global oil demand can also be problematic though for different reasons. Although agreements to increase quotas are easier to reach and implement when global demand is rising, OPEC might not respond fast enough to buoyant demand because

9 See for instance, Stanley Reed, "Cheap Oil? Forget It", Business Week. 3/8/2004, Issue 3873 and Weston and Christiansen (2003).

of imperfect information and uncertainty about future demand. After all, the decision to wait and not to raise output is more profitable than to increase output and subsequently realise that demand expectations turn out to be false. Anticipating this response, market participants may ignore the signal of an agreement to boost output because they judge such an agreement unlikely to be adhered to. A rise in global demand for oil can affect OPEC pricing power through another channel: the erosion of spare capacity. This became evident in 2004 when doubts about the ability of OPEC's dominant producer, Saudi Arabia, to deliver additional crude oil of the required quality rendered any OPEC announcements of production increases ineffective.

All in all, OPEC's pricing power is not straightforward. It varies over time and can occur both in weak and tight market conditions. This does not imply that market participants can afford to ignore OPEC. In fact, OPEC has often cut output successfully with a view to preventing a decline in oil prices. This being said, output policies aimed at influencing prices have become more complicated with the growing importance of the futures market for the oil price discovery process (Fattouh 2007b).

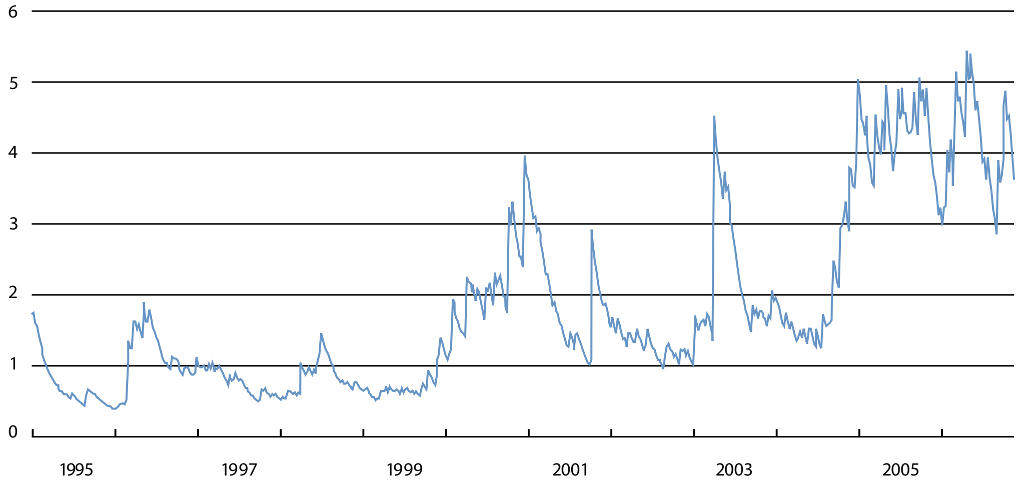
### 4.2 Erosion of spare capacity

*Recent oil price hikes have revealed an oil market with much less flexibility to deal with supply shocks or large increases in global oil demand.*

The oil price hikes in 2004 and 2005 revealed an oil market with much less flexibility and capacity to deal with supply shocks or large unexpected (or even expected) increases in global oil demand. For most of the 1980s and 1990s, OPEC's spare capacity, chiefly that of Saudi Arabia, helped offset large demand and supply shocks. Spare capacity however has witnessed a gradual decline since the early 1990s. Many observers argue that the conditions responsible for the emergence of a large spare capacity cushion in the mid 1980s – mainly the surge in non-OPEC supply accompanied by a decline in global demand – cannot be repeated and thus spare capacity is a thing of the past. For advocates of peak oil, spare capacity is a myth. International institutions such as the IMF and IEA argue that the erosion of spare capacity has been the result of worldwide under-investment in the oil sector and hence they call for removing barriers to investment in order to restore spare capacity in all parts of the supply chain. Others such as Goldman Sachs (2005) are more pessimistic about the realisation of investments, arguing that "demand destruction will be needed to recreate a spare capacity cushion in order to return to a period of lower energy prices" (p.18). Saudi Arabia's declared policy of maintaining a volume of spare capacity of around 2 mbd could be achieved, but this spare capacity is too small compared to global demand. It is interesting to note that although these views are fundamentally different, they all seem to agree on one thing: we have entered a 'new era' in which oil market's ability to rely on spare capacity to absorb shocks has greatly diminished.

This situation, if it turns out to be correct, would have strong implications both on price levels and the dynamic behaviour of crude oil prices. Given that the crude oil market is characterised by low price elasticity of supply, any increase in demand cannot be met by an increase in oil supply, especially in the short run. Thus, in the absence of spare capacity, demand shocks would require a large change in prices to clear the market. In particular, when capacity constraints become the driving force in the market, the following price dynamics are likely to emerge: an accelerated rise in the average level of oil prices, more frequent spikes in crude oil prices, and an increase in the volatility of oil prices. The behaviour of oil prices in the last three years is consistent with these price dynamics where we witnessed an accelerated rise in oil prices and many frequent oil price hikes. Volatility has also increased and reached high levels in the last two years. We used a GARCH (1,1) model to estimate the conditional volatility of weekly spot price returns of Western Texas Intermediate (WTI) crude oil from January 1995 to November 2006. Figure 1 plots the estimated conditional variance. As can be seen from this graph, volatility rose markedly especially in 2004 and remained high until the end of our sample period – in particular compared to the mid and late 1990s.

**Figure 1. Conditional volatility of crude oil price (in percent)**




Notes: Based on GARCH (1,1) model; weekly data of spot WTI price; January 1995-November 2006.

### 4.3 Speculation

***Tight market conditions, geopolitical uncertainties, and very limited spare capacities have made some of the bets on potential supply shocks extremely attractive.***

In a number of articles in energy publications and international policy reports, many observers have raised concerns about the possible impact of speculators on the recent rises in oil prices.[10] It is often argued that in recent years, a large number of speculators have entered the oil market lured by the market's high returns. The BIS Quarterly Review (2004) notes that "the rapid increase in oil prices in recent months has focused attention on the role of speculators in the oil market. With prices in most major equity, bond and credit markets moving sideways or even declining, investors in search of higher returns have reportedly turned to commodity markets, oil in particular" (p.6). In a similar vein, Greenspan (2006) has noted that "when in the last couple of years it became apparent that the world's industry was not investing enough to expand crude oil production capacity quickly enough to meet rising demand, increasing numbers of hedge funds and other institutional investors began bidding for oil" (p.3). Tight market conditions, geopolitical uncertainties, and very limited spare capacities have made some of the bets on potential supply shocks extremely attractive. For instance, although the probability of a supply shock might not have changed compared to previous years or might have increased only slightly, the upside potential in the event of such a shock can be extremely high in the absence of sufficient spare capacity. Although inventories have risen, investors believe that in case of such a supply shock, the current level of inventories would not be enough to absorb the price rise.

Many observers hold the view that the new players trade on noise and sentiment rather than on fundamentals – with adverse effects on the functioning of oil markets. Black (1986) defines noise traders as agents who sell and buy assets on the basis of irrelevant information rather than on market fundamentals or the arrival of new information. These are usually contrasted with arbitrageurs, rational speculators, or 'smart money' that trade on the basis of information and thus tend to push prices towards fundamentals. Although noise traders may be active in financial markets, the traditional view has been that speculators trading on noise can be ignored in models of price formation because they

10 See for instance Unites States Senate (2006), Staff Report on "The Role of Market Speculation in Rising Oil and Gas Prices: A Need to Put the Cop Back on the Beat", June 27, 2006.

will continuously lose money and will eventually exit the market. This argument was forcefully made by Friedman (1953) who states that "people who argue that speculation is generally destabilizing seldom realize that this is equivalent to saying that speculators lose money since speculation can be destabilizing in general only if speculators on average sell low and buy high" (p.175).

This traditional view has been challenged recently. Shleifer and Summers (1990), for instance, argue that on average noise traders may be more aggressive than arbitrageurs, either because they are more optimistic or overconfident, and thus are likely to bear more risk. If higher risk is rewarded in the market, then noise traders can earn higher expected returns on average and hence as a group they need not disappear from the market. Kogan *et al.* (2003) find that irrational traders can affect prices even if trading decreases their wealth over time implying that the price impact of irrational traders does not rely on their long-run survival.

***If higher risk is rewarded in the market, then noise traders can earn higher expected returns on average and hence as a group they need not disappear from the market.***

However, even if we assume that noise traders survive in the market, the question is whether changes in demand due to noise trading are big enough to affect prices and destabilise the market. Many have argued that herding behaviour can lead to such a situation. Herding results from investors' decision to follow the trading strategies of others. If the shifts in demand are correlated across noise traders and do not cancel each other out, noise trading is capable of influencing market prices. Furthermore, the potential for herding implies that arbitrage is not riskless and hence arbitrageurs will not necessarily always be able to arbitrage away the noise trade. In fact, the arbitrageurs may not have the incentive to counter shifts in demand by noise traders and may instead decide to ride the wave in the hope that they can dispose of the assets near the top before the noise traders. In an interesting study, Brunnermeier and Nagel (2004) show that rational traders may have the incentive to trade in the same direction as irrational traders in the short run (i.e., rational traders herd too) if convergence is expected to be slow.

There are many explanations as to why investors may decide to engage in herding.[11] One approach explains herding in terms of investors' irrational behaviour (De Long *et al*. 1990; Froot *et al*. 1992). Another approach tries to explain why fully rational profit maximising investors may be influenced by other investors' decision and decide to reverse their investment strategy and follow the herd. Several reasons are given, the most important of which are informational asymmetries (Bikchandani *et al*. 1998), compensation structures of money managers (Roll 1992), and reputation concerns (Scharfstein and Stein 1990). Despite the richness of these theoretical discussions, the empirical evidence on herding lags behind. In reviewing the literature, Sias (2005) notes that that out of the eleven studies reviewed, four did not find any momentum trading (that is, herding), five did find weak evidence of institutional momentum trading, while two found strong evidence of momentum trading. He concludes that "as a whole, extant evidence of institutions momentum trading is, at best very weak" (p.2).

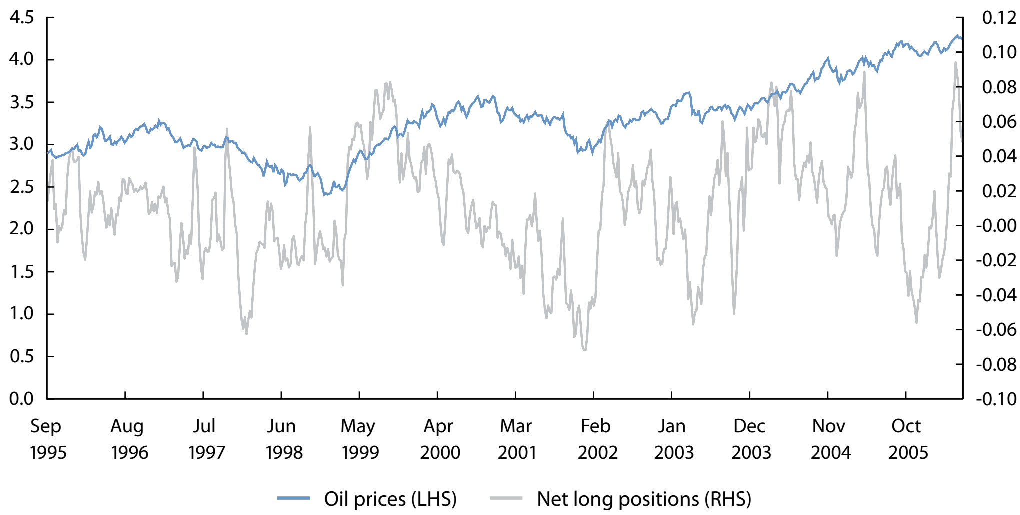
Empirical studies applied to oil market have mainly focused on the changes in non-commercial traders' net long position and have noted that these have tended to coincide with changes in the oil price. Figure 2 below plots the net long positions of non-commercial traders and the spot price. Based on this graph, it is possible to make three broad generalisations. First, prices appear to be less volatile than speculative positions. Second, there is no common trend between prices and speculation. In other words, there is no persistent pickup in net long positions coinciding

11 This should be distinguished from 'spurious herding' where investors facing the same information decide to undertake the same investment decisions. Spurious herding is efficient whereas intentional herding may be inefficient. In practice, it is very difficult to distinguish between the two forms of herding (Bikchandani and Sharma 2000).

***Evidence that changes in non-commercial traders' net long position have tended to coincide with changes in the oil price could be the result of a change in fundamentals that affect both oil prices and futures position of speculators.***

with an upward trend in oil prices. Finally, changes in non-commercial traders' net long positions may coincide with changes in oil prices. But this observation does not establish that speculators necessarily influence oil prices. Evidence that changes in non-commercial traders' net long position have tended to coincide with changes in the oil price could be the result of a change in fundamentals that affect both oil prices and futures position of speculators. That is why the BIS when commenting on the role of speculators in the oil market has been careful in noting that "it is also possible that shifts in activity in the futures market were driven by changing perceptions of fundamental imbalances in the supply of and demand for oil, including the changing perceptions of commercial traders" (p.6). When speculators react and change their position in response to new information, speculation is not necessarily destabilising. In fact, if speculators have superior information that enable them to respond fast to the arrival of new information, then they may even improve the functioning of the market by speeding up the price adjustment process. Consistent with this, Fleming and Ostdiek (1998) find an inverse relationship between open interest in crude oil futures and spot market volatility. They interpret these findings as evidence that trading improves the depth and liquidity of the underlying market.

**Figure 2. Oil prices and net long positions of non-commercial traders**




Source: International Monetary Fund (2006)
Notes: Spot price in log scale (left scale); net long positions in millions of contracts (right scale).

In a more recent study, Haigh *et al.* (2005) use a unique dataset from the Commodity Futures Trading Commission to examine the role of hedgers and speculators in the crude oil market. The disaggregated data allow the authors to examine the role of hedge funds, considered by many as responsible for the recent heightened speculative activity. Interestingly, the authors find that these funds provide liquidity to hedgers and not the other way around. They also find evidence that these large speculators have little influence on oil prices. Finally, they find that the evidence of herding is very weak and even if it exists, herding is not destabilising in the sense that traders do not buy when prices are low and sell when prices are high and hence do not cause the overshooting of oil prices.

### 4.4 Inventories and the term structure of oil prices

The last three years have witnessed a high build-up of inventories in the United States and other OECD countries. To illustrate, total commercial inventories in the United States amounted to around

1,022 million barrels – almost 47 million barrels more than the five-year average. This rapid rise in inventories raises two key questions: why have inventories risen so fast in recent years and what has been the impact on oil prices?

Some have argued that the current build-up of inventories is a sign of oversupply in the crude oil market. When supply exceeds (effective) demand at any point in time, the difference would be added to inventories. This explanation however suffers from a major drawback: why would customers want to lift more crude oil than what they effectively need? Unless there is an incentive for them to hold inventories, customers are under no obligation to absorb the oversupply from the oil producers. Supply does not create its own demand!

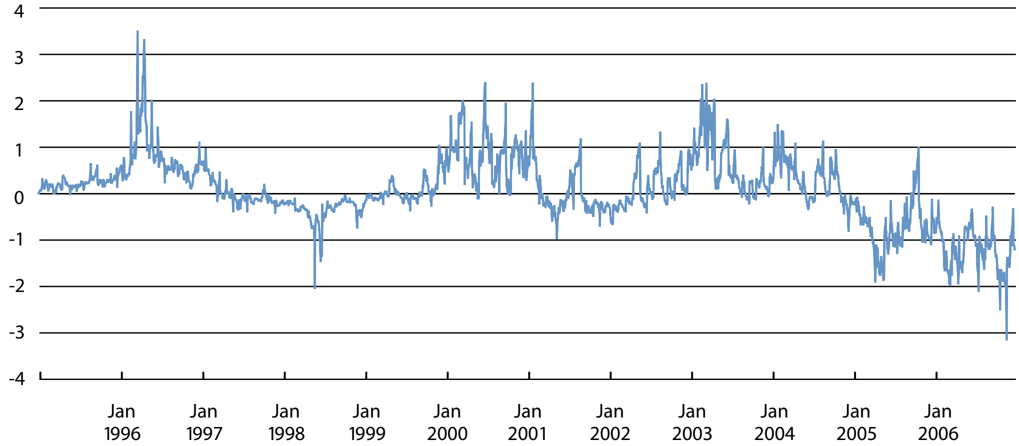
***The recent rapid rise in inventories raises two key questions: why have they risen so fast and what has been the impact on oil prices?***

Others have argued that the current build-up is driven by the demand for precautionary inventories in the face of tightness throughout the oil supply chain. For instance, Petroleum Argus (19 June 2006) argues that the market is signalling that "just-in-time inventories are no longer appropriate as OPEC has lost the spare capacity that enabled it to act as a buffer, shifting stock risk management down the crude supply chain to refiners". This explanation implies that private oil companies would keep inventories even when it is costly for them to do so. It also implies a fundamental shift in the behaviour of oil companies and refineries towards a new inventory policy. Under pressure to maximise shareholder value, international oil companies have undergone major cost-cutting exercises. In contrast to what the Petroleum Argus seems to suggest, cost-cutting has included slashing inventories to their lowest possible level and shifting to a 'just in time inventory policy'. In this new era, oil companies rely on OPEC's large holdings, consuming countries' strategic petroleum reserves, and on a developed spot market for immediate deliveries. Thus, a shift back towards holding precautionary inventories would imply a structural break in the oil market. There is nothing to suggest that this has happened. The shift in inventory policy would also imply a fundamental change in international oil companies' behaviour. Given that international oil companies are under pressure to maximise shareholder value, the proponents of the 'structural shift in inventory policy' must show how holding precautionary inventories would maximise shareholder value even when it is not commercially profitable to hold inventories.

A more plausible explanation is that the recent build-up of inventories is due to the term structure of oil prices. In an influential article, Litzenberger and Rabinowitz (1995) noted that 80-90 percent of the time the oil forward curve is in backwardation, i.e., futures prices are lower than spot prices. The authors explain backwardation as follows. Ownership of oil reserves constitutes a call option – that is, producers have the option of extracting and selling oil, but they also have the option of leaving it in the ground – extracting and selling it in the future. Postponing extraction makes sense if discounted futures prices are higher than spot prices and if extraction costs grow by no more than the interest rate. But if all producers wait, there will be a shortage of oil today causing the spot price to rise. The net result is backwardation in which the oil price rises today to offset the advantage of postponing oil extraction. Thus, according to this explanation, weak backwardation is a necessary condition for current production.

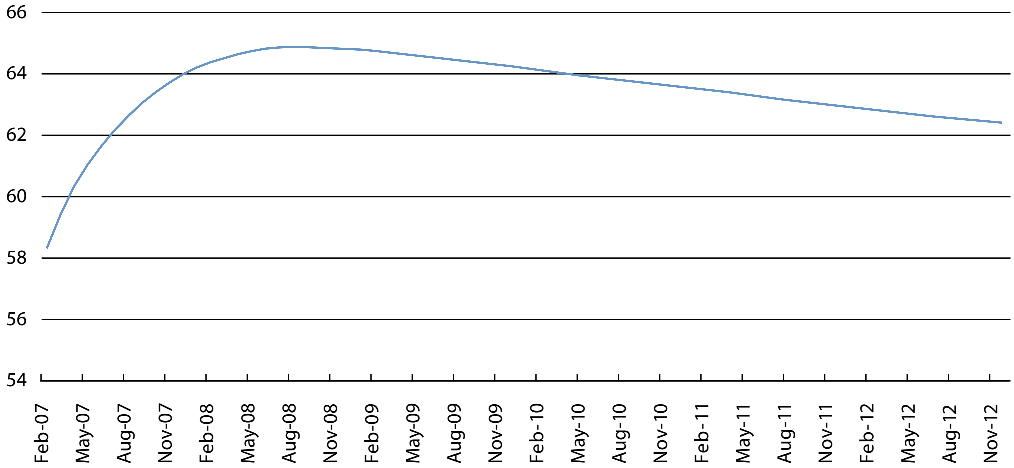
However, a striking feature of recent times has been a prolonged contango in the oil market, that is, a situation where future prices are higher than spot prices. Figure 3 shows that during the last 20 months or so, the first-month futures contracts for WTI oil have been trading at a discount to the second-month futures contract. Figure 4, which plots the WTI forward price curve, shows a very steep slope, with the nearby contract trading at a discount of almost $7 to the August 2008 contract.

**Figure 3. First-month *vs.* second-month futures contract for WTI**




Source: EIA website http://www.eia.doe.gov/
Notes: $/barrel on the vertical axis. Years on horizontal axis show data for March.

**Figure 4. WTI forward price curve (as of 3 January 2007)**




Source: NYMEX website http://www.nymex.com/index.aspx

*If oil for future delivery is trading at a large premium over immediate delivery, the cost of carrying inventories is covered.*

Given this oil price term structure, it is no surprise that commercial inventories have been rising fast. If oil for future delivery is trading at a large premium over immediate delivery, the cost of carrying inventories is covered, prompting market participants with storage facilities to accumulate inventories, stock up their tanks, and make a profit by selling contracts in the futures market. Finding a buyer to take the other side of the bet is not a problem in an environment where the crude oil market is expected to be tight in the future and where geopolitical uncertainties and very limited spare capacities have made financial bets on potential supply shocks extremely attractive.

Let us then turn to the question of how the build up in inventories affects oil prices. As Figure 3 shows, the last time the crude oil market entered in a prolonged contango (lasting for more than 12 months) was in 1998. Contrary to the current contango, the 1998 episode was associated with a downward price trend and it shows that contango can become self-reinforcing. This is because it might encourage market participants with storage facilities to accumulate inventories. If the market interprets rising inventories as an increase in crude oil supply relative to demand, the spot price of oil would go down, thereby widen the size of the contango. This, in turn, might induce a further increase in inventories and, if interpreted as a sign of ample supply, reduce prices for immediate delivery. This self-reinforcing contango can continue for a while, causing sharp falls in spot crude oil prices. In sum, as the 1998 episode has shown, contango can be associated with falling oil prices and rapidly increasing inventories.

This time round the situation is quite different, however: until very recently, the contango and the associated rise in inventories occurred together with an upward trend in oil prices. In explaining this, some observers argue that large inventories are no longer seen as a sign of oversupply and hence do not exert downward pressure on prices.[12] Given the decline in OPEC spare capacity, the argument continues, the market's perception of what constitutes a high level of inventories has changed so much that current inventories – although high by historical standards – are not seen to signal oversupply in the oil market.

A more plausible explanation is that the relationship between inventories and oil prices has remained unchanged. Higher-than-expected inventories still cause oil prices for immediate delivery to decline. However, other factors are pushing spot prices in the opposite direction, disguising the impact of inventories on oil prices.

### 4.5 Have there been structural changes in the oil market?

Are the above drivers cyclical or structural in nature or, to put the question differently, are the observed changes in the oil market temporary or permanent? The informal approach adopted here cannot provide a quantitative assessment of changes in the oil market – such as changes in price and income elasticity or the inventory-price relationship (Stevens 2005). That being said, the informal approach allows a qualitative assessment of whether the market has witnessed structural changes with a lasting impact on oil price behaviour and whether the recent strength in the oil prices has been mainly due to temporary drivers. In what follows we focus on two aspects: spare capacity and the greater reliance on the futures market for price discovery.

***The most obvious change in the global oil market has been the gradual decline of spare production capacity to a very low level.***

The most obvious change has been the gradual decline of spare capacity to a very low level, especially when compared to the mid 1980s and early 1990s. As discussed above, low spare capacity implies that in the case of shocks, prices will bear the bulk of the adjustment. This raises an important question: will the spare capacity in the upstream oil be re-established to its previous high level? To answer this question, it is important to stress that the spare capacity that has provided a large cushion against oil market shocks has not been the outcome of a rational investment decision. Instead, it has emerged as result of specific market developments in the mid 1980s and early 1990s that left OPEC member countries with large spare capacity. Most observers suggest that these market conditions will not come back and, hence, an increase in spare capacity will not materialise unless new investments are made. But who should bear the costs of investment in spare capacity? The international oil companies have no interest in bearing them since investment in spare capacity implies that companies would hold idle assets, which would run counter to maximising shareholder value. As far as national oil companies are concerned, most of them may not be able to invest in new capacity due to a variety of financial and political constraints. The exception here might be Saudi Aramco, the national oil company of Saudi Arabia, whose declared policy is to maintain a spare capacity of 2-3 mbd, which is not really a lot – representing only around 2 percent of global production. The obstacles facing investment in the oil

12 Edward Morse, for instance, argues that "key truisms of the old market are that prices fall in a contango and that stock builds will undermine any price rise. However, in a structurally tight market, these 'truisms' may not be valid." See Edward Morse, "The Global Oil Market Outlook: Ten Lessons About the Petroleum Sector", presentation given at the 2006 Summer Fuels Outlook Conference Washington, D.C., April 11, 2006.

sector and the failure to address the complicated issue of who should bear the costs of creating spare capacity simply mean that the required investment in spare capacity is unlikely to materialise. It seems that the 'international oil order' – where non-OPEC supplies most of the incremental global oil demand and OPEC provides the capacity cushion – has been shaken in recent years with probably permanent implications for oil markets.

A less obvious transformation has been the increasing importance of futures markets, in lieu of spot markets, for the price discovery process (see Fattouh 2006). This has increased the role of financial investors and traders in influencing oil prices. While this may have lasting effects on short-term movements in oil prices and volatility, it is unlikely to affect the long-run behaviour of oil prices. All in all, any long-term trends in oil prices will continue to be dictated by market fundamentals rather than investors' sentiment.

The shift to the futures market may also affect the market through its impact on OPEC behaviour. When deciding on its output, OPEC now needs to consider a wide range of factors such as the level of inventories, the shape of the forward curve, the size of speculative positions in the futures market, and the sentiment (bearish or bullish) of traders. As we argue elsewhere in greater detail (Fattouh 2007b), this poses dilemmas for OPEC and greatly complicates its decision making for the simple reason that OPEC has only one policy tool at its disposal (that is, choosing its output) with which it would like to achieve a wide range of objectives. This may have undesired consequences on oil price fluctuations, inducing volatility and causing sharp rises or falls in oil prices in some instances.

To wrap up, this section has taken an informal approach to analysing oil price behaviour – an approach that emphasises the specific economic and political context in which prices evolve. Although this approach is essential for understanding current and past developments in the oil market, it can only provide a cursory view about how the market and prices might develop in the future.

## 5. Conclusions

***Pushing hard for policies based on projections resulting from the approaches presented in this paper defeats their purpose and may result in misguided policies.***

This paper discusses three main approaches for analysing oil prices: the exhaustible resources, the supply-demand, and the informal approach. Each approach suggests a certain set of drivers of oil prices. However, we have emphasised that they all suffer from major limitations especially when used to make predictions. This is not to say that current frameworks for analysing oil prices should be avoided. They usually provide useful insights into the functioning of the world oil market and how it might evolve in the future. Expecting these approaches to offer accurate predictions about oil market developments will inevitably result in disappointment, however. Various players in the oil market – such as international organisations, oil companies, and governments – should keep this in mind when making their investment decisions or policy recommendations. Pushing hard for policies based on projections following from these approaches defeat their purpose and may result in misguided policies – not to say dangerous ones.

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