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More Natural Gas for Climate Protection?

Opportunities and Risks of an Expanded Gas Strategy for the European Energy Supply

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Table of Contents

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More Natural Gas for Climate Protection? Opportunities and Risks of an Expanded Gas Strategy for the European Energy Supply

The European energy supply will even in the foreseeable future rely on fossil fuels. One option to make them more climate-friendly may be an increased share of low-carbon energy carriers. Especially natural gas has the potential to significantly contribute to reduced CO2 emissions. The measures suggested in this study for an increased use of natural gas would result in a Europe-wide long-term avoidance of approximately 85 million tons of CO2 emissions. Will it, however, be possible for Europe to follow such a strategy without increasing supply risks and jeopardizing the competitiveness of its energy supply?

The present study shows what an “expanded natural gas strategy” may look like and evaluates this strategy from an energy policy perspective. It arrives at the conclusion that an increased share of natural gas would both be responsible regarding the energy policy and constitute a contribution to achieving the climate goals—an opportunity that the EU should not waste. At least 20 percent of fuel oil, 15 percent of solid fuels in the heat markets, and 25 percent of the European vehicle fleet (“transport sector”) should be converted to natural gas. However, the study does not support a significant increase of power generation from natural gas. For the implementation of the here suggested European gas strategy, the EU should mainly take into account the following five aspects:

- Together with measures for enhancing natural gas demand, the efficiency of European gas utilization should be improved, at least in the range defined by the EU (20% in relation to the baseline). The importance of this safe, sustainable and largely economic “energy source” is still widely underestimated.
- Given the decreasing natural gas production in Europe it becomes increasingly important for the EU to secure access to new gas sources via pipelines. Europe should continue the Nabucco project and assess other supply option (e.g. Iraq, Iran) in addition to Central Asian sources of natural gas.
- The purchase of liquefied natural gas (LNG) increases the diversity of supplier relations and provides access to the international gas markets. This will, however, increase gas price volatility and lead to an adjustment to higher-price gas markets.

Europe should nevertheless strengthen the infrastructure that is necessary for the LNG supply, preferably also at a location in Germany and/or Poland.

- Biogas is an energy source that—given a large-scale direct feeding-in into the natural gas networks—can contribute to further decreasing the CO_2 emissions of gas utilization, to reducing import dependence and to effectively utilizing the existing land areas. Throughout Europe, its potential capacity lies at least in the range of the annual production of a large gas pipeline, such as Nabucco. Europe should give a new direction to biomass promotion and, in this context, provide a larger support to biogas.
- The underground storage of natural gas is an adequate means against supply interruptions. Even without any political directives, the European gas industry has started to increase commercial storage capacity from today's 17 percent to 26 percent of the European gas demand. Further additional storage capacity will require a thorough cost-benefit-analysis and an effective mechanism for supplying gas reserves in the case of emergency situations, in the sense of an energy solidarity. Certain countries still have a shortage of storage capacity, though.

All in all, we clearly recommend an expanded gas strategy in the areas heat markets and transport. It is important that the EU keeps in mind the mentioned task areas: increase of energy utilization efficiency, construction of new pipelines, increase of the share of liquefied gas and biogas as well as the extension of storage capacity for natural gas. These combined measures will enhance the security of European gas supply and not have a negative effect on the competitiveness of the energy supply.

Challenge of Climate Protection and Fossil Fuels

In March 2007, the European Council has passed a resolution that requires the European Union to reduce the emission of greenhouse gas (GHG) until 2020 by 20 percent in relation to the 1990 levels. Provided that an International Agreement on Climate Protection[1] is signed, the EU will even adopt a 30 percent reduction of greenhouse gas. In 2005, greenhouse gas emissions were only about 8 percent lower than in 1990. This means it is still a long way to go for the EU to achieve its own goals regarding climate protection.

Among greenhouse gas emissions, carbon dioxide (CO_2) with an 82 percent share (measured in relation to CO_2 equivalents in 2005) accounts for the largest part. The majority of CO_2 emissions (93%) results from the conversion and use of energy. This means that 76 percent of European greenhouse gas is caused by energy-related CO_2 emissions. It is obvious that strategies for avoiding these emissions are top priority for achieving the EU's ambitious goals. In 1990, the energy-related CO_2 emissions of the EU amounted to 4109 megatons (Mt) and in 2005, still to 3973 Mt. Thus, regarding the energy use, a decrease of only 3.3 percent was achieved. If the goal of a 20 or 30 percent reduction of energy-related CO_2 emissions is to be achieved, there remains the obligation to reduce emissions by 685 Mt, or by 1096 Mt in relation to 2005, if an international agreement for the protection of the climate will be signed, such as a follow-up agreement to the Kyoto Protocol.[2]

The different options for reducing energy-related CO_2 emissions can be summarized under the term "decarbonisation". In principle, there are four different approaches:

1. Reduction of energy demand, for instance by increasing energy efficiency;
2. Increasing the share of (nearly) CO_2 free energy carriers in the energy mix, i.e. nuclear power and renewable energies;
3. CO_2 capture during energy conversion and permanent storage of the absorption product (Carbon Capture and Storage, CCS);
4. Substitution of energy carriers with high CO_2 intensity by carriers with a lower CO_2 intensity (e.g. coal by gas).

The two first mentioned strategies for decarbonisation, i.e. increased energy efficiency and the utilization of carbon-free (particularly renewable) energy carriers will make substantial progress over the next decades. But even the most ambitious scenarios do not expect the dominance of fossil fuels to end during that period. Therefore we also need strategies for the next decades that address fossil fuels themselves without losing sight of the necessary change towards a carbon-free energy supply. Regarding the four decarbonisation options, this applies to the two last-mentioned strategies.

For CCS, there is a number of technical, political and economic problems that need to be resolved which means that this method will not be commercially available prior to 2020. In addition, CCS can—from today's perspective—only be used for large commercial applications (e.g. in power stations). As opposed to this, fossil fuels with low CO_2 content, particularly natural gas, could be used to a larger extent already in the foreseeable future in order to reduce emissions. The present study will focus on this option. It will analyze the question of how an increased use of natural gas can contribute to achieving the European goals of avoiding CO_2 and what measures European energy policy should adopt in order for that contribution to materialize without jeopardizing other energy policy goals (safety of supply, competitiveness).

1 An additional condition is that other industrialized countries will "commit to a similar emission reduction and the economically further advanced developing countries will commit to a contribution that appropriately reflects their responsibilities and respective capabilities."

2 All emission data for 1990 and 2005 in this section come from the website of the United Nations Framework Convention on Climate Change (UNFCCC), http://unfccc.int/di/DetailedByParty/Setup.do (accessed April 9, 2008).

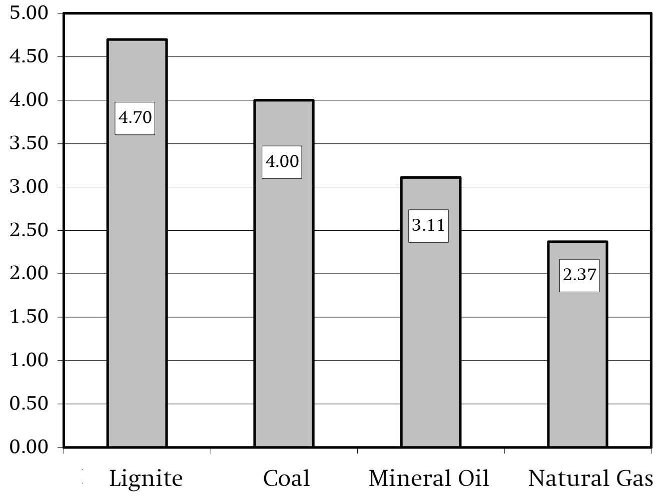
The Potential of Natural Gas for Avoiding CO_2 Emissions in Europe

In 2006, natural gas amounted to 24 percent of total primary energy consumption in the EU-27. It is mainly used for heating residential buildings and for generating process heat in the industry (ca. 71%). About 29 percent of the natural gas used in Europe is combusted in central power and heat generating facilities of power stations and heating plants. However, natural gas as motor fuel accounts today for only about 0.1 percent of total European gas demand.[3]

In the different member countries of the EU, natural gas is of varying importance: Natural gas as a share of primary energy supply varies between 0 percent (Malta, Cyprus) and 49 percent (The Netherlands). Sevral member states such as Finland, Greece and Portugal use about two thirds of the gas for power generation; in other countries, such as Estonia, France, Poland and Slovakia, power generation from natural gas does only play a minor role. There are only three EU countries that have a sizable fleet of vehicles using natural gas: Italy (ca. 400,000) and Germany (64,000) are leading in this area. France with about only 8,000 takes the third place.[4]

During combustion, natural gas emits comparatively little CO_2 due to its high proportion of hydrogen (see Figure 1). In order to exactly specify the savings potential of natural gas in comparison to coal or oil, it is not sufficient to compare the emission factors of the fuels. A precise comparison of emissions will only be possible if the respective applications of energy carriers will be described as specifically as possible. It would also require a thorough live-cycle analysis, which means to carry out a comprehensive evaluation of emissions—from production to operation and to disposal, assessing their relevance to the climate. For the purpose of this study it will suffice to estimate the savings potential using a simplified procedure. We will basically use the emission and utilization factor of the respective technology during operation (i.e. without production and disposal) for determining the CO_2 reduction potential.

Figure 1
CO_2 Emission Factors of Different Fuels (in t CO_2 per t Crude Oil Equivalent[5])



Source: Hans-Wilhelm Schiffer, “Deutscher Energiemarkt 2007”, *Energiewirtschaftliche Tagesfragen* 58, no. 3 (March 2008), p. 47.

Potentials in the Power Industry

In the power industry, natural gas competes with energy carriers such as coal, nuclear energy and hydro power. What kind of power generating plants is operated with what kind of energy sources depends mainly on two criteria:

- Legal priority regulations can lead to that certain power stations have to be operated as so called “must-run” facilities. This means that their operation depends only on their technical availability and not on marginal costs: whenever they want to supply generated power, they can feed it in. Examples are facilities that operate with renewable energy carriers, but also combined heat and power plants that have priority due to ecological reasons.

3 According to Eurostat, in 2005 the consumption of natural gas in the vehicle sector amounted to 508 ktoe, which amounts to slightly less than 0.12% of total European gas demand.
4 There was no information available regarding the volumes in other EU member states; they should be negligible, though.
5 One tonne oil equivalent (toe) is the energy content of a certain type of crude oil and corresponds to about 41.9 Gigajoule.

- In the power market, all other facilities are operated according to their marginal costs, i.e. the costs that result from producing one additional unit of a product. The result is a “merit order”, i.e. an operational ranking of the power stations. Facilities with very low marginal costs are able to operate first (e.g. run-of-river hydro, nuclear power, lignite). They reach 7,000 or more full-load hours per year and supply the base load.[6] Medium load is supplied mainly by older lignite-fired power stations and coal-fired power stations as well as by more recently built, high-efficiency gas-fired power stations (gas and steam power plants). They reach between 1,000 and 5,000 full-load hours, occasionally even more. And finally, peak load is supplied by gas turbines, pump-storage plants, oil-fired power stations and other plants with high marginal costs.

The decisive component of marginal costs is fuel costs as they constitute the main share of variable costs. In addition, there is the cost of CO_2 certificates which—with increasing CO_2 prices—significantly affects variable costs.

In addition to the named criteria, it is important whether power stations are flexible enough to compensate short-term load fluctuations for which there is a specific market.

In the power station industry, natural gas mainly competes with coal, as both energy carriers are used to supply medium load. Due to high oil and gas prices, marginal costs of natural gas-fired power stations are currently significantly higher than that of coal-fired plants. Even older coal-fired plants produce at lower costs than new gas-fired power stations, unless the plant operators had been able to secure a much more favourable gas price prior to the high increase in oil prices. Only with high CO_2 prices (e.g. over 40 Euro/t), gas-fired power stations will become more economical than coal-fired plants. This depends, however, on how large the price difference between coal and gas actually is.

Against this background, we can raise the question: what is the potential of using gas for power generation? Assuming that politics does not intend to abandon the power markets’ principals of market economy, the potential is rather limited. Regarding the use of gas in power stations, it was—until 2005—industry standard to sign agreements including price escalation clauses linking the price to coal prices in order to maintain competitiveness between the two energy carriers. Due to significantly increased oil and gas prices over the last years, such agreements have been offered only occasionally. The competitiveness of natural gas in the power markets has suffered considerably by this. It might be an option to agree with Russia—or another supplying country—a partnership on the highest political level that would be intended to secure the supply of natural gas for power generation.

Another option would be to intervene into the market-economy structure of power generation. Politics could promote a higher share of natural gas in the power generation market—using tools that would still need to be defined. It would be possible to use regulations that are similar to that of the Renewable Energy Law (EEG). It guarantees priority to renewable energies regarding power generation and sets an economically attractive feed-in tariff for these energies. Such legislation would fall under the responsibility of the individual member states. The European institutions repeatedly stated that each country decides on its own energy mix.

As soon as Carbon Capture and Storage technology (CCS) is available, coal-fired power stations are likely to have a larger CO_2 savings potential than natural gas-fired plants without CCS: Coal-fired plants with CO_2 capture are expected to emit at least one third less CO_2 than gas-fired combined-cycle power stations without CCS.[7]

Against this background, the potential of an additional use of natural gas in power generation appears to be limited. An initial estimate of this potential would be as follows:

In 2005, 236.7 Mtoe of solid fuels were used for power generation in Europe. 126.9 Mtoe of gas were used. If 20 percent of solid fuels (assuming coal, for reasons of simplicity) were to be substituted by natural gas, energy-related CO_2 emissions would

6 The terms base load, medium load and peak load are used in the energy industry for defining phases with different intensities regarding power consumption. Throughout the year (i.e. also at night and during public holidays), there is a (base)load of ca. 30% of maximum power demand. During the day, power demand increases significantly (medium load) and at around midday and early evening it reaches peak values (“peak load”) and clearly decreases towards night. Weekends and public holidays have a different load curve due to the lower industrial demand. Power stations have to be able to supply the required effect at all times and with a sufficient security.

7 Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Ed.), *RECCS Strukturell-ökonomisch-ökologischer Vergleich regenerativer Energietechnologien (RE) mit Carbon Capture and Storage (CCS)* (Wuppertal, 2007), p. 19.

decrease by 106 Mt and natural gas demand in the power station industry alone would increase by about 28 percent to 161.9 Mtoe.[8]

Potential in the Heat Markets

As today European countries have an extensive supply of gas, in the heat market natural gas competes with energy carriers such as fuel oil, coal and other solid fuels or electricity. In Western Europe, natural gas constitutes today an alternative to oil or other nationally important energy carriers. In Eastern Europe, and in the Eastern parts of Germany, we have a—partially—significant share of coal-fired heating installations. Particularly within the lower-income population, coal is an accepted energy carrier as it is cheaper.

The application of natural gas in the heat markets depends—to a large extent—on the availability of a grid and the regional competitiveness of gas. Therefore it is not possible to arbitrarily increase gas penetration levels. Gas network regulations stipulate restrictions for network extensions. As the regulations increase the cost pressure on gas network operators, the main decision criterion for or against a network extension is economic feasibility. The result is that there are no gas networks being developed in sparsely populated regions as development is not profitable there. The development potential of gas in heat markets is therefore also assumed to be rather low.

We can make the following assumptions to assess the savings potential: Gas heating systems using flue gas condensation utilize about 98 percent of the maximum calorific value of the fuel as they also make use of the condensation heat of the flue gas. The utilization coefficient of oil-fired heating using flue gas condensation is slightly lower than that of gas-fired heating facilities. In comparison, coal-fired central heating systems lie in the range of 70–75 percent, coal-fired individual stoves are estimated to have a utilization coefficient of approximately 65 percent.[9] Due to better emission factors (see Figure 1), CO_2 emissions of a natural gas-fired heating system are about one fourth lower than those of a comparable oil-fired system. In comparison to coal, savings are even larger as coal has a lower utilization ratio for the same heat output.

In 2005, the whole of Europe (EU-27) used 52.7 Mtoe of solid fuels and 148 Mtoe of fuel oil for heating purposes and process heating. Assuming that it was possible to substitute 15 percent of solid fuels (coal, for reasons of simplicity) and 20 percent of fuel oil with natural gas, this would lead to an additional gas demand in the heat markets of 33 Mtoe (+12%) and to a reduction of direct CO_2 emissions by 46 Mt.

Potential in the Transport Industry

The calculation of the potential that an additional use of natural gas in the transport industry would have for avoiding CO_2 emissions requires a more detailed analysis. The reason is the technological advantage that vehicles driven by traditional liquid fuels have in comparison to natural gas-driven vehicles. In addition, all natural gas-driven vehicles operate with spark ignition (SI) engines, which are not as efficient as diesel engines. As already mentioned, natural gas only occupies a niche in the European vehicle industry. Only Italy has a comparatively large number of natural gas-driven vehicles. In Germany—despite significant increases – the number of vehicles that are driven with natural gas has not yet exceeded one-tenth of a percent.[10] Therefore, there is no learning curve for natural gas-driven engines - with the corresponding effect on costs and technological maturity - that would be comparable to that of petrol- and diesel-driven vehicles.

The Concawe-Project[11] includes numerous analyses that assess vehicle systems in relation to fuels. The results show that today's modern diesel-driven vehicle systems are still partially superior to natural gas-driven vehicles regarding fuel demand and green-house emis-

8 Assuming a utilization rate of 37% for coal-fired power stations that are to be substituted and 50% for planned and existing gas-fired power stations. The used CO_2 emission factors only relate to the fuel: 4.0 kg CO_2/kg oe (=oil equivalent) of fuel for coal and 2.37 kg CO_2/kg oe of fuel for gas.

9 See EWI/Prognos, *Auswirkungen höherer Ölpreise auf Energieangebot und -nachfrage – Ölpreisvariante der Energiewirtschaftlichen Referenzprognose 2030* (Köln/Basel, 2006), p. 42.

10 On 1 January 2008, 64,436 natural gas-driven vehicles were registered in Germany, according to the Federal Motor Transport Authority (Kraftfahrt-Bundesamt). This corresponds to a proportion of 0.13% of all registered vehicles in Germany, www.kba.de/> (accessed April 22, 2008).

11 European Council for Automotive Research and Development (EUCAR)/Joint Research Center of the European Commission/Concawe, *Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context*, March 2007 (=Version 2c), http://ies.jrc.ec.europa.eu/WTW (accessed October 14, 2008).

sions.[12] Only if we include the improved efficiency of natural gas-driven engines into the calculations, natural gas-driven vehicles will "pass" diesel-driven vehicle systems in the named categories. Therefore we will estimate the advantage of natural gas-driven vehicles regarding carbon dioxide emissions at only 15 percent (even though a comparison of emission factors of fuel oil and gas suggests 24% lower emissions).[13]

Assuming that 25 percent of the European vehicle fleet will be substituted by natural gas-driven vehicles, the additional demand of natural gas would amount to 90 Mtoe and the reduction of CO_2 would be 39 Mt. That corresponds to about 3.6 percent of European emissions in the transport industry.

Altogether, the initial estimation shows that—with an increased use of natural gas—the EU-27 would be able to save 191 Mt of CO_2, including 106 Mt in the power station industry, 46 Mt in the heat markets and 39 Mt in the transport sector. This corresponds to 28 percent of the 685 Mt savings that would be required to comply with the 20 percent goal. The following table summarizes the effect on natural gas demand and CO_2 emissions.

Table 1
CO_2 Savings Potential and Additional Natural Gas Demand Due to Increased Use of Natural Gas in the EU-27

Industry	*CO_2 Savings [Mt]*	*Natural Gas Additional Demand [Mtoe]*
Power stations	106	162
Heat markets	46	33
Transport sector	39	90
Total	191	285

Source: Author's estimations and calculations.

This presentation shows clearly that—under the assumptions made for this calculation—the power station industry has the highest CO_2 savings potential in case of an increased use of natural gas. But also the other two application areas have obvious savings potentials that are attractive enough to analyse them more thoroughly regarding a reduction of CO_2 emissions. It has also become clear, though, that such a strategy would lead to a substantial additional demand of natural gas. Therefore, we want to look at whether an increased use of natural gas is consistent with other energy policy goals, and subsequently, whether and how it could be implemented.

12 The assessment of data provided by manufacturers during the first six months of 2008 shows for natural gas-driven vehicles available in Germany that the mean direct CO_2 emissions of natural gas-driven vehicles amount to 153 g/km. The comparison group of the same models with optimized diesel drives lies at 148 g/km.
13 Alternative Fuels Contact Group, *Market Development of Alternative Fuels* (Brussels, 2003), p. 2, states 13% in comparison to diesel driven- and 16% in comparison to petrol-driven vehicles from 2010.

Energy Policy Assessment of an Expanded Natural Gas Strategy

The starting point of the present study has been the idea that an increased use of natural gas in the energy supply might lead to CO_2 savings (and also of other emissions) and thus constitute a significant contribution to achieving the European sustainability goals.[14] The EU has defined an energy strategy that consists of an energy policy goal triangle, though, that does not only include sustainability, but also security of supply and competitiveness of the energy supply. Even though the debate of the EU's energy policy has focused on the concept of sustainability—with a strong emphasis on climate protection—in 2007 and particularly in 2008, the discussion has turned more and more towards supply security. At the same time, there is the permanent issue of oil and fuel prices that have reached a historical high in the summer of 2008. Despite these short-term fluctuations in the economic situation, the energy strategy does not set any priorities or rank the three goals. In the following we will analyse whether and how the suggested expanded natural gas strategy could coexist with the other two core goals of the energy policy: "security of supply" and "competitiveness". Here we will compare the energy carriers oil, coal and natural gas in order to be able to assess how an increased natural gas share—to the disadvantage of the other two energy carriers—would affect the possibility to reach the energy policy goals of the EU.
At first, we will test the starting hypothesis that an expanded natural gas strategy can contribute to an increased sustainability.

Sustainability

In the debate on the adequate energy policy, the goal of sustainability is often identified with the protection of the environment and the climate. Thus, the repeatedly mentioned energy strategy *An Energy Policy for Europe* focuses on the threat of climate change and the necessity to reduce greenhouse gas emissions. The present study also adopts this perspective. It starts from the hypothesis that an increased use of natural gas can contribute to reducing greenhouse gas emissions.

The section "The potential of natural gas for avoiding CO_2 emissions in Europe" shows the savings potential of an increased use of natural gas in the three analyzed industries. The results illustrate that it would be possible to avoid a total of 191 million tons of CO_2 per year by using more natural gas. This already constitutes the proof that an increased natural gas utilization means higher sustainability in comparison to the energy carriers oil and coal.

Natural gas has also other environmental advantages in comparison to oil and coal: It does not contain any aromatics, substantially less sulphur and is practically dust-free. This fact is of growing importance given the fine dust pollution that has increased over the last years particularly in large population centres. Looking at these air pollutants, the proportional savings potential of natural gas in comparison to oil or coal exceeds that of CO_2 by far.

For the sake of completeness, we also want to provide a (theoretical) comparison with coal in the transport sector. Due to missing reference values in Europe, such a comparison will be only qualitative. Following the high crude oil prices, countries such as South Africa, China and the US will use coal-liquefying technologies in order to produce synthetic fuels. OPEC assumes in its *World Oil Outlook 2008* that in 2030 each day about 1.5 million barrel of oil equivalent will be produced from coal.[15] Due to the unfavourable CO_2 factor of the fuel produced from coal, it has a larger impact on the environment. In addition, coal contains—in comparison to oil and natural gas—the largest proportion of dust and sulphur. When in the future the technology has matured it might be possible to capture CO_2 using CCS. However, until then petrochemical products made of coal will continue to have a significantly larger impact on the environment than oil and gas.

14 A larger utilization of natural gas in the vehicle sector could lead to a substantial reduction of nitrogen oxides (>80%) and fine dust pollution (almost 100%) in the traffic. Regarding these "classical" air pollutants, the benefits of natural gas are much large compared to carbon dioxide, www.umweltbundesamt.de/verkehr/alternative-kraftstoffe/erdgas/lpg1.htm (accessed May 30, 2008).

15 OPEC, *World Oil Outlook 2008* (Vienna, 2008), p. 86.

The following table provides a ranking of the environmental impact of coal, oil and gas in relation to the application. The evaluation is exclusively based on CO_2 emissions. In the power station industry and the heat markets, natural gas is clearly superior from an environmental perspective. In the transport industry, today's natural gas-driven vehicles still slightly lag behind comparable top models with traditional diesel drive. Within only a few years, though, the use of natural gas is expected to provide decisive environmental benefits in this industry.

Table 2
Ranking of Oil, Gas, and Coal Regarding Their Environmental Impact

	Oil	*Gas*	*Coal*
Power stations	2	1	3
Heat markets	2	1	3
Transport industry (today)	1	2	3
Transport industry (2010+)	2	1	3

From the assessment of the environmental impact, it can be concluded that the use of natural gas in all mentioned areas of application could lead to reduced CO_2 emissions. In the transport industry, an expanded use of natural gas would have the additional benefit of clearly reducing the impact of dust and other air pollutants.

Security of Supply and Energy Security

Energy security as a multi-dimensional concept. In addition to the term of "security of supply" that is still predominantly used in German[16], recently the term "energy security" has been introduced as a result of the political debate in the Anglo-Saxon region. However, the energy strategy of the EU explicitly states "security of supply" as one of its goals. The semantic difference between the two terms can be explained as follows: Whereas the main focus of "security of supply" is a secure energy distribution and the availability of power for the end user, "energy security" does not contain such connotation. "Energy security" puts a stronger emphasis on the total supply chain, including production of raw materials, ("upstream") and the related aspects of foreign and security policy. Many publications use security of supply and energy security interchangeably. In English-speaking areas, "energy security" is also used as a generic term for the total of energy policy goals, consisting of sustainability, competitiveness, and security of supply.[17] So far, there is no commonly agreed definition or delimitation of these terms available. The present study defines energy security/security of supply as follows: *the uninterrupted availability of a sufficient quantity of energy with an appropriate quality at predictable and affordable prices over a defined period of time*.

Uninterrupted availability: Already the first term of this definition shows how different the needs for energy security—and therefore the idea of what it means—can be. Whereas the energy supply of information technology facilities must not be interrupted for even a split second, such an interruption would hardly be noticed when operating a washing machine in a private household. In principle, applications using electricity have higher no-break requirements regarding energy supply than fuel applications such as heating facilities or process heating plants because of the thermal inertia of buildings or plants. The present study only refers to a comparison of the security of supply of oil, gas and coal, i.e. only fuels. The perspective of the study is mainly that of the entire economy and not that of an individual person.

We have to differentiate the availability of energy carriers depending on whether we look at the short, middle or long term. Short-term supply bottlenecks can be mainly caused by interruptions of the transport routes. In the medium term it is rather decisive whether the supplying countries have production capacities that are sufficient for the energy demand. As opposed to this, the long-term availability of energy carriers mainly is related to the geological dimension and how large the reserves and resources of the respective fuel are. From a long-term perspective it is also important, though, whether politics, economy and infrastructure allow to access these resources.

The development of redundant and diversified supplier relationships is an option for reducing the probability of supply interruptions. Political stability in the supplying countries and low vulnerability of the transport routes are other criteria.

16 See Manuel Frondel/Christoph M. Schmidt, "Die Sicherheit der Energieversorgung in Deutschland: eine empirische Analyse", *Energiewirtschaftliche Tagesfragen* 58, no. 4 (April 2008), p. 8–14.

17 See Florian Baumann, *Energy Security as Multidimensional Concept*, CAP Policy Analysis 1/08 (München: Centrum für Angewandte Politikforschung, March 2008).

Sufficient quantity: According to economic theory, the required amount of a merchandize is not fixed but related to the price. In the energy industry, price elasticity of demand is considered to be comparatively low. In general, higher prices initiate adaptation processes, though, that—in the long term—may lead to lower consumption. In the short and medium term, consumed quantities are comparatively stable even with fluctuating prices.

Appropriate quality: In large parts of the world, the physical quality of energy products is ensured as there are industrial standards for the final products. Otherwise, the industry is able to handle different qualities, which becomes obvious if we look at the varying natural gas quality throughout Europe. Proof of how important an appropriate quality of energy products is was the attempt to introduce increasing minimum rates of bio-fuels in Europe. The project had to temporarily be stopped as it became clear that older vehicles were not able to use a mix with bio-fuels.

Predictable and affordable prices: Especially for the industry, but also for private consumers, both the absolute energy price and its volatility constitute a problem. Whereas companies are able to hedge against large price fluctuations, final consumer are exposed without protection to price fluctuations of the markets.

The affordability of prices to a large extent depends on the disposable income and the purchasing power of the consumers and cannot be defined uniformly. For about one third of the global population, energy is a luxury they cannot afford. But also in richer countries, low-income energy consumers will have to abstain from consumption in case of large price increases. Already in 2004, the German Advisory Council on Global Change (WBGU) pointed out an increasing "energy poverty" in its expert report on poverty.[18] Also the International Energy Agency (IEA) has taken up this issue and will emphasize it in the *World Energy Outlook 2008*.[19]

The issue of the affordability of prices overlaps with the EU goal of the "competitiveness of energy supply", which we will look at separately in the next section. Therefore we will not use a specific indicator for it in the subsequent evaluation.

Defined period: This last aspect of the above definition on energy security (see p. 13), i.e. to be related to a certain period, is important as the long-term security of energy supply requires different measures than the short-term protection against supply interruptions. Short-term disturbances of the energy supply can be handled by sufficient storage capacity, redundancy of the technical systems or the diversity of suppliers. As opposed to this, a long-term access to energy resources has to be ensured by infrastructure and long-term political decisions ("energy turnaround"). This issue will be discussed in more detail at a later point of this study.

Evaluation of the energy security. Using the described concept of energy security, an evaluation of the expanded natural gas strategy faces the challenge that the described dimensions can only partially be used in that process. Current studies that deal with measuring energy security or the vulnerability of the energy supply, respectively, use the following indices:

- Concentration rates, such as Hirschmann-Herfindahl or Shannon-Wiener index regarding supplying countries;
- Indices of the political stability of supplying countries, e.g. the Hermes index;[20]
- Import quota;
- Energy intensity[21] or the value of energy imports as a proportion of gross domestic product;[22]
- CO_2 intensity of primary energy demand;[23]
- Distance between supplying and importing country.[24]

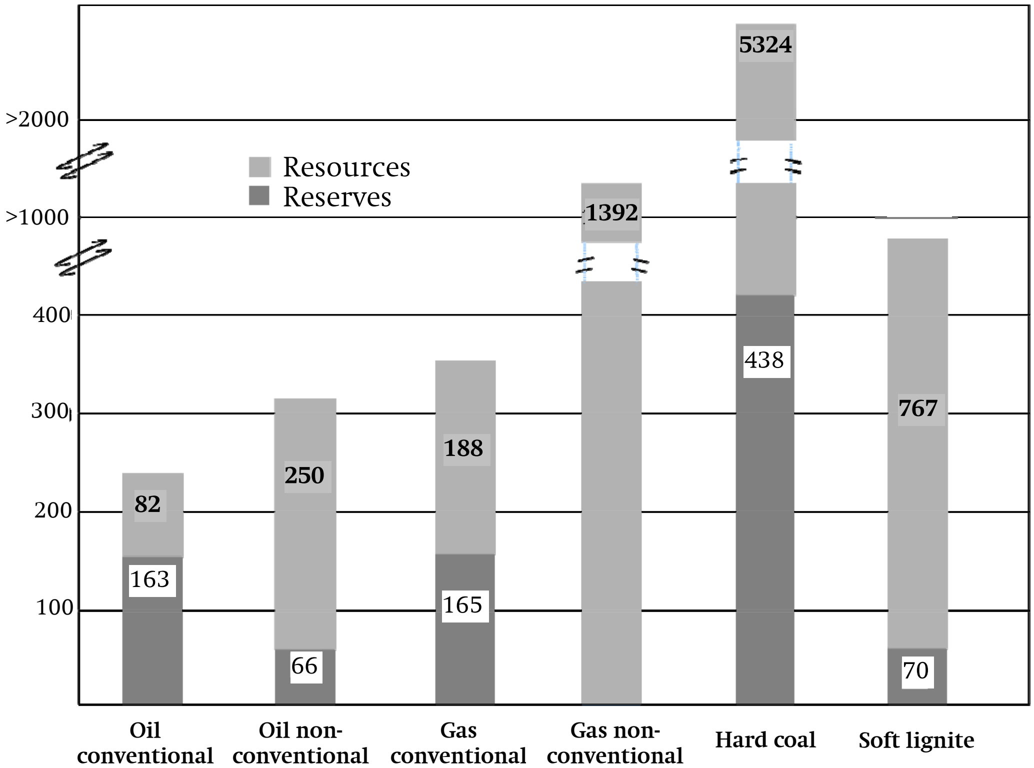
Usually countries are evaluated individually regarding their energy security as each country has its own energy mix and individual supplying structures. For the evaluation of larger regions (e.g. EU) it is common practice to use weighted mean values.

In the following, energy security will be evaluated under the condition of an expanded gas strategy.

18 Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen (WBGU – German Advisory Council on Global Change), *Welt im Wandel: Armutsbekämpfung durch Umweltpolitik* (Berlin/Heidelberg, 2005), p. 39.
19 See International Energy Agency (IEA), *World Energy Outlook 2008*, Paris (under publication), www.worldenergyoutlook.org/2008.asp (accessed June 9, 2008).

20 Frondel/Schmidt, "Die Sicherheit der Energieversorgung in Deutschland" (see note 16).
21 World Energy Council, *Europe's Vulnerability to Energy Crises* (London, 2008).
22 ibid, p. 8.
23 ibid, p. 9.
24 Chloé Le Coq/Elena Paltseva, *Common Energy Policy in the EU: The Moral Hazard of the Security of External Supply*, SIEPS Report 1/08 (Stockholm: Swedish Institute for European Policy Studies, February 2008).

Figure 2
World-wide Reserves and Resources of Fossil Energy Carriers (in gtoe) for 2006, According to the German Federal Institute for Geosciences and Natural Resources (BGR)



Source: Federal Institute for Geosciences and Natural Resources, Energierohstoffe, www.bgr.bund.de/cln_101/nn_322882/DE/Themen/Energie/energie__node.html?__nnn=true (accessed June 10, 2008)

Special emphasis will be put on the comparison between oil, gas and coal. The purpose of this evaluation is not to measure the absolute numerical value of energy supply. The goal is rather to assess the principal impact that a strategy aiming at an increased use of natural gas has on the energy security in Europe.

Below, we will discuss in detail the individual criteria for comparing the energy security of coal, oil, and gas. A table at the end of this chapter will summarize the results (p. 19).

Geological (long-term) availability. Current studies on the long-term (geological) availability arrive uniformly at the conclusion that coal resources are the ones that will last longest, and that the availability of gas exceeds that of oil. The *BP Statistical Review of World Energy* from June 2008, for instance, states a stationary reserve-production ratio (calculated based on the ratio of today's internationally accessible reserves and world-wide production in 2007) of 41.6 years for conventional crude oil, of 60.3 years for natural gas, and of 133 years for coal. These numbers vary for each country, depending on the respective production or resources. Including non-conventional reserves and resources (e.g. oil shale, tar sands, gas hydrates) into the calculation, the values—particularly for gas and coal—are substantially higher, as the figure shows.

Medium-term availability of capacities. In the current discussion on oil price levels, there is an increasing number of experts who support the so-called "peak-oil" theory and consider the price increase over the last seven years as a proof of that this theory is correct. The theory states that after reaching the (world-wide) mid-depletion point, i.e. the point at which 50 percent of the reserves are depleted, production numbers will be forced to go down as newly developed oil wells will not be able to compensate the decrease in the existing wells any longer. In 2007, production actually decreased for first time after 2002 by 0.2 percent, even though world-wide demand increased. It appears to be too early, though, to interpret this development as a trend change. However, during the first six months of 2008, several renowned experts from countries such as Russia and Saudi-Arabia and also from the IEA who previously had constantly optimistic expectations regarding the oil production have now publicly expressed doubt on whether oil production can be increased to the required extent, particularly over the next five years. Leading IEA representatives now are unusually clear about the fact that, lately, upstream investments have been insufficient and that this has lead to a gap between required and possible production quantities. This shows that independent of whether the Peak Oil Theory is correct or not, production capacities are of decisive importance for the energy security. This fact applies to all energy carriers. However, capacity bottlenecks are expected to occur particularly in the oil production. The IEA has analysed all new oil production projects world-wide in regard to newly created production capacity and arrives at the conclusion that in 2015 there will be a gap of 12.5 million barrel per day between expected demand and total expected production capacity. That corresponds to 15 percent of the world's oil demand.[25] Even if all stake holders stood up to that challenge with determination, it would still remain questionable whether in the future there would be enough flexibility to adapt production capacities to the demand. It is more likely that the demand—forced by the high prices—will adapt to the available capacities. The global financial crisis that according to current assessments will leave a clear dent in the international economic growth should provide a certain relief in that context; something that has already become apparent in the halving of oil prices in comparison to the peak values in July 2008.

The general framework conditions for gas production capacities are very similar to that of oil. However, due to the fact that gas is grid-bound, there is no world market for natural gas (yet). In addition, the development of this energy carrier lags 20 years behind that of oil. In that context, Europe has the advantage that 80 percent of the world-wide gas reserves lies within 4500 kilometres of its borders. The main supplying regions for the increasing European gas demand are Russia, North Africa and the Persian Gulf. There is no plausible proof yet for a Russian "gas gap", which is mentioned by several authors. At the most, there will be delays in the development of the large gas fields on the Jamal peninsula and of the Shtokman field in the Barents Sea.[26] The Russian gas group *Gazprom* currently develops new export capacities to the West. Algeria and Nigeria are also able to develop new production capacities. If the difficult political problems in Iran were successfully solved and the security situation in Iraq improved, also these two countries with their large and still underdeveloped gas reserves might become important partners for gas supplies to Europe. Current model-based analyses arrive at the conclusion that the growing European natural gas demand can be met, however at the expense of a growing dependency on a limited number of suppliers.[27]

In general, the supply situation regarding coal is less problematic than that of oil and gas. The number of supplying countries is substantially larger as many countries have sufficient coal. That is one of the reasons why only 16 percent of the world-wide coal demand is traded internationally. Due to growing shipping rates and the overall high energy price level, also coal prices have increased significantly. Mainly because of the fast growing Chinese coal demand, the markets are currently "short". This does not affect the overall assessment of that it would be possible to develop coal capacities for meeting medium- and long-term international coal demand.

Import dependence. Usually domestic resources are evaluated to be more reliant than third-country raw material imports. One reason is that transport routes for domestic resources are shorter and less vulnerable. Another one is that in general it is considered a risk to be dependent on third parties, above all in politically unstable countries. The vulnerability of the transport routes and the political stability of the supplying countries will be evaluated using separate indicators. The measurement of import dependence will therefore be limited to the import quota which can be derived from the (better documented) quota of gas sourced from own production:

Import quota = 1 minus quota of gas sourced from own production.

The energy carriers produced in the EU are assumed to be consumed entirely in the European Union. This

25 "'Die Sirenen schrillen'. Gespräch von Astrid Schneider und Fatih Birol", *Internationale Politik* 14, no. 4 (April 2008), p. 35.

26 Roland Götz, *Russlands Erdgas und Europas Energiesicherheit*, SWP-Studie 21/07 (Berlin: Stiftung Wissenschaft und Politik, August 2007).

27 See David Bothe/Stefan Lochner, "Erdgas für Europa: Die ewiGAS$_{2008}$ Prognose", *Zeitschrift für Energiewirtschaft* 32, no. 1 (2008), p. 22–29.

simplification may ignore the fact that—to a limited extent—energy carriers are exported from the EU into non-EU countries. This error is negligible as the difference between the energy carriers regarding their import dependence is sufficiently large as to not affect the result. The following table provides an overview of the import quotas.

Table 3
Import Quotas of EU-27 by Energy Carriers in 2007

	Oil	*Gas*	*Coal*
Import quota	83.9%	60.2%	43.9%

Source: Author's own calculations based on *BP Statistical Review of World Energy June 2008* (London, 2008).

In the long run, the import dependence regarding all named energy carriers will continue to grow as European reserves are being depleted. The ranking of the three energy carriers will not change in the foreseeable future, though.

Political stability in the supplying countries. Manuel Frondel and Christoph M. Schmidt adopt a pragmatic approach for measuring or assessing the economic stability using the classification of *Euler Hermes Kreditversicherungs-AG.*[28] This classification measures the risk of a loan default for business done in a particular country and is based on the "Country Risk Classification" of the OECD. The classification applies an eight-stage scale reaching from 0 (no default risk – politically stable) to 7 (highest default risk – politically extremely instable). Frondel and Schmidt normalize this scale to values between 0 (low risk) and 1 (high risk). The present study also applies the normalized Hermes classification to assess the political stability.

In addition to the political stability of supplying countries, it is also decisive whether there are only a few or many suppliers and how the market shares of the suppliers are distributed. The larger the number of suppliers and the more even their market shares are distributed, the lower the default risk will be. One of the most well known concentration ratios is the Herfindahl index. By squaring and totalling the market shares of the suppliers, we arrive at a measure that amounts to 1.0 for just one supplier and decreases rapidly to smaller values, particularly for comparatively evenly distributed market shares. The closer the Herfindahl index is to 1.0, the higher the supplying risk.

In order to measure the dependence on individual suppliers and their political stability simultaneously, we multiply the squared market shares of the supplying countries with the normalized risk assessment according to Hermes. The result is a Herfindahl-weighted risk evaluation. Its value can vary between 0 and 1. Due to limited data availability, only the supplying countries that in total provide 90 percent of the imports have been individually assessed. Table 4 below includes only these countries. The remaining

Table 4
Share of the Most Important Supplying Countries of Energy Imports to Europe (in %) and Their Classification According to *Hermes-Kreditbürgschaften*

	Oil	*Gas**	*Coal***	*Hermes*	*normalized*
Russia	34.0	39.5	26.0	3	0.43
Norway	13.6	28.0		0	0
Libya	9.0	3.2		6	0.86
Algeria	2.9	15.9		3	0.43
Saudi-Arabia	5.8			2	0.29
Iran	5.2			6	0.86
South Africa			20.5	3	0.43
Nigeria	2.4	4.7		6	0.86
USA	1.9		9.4	0	0
Kazakhstan	4.0			4	0.57
Australia			14.0	0	0
Columbia			12.6	4	0.57
Iraq	2.7			7	1
Azerbaijan	2.7			5	0.71
Venezuela	2.0			6	0.86
Indonesia			8.1	5	0.71
Kuwait	1.3			2	0.29
Mexico	1.3			2	0.29
Angola	1.2			6	0.86
Syria	1.2			7	1
Qatar		2.4		2	0.29
Total	**91.2**	**93.7**	**90.7**		

Here, the countries' share of the imports into EU-27 in 2007. The ranking corresponds to the total of oil, gas, and coal
* Pipeline gas and LNG
** Only "hard coal"
Source: The author's own calculations based on *BP Statistical Review of World Energy June 2008* (London, 2008), Eurostat and on Hermes Kreditversicherungs AG.

28 Frondel/Schmidt, "Die Sicherheit der Energieversorgung in Deutschland" (see note 16), p. 11. During the production process of this study, the country classification of three countries, among them Russia, has already become outdated. For a current classification of the countries, www.agaportal.de/pages/aga/deckungspolitik/laenderklassifizierung.html#top> (accessed June 27, 2008).

supplying countries were combined and treated as one country.[29] Table 5 below represents an overview of the results of the Herfindahl-weighted risk assessment.

Table 5
Herfindahl-weigthed Risk Assessment of Energy Imports into EU-27 According to Energy Carriers in 2007

	Oil	*Gas*	*Coal*
Risk assessment	0.065	0.085	0.068

Source: see Table 4.

In several respects, this is a surprising result: On the one hand, oil does not do worse than gas—as might be the initial "feeling". On the other hand, the risk assessment of coal supplies is not better than that of the oil supply, which is particularly remarkable. There are several reasons for that. There is a comparatively large number of oil exporting countries; in 2007, a total of 16 supplying countries provided 90 percent of the EU imports. In the case of coal supply, there are only 6 countries for coal imports and only 5 for gas supply that cover 90 percent of the imports. Due to the Herfindahl-weighting, the exporting countries with the largest market shares are more relevant for the assessment. The Hermes classification assesses the most important coal suppliers, Russia and South Africa, only with 3 (normalized 0.43). For oil and gas, though, Norway—which is assessed to be risk-free—takes a second place. This means a higher classification of the supply security of oil and gas. In total, the energy carriers show similar assessment results with gas having slightly less favourable values. From a longer-term perspective, though, we have to take into consideration that Norway's market share will decrease due to sinking production numbers. This means that the risk of oil and gas supply will tend to increase, whereas it will remain at the same level for coal supply. Future gas supplies are likely to come from countries that today are assessed to be politically instable. The political development in the export countries is hard to predict, though.

Vulnerability of transport routes. For the transport from the well to the end consumer, the transport of the energy carriers oil and gas is bound—at least partially—to pipelines. This applies particularly to natural gas—only liquefied natural gas (LNG) is delivered by ship to regasification terminals in order to be transported through pipeline systems to the final customers. The opposite applies to coal. It is delivered to consumers, mainly power stations, steel mills and cement plants exclusively by ship, railway or trucks. Only conveyor belts in the conversion of lignite into electricity can be considered as ducts. Usually, they are only a few kilometres long and cannot be compared to the large "gas highways" that deliver gas over several thousands of kilometres to Europe. The oil is shipped to the large European import harbours where they are transported by inland navigation vessels or via pipelines to the refineries. Final products are usually transported and distributed via roads to the end consumers.

Pipeline-bound transport routes are more vulnerable than non-pipeline routes as interruptions through accidents, damages or terror attacks affect the entire pipeline. As opposed to that, if an oil tanker is attacked by terrorists or captured by pirates this will not affect the remaining supply chain. If the pipelines go through third-party countries, there is the additional risk of impacts from the transit country, particularly if the transport pipelines are physically linked to the remaining pipeline network in the respective country.

Shipping routes are risky if large quantities have to be transported through narrow sea-passages. A prominent example is the Strait of Hormuz in the Persian Gulf through which in 2004 about 30 percent of world-wide oil exports were shipped; or the Strait of Malacca between Malaysia and Singapore which is of decisive importance for the Asian consuming countries.[30] Due to its outstanding importance, the Strait of Hormuz has been protected by US marines for a long time.

Coal shipping does not face these problems, and is therefore, in general, considered unproblematic. From none of the important coal supplying countries sea-passages that are as vulnerable as the Strait of Hormuz have to be shipped through.

For the purpose of this study, such qualitative considerations will be sufficient. From a European perspective, transport routes for coal are the safest, followed by oil. The most vulnerable transport routes are pipelines for gas supply.

29 For the fictitious country "Rest of the World", we assumed a risk assessment of 0.57, which corresponds to the risk assessment of countries such as Kazakhstan.

30 See Enno Harks, *Der globale Ölmarkt, Herausforderungen und Handlungsoptionen für Deutschland*, SWP-Studie 11/07 (Berlin: Stiftung Wissenschaft und Politik, May 2007), p. 22.

Appropriateness of quality. The physical quality of the supplied energy carrier is of extreme importance, particularly for industrial consumers that adjust their processes to a particular fuel quality. The material characteristics of coal, oil and gas are variable, though. Often it is possible to reach a comparatively even quality if imports are supplied over a longer period from one and the same supplying region. Refineries, power stations, and industrial processes can be adapted—to a certain extent—to a fluctuating quality. In that respect, there is no general difference between the different energy carriers. For all three, the energy industry has succeeded in providing the end consumers with an appropriate fuel quality. Therefore, all three energy carriers receive the same assessment.

Predictability of prices. According to the definition above, the possibility to forecast prices of energy carriers is part of a secure energy supply. Such prices emerge in the markets. They cannot be pre-calculated for a longer period ahead because they fluctuate in line with supply and demand. The physical and perceived supply situation plays a role, as well as expected bottlenecks. The volatility of energy prices has increased over the last years. Oil prices as the "key currency" of the energy industry emerge independently of price movements of other energy carriers. Due to the high exchangeability of its products and its world-wide links, the oil market is considered to be highly reactive and efficient. These characteristics, however, are also one of the reasons for the increasing number of extreme price events over the last years.

Short-term gas prices are—at least in large parts of Central Europe—more predictable than oil prices as on the wholesale level for the supply of power stations or large industrial consumers, gas prices are usually fixed with a delay of three to six months. Prices are set using a base price to which a variable component is added. The variable component depends on the oil price mean value over a period of approximately three months. Therefore, large gas customers that have contracts with oil price fixing know three to six months in advance what price they will have to pay. Current studies assume that the oil price fixing will be relaxed, but not completely disappear.[31] As gas prices use mean values, they fluctuate much less than oil prices. Only on gas spot markets—which are of increasing importance - we can see price fluctuations that are similar to that on oil markets.

In the past, coal prices were usually less volatile than oil and gas. They were always lower than the prices of competing fossil fuels.[32] From a long-term perspective, coal prices can be considered to be the most stable ones, even though short-term relative price jumps can reach similar dimensions as oil prices.

Affordability of prices. We have already pointed out that the issue of affordable prices partially overlaps with the issue of the competitiveness of energy supply. For this reason, we will exclude this aspect from the assessment of energy security.

The following table presents an overview of the assessment of energy security. The assessment is partially based on absolute measured quantities that have been transformed into a ranking in order to make them comparable. Rank 1 means that the energy carrier is assessed to be superior to the other two regarding this particular criterion. In total, the energy carrier that has the lowest total sum of the rankings will receive the most favourable assessment. The criteria are not weighted as they are assumed to be of equal importance.

Table 6
Comparative Assessment (ranking) of Oil, Gas, and Coal Regarding European Energy Security

Criteria	*Oil*	*Gas*	*Coal*
Medium- and long-term availability	3	2	1
Import dependence	3	2	1
Political stability and concentration of supplying countries	1	3	2
Vulnerability of transport routes	2	3	1
Appropriateness of quality	1	1	1
Predictability of prices	3	1	2
Total	13	12	8
Final ranking	3	2	1

31 Clingendael International Energy Programme, *Pricing Natural Gas. The Outlook for the European Market* (Den Haag, January 2008), www.clingendael.nl/publications/2008/20080100_ciep_energy_pricing.pdf.

32 See Hans-Wilhelm Schiffer, *Global Trends in World Coal Markets: Supply, Demand and Perspectives for CCS, Paper Presented at the ENERDAY – Conference on Energy Economics and Technology*, (Dresden, April 11, 2008), p. 18, www.tu-dresden.de/wwbwleeg/events/enerday/2008/download.html?9,3 (accessed June 22, 2008).

The table shows that oil and gas are very close regarding their energy security ranking, with a slight advantage for gas, whereas coal leads the list. A strategy that aims at a higher gas use has to be assessed (slightly) positively, if gas replaces oil. If gas is used as a substitute for coal, it will decrease the security of supply.

The assessment reflects our current knowledge. These evaluations may change with political changes, the discovery of new resources, technological developments or an increasing supplier concentration. However, it is probable that an energy supply with coal is sustainably securer than one with oil or gas.

In addition, we would like to mention here that there will be no complete energy security. Even the most sophisticated technical systems can fail, as accidents in nuclear power stations prove. The complex chain of energy supplies can be interrupted or disturbed by technical failure, accidents, extreme weather events, earthquakes, terrorism and crime, exertion of political influence or even simply by human failure. Energy policy can only counteract part of the mentioned causes. In order to increase energy security, an energy policy should work towards reducing the probability of the occurrence of such events or making their consequences manageable and reducing the overall economic damages caused by interruptions or disturbances. In addition, energy policy can contribute to permanently secure the energy supply by creating a stable legal framework and promoting infrastructure project.

Competitiveness of the Energy Supply

In addition to sustainability and security of supply, the third main goal of the EU energy policy is the competitiveness of the energy supply. The Commission's publication *An Energy Policy for Europe* does not define what a competitive energy supply is, though.[33] The report only mentions volatility and the increase in energy prices as well as the challenges they create for the European national economies. In addition, it names the contributions of the European Single Market to competitive energy prices and investments.

The competitiveness of (primary) energy supply is important both for the power industry and, above all, for manufacturing industries and there, particularly, for businesses with a high energy intensity. Private end consumers do not compete against each other; and for companies with a lower energy intensity, energy consumption does only play a minor role in their business.[34] However, due to the substantially increased energy prices, energy costs are becoming important for an increasing number of industries.

From a microeconomic perspective, the energy supply is competitive if all competitors incur about the same energy costs for the manufacturing of a certain product. This does not necessarily mean that the energy price level has to be low. On the one hand, energy costs depend on the price level of energy (including taxes); on the other hand, it depends on the energy efficiency of the production process. A company with an energy-efficient production has a cost advantage over companies with less efficient facilities, provided all other conditions are equal. Different energy taxes and subsidies affect the companies' competitiveness to a similar extent. Examples are China, India or Venezuela that subsidize energy consumption and thus support domestic production facilities.

If countries that are rich in resources seal off their domestic markets, the effect is similar to that of subsidies. Domestic production companies buy energy at favourable conditions, far below the level of world market prices. Saudi-Arabia and the United Arab Emirates use this approach and very successfully establish their own energy-intensive industries.[35] Possible shortage signals of the world market are not transmitted to the domestic businesses. This leads to an international distortion of competition, and the companies in the respective countries lack incentives to save energy.

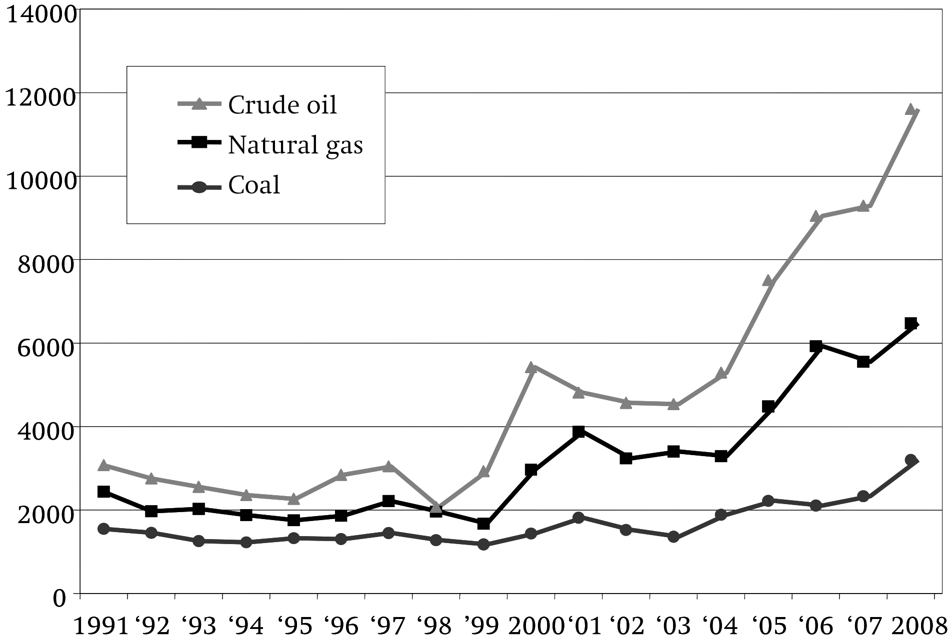
The EU Commission underlines correctly that high energy prices constitute a burden for European consumers as they result in a decrease of purchasing power in Europe. In this context also absolute energy prices are important. This loss of purchasing power indirectly weakens competitiveness, as the companies'

33 Commission to the European Council, *An Energy Policy for Europe* (Brussels, January 10, 2007), COM(2007) 1 final, p. 4.

34 Exceptions are such industries as hotel businesses, hospitals or forwarding companies where energy costs correspond to a large share of total costs.

35 From an economic perspective, it is useful for oil-producing countries to enlarge the value-added chain for oil, e.g. in form of oil-processing companies. Using oil and gas for power generation in a power-intensive aluminium industry, such as in the United Arab Emirates, cannot be explained as such an economic optimization, though, as these products currently are four times as expensive as coal, for instance. A decisive point for this decision might be the VAE's strong refusal of raw material imports.

Figure 3
Development of the Cross-border Prices of Natural Gas, Coal, and Crude Oil, Free German Border in Euro/ Terajoule (TJ)



The 2008 prices stated here are mean values of the first three months.
Source: Federal Office of Economics and Export Control <www.bafa.de/bafa/de/energie/rohoel/energieinfo/2008/mai.html> (viewed on 8/7/2008).

ability to invest decreases and the domestic demand for products is reduced.

The purpose of the energy policy assessment in this chapter is to evaluate whether an increased natural gas use in Europe is consistent with the energy policy goals of the EU. In order to answer that question in respect to the competitiveness of the energy supply, we will initially analyze the energy carriers oil, natural gas and coal regarding their price levels, without taking into account different taxation levels as they vary among EU member states.[36] Figure 3 illustrates for Germany the development of the cross-border prices for fuel oil, natural gas and coal in the period 1991-2007. These prices vary slightly between the individual European countries; however, the prices are—in principle—transferable. The figure shows that oil has been the most expensive energy carrier since 1999, with a strong lead particularly since 2002, followed by gas and the substantially cheaper coal.

36 In Ireland, Greece, Luxembourg, Portugal and the UK, the value-added tax rate is substantially lower than the general value-added tax rate of these countries. Other EU member states do not have such regulations.

The competitiveness of natural gas in comparison to the other fossil energy carriers does not only depend on cross-border prices as—from the consumers' perspective—transport and distribution costs of the energy account for a substantial part of the total price. In order to evaluate the competitiveness of natural gas on this level it is necessary to distinguish between different applications or sizes of customers. In the introductory chapter "The potential of natural gas for avoiding CO_2 emissions in Europe", we have identified the power station industry, heat markets and the transport sector as potential application areas for an increased natural gas use. Therefore, we will look at the competitiveness of gas in theses three areas.

Power stations industry. The power stations industry is characterized by a high competition between the used fuels. Above we have already mentioned the *merit order* of the power stations (see p. 9), i.e. the order of use that exclusively depends on the marginal costs of the power production. These are mainly determined by fuel costs and costs for CO_2 emission certificates. That means that the competitiveness of natural gas in relation to coal and oil depends on the price constellation of these two variables.

- As oil prices are always substantially higher than those of natural gas and coal, oil does only play a subordinated role in Europe's power production: In 2006, only 3.9 percent of the power consumed in the EU was generated from oil. It can be assumed that the importance of oil in the production of power will further decrease in the future.
- In the 1990s, the price difference between coal and gas was less than 0.5 ct/kWh of fuel. In that period, it was more profitable to use natural gas for power generation than coal.
- From mid-2000 to 2005, the price difference between gas and coal was 0.7 ct/kWh of fuel. For this price constellation, it was more profitable to use natural gas than coal from a CO_2 price of 20-25 Euro/t.
- From mid-2006 to 2008 (first three months), the price difference between gas and coal amounted to approximately 1.2 ct/kWh of fuel. Under these conditions, the use of natural gas for power generation becomes more economic than the use of coal from a CO_2 price of 40-45 Euro/t.[37]

In 2006, 21 percent of the power consumed in the EU was generated from gas and 28.6 percent from coal.[38] The EU's current baseline scenario assumes that the fuel demand of gas- and coal-fired power stations will increase between 2005 and 2030 by about 12 percent each, whereas the use of oil in power generation is assumed to decrease by 64 percent.[39] Here, the authors of the study have clearly reduced the use of gas for power generation in comparison to the preceding study from 2005 which still assumed an increase of 26 percent regarding the use of natural gas for power generation. The already minor importance of oil is expected to diminish even further.

Due to the still predominant gas prices fixing to oil prices in continental Europe, natural gas can be expected to remain substantially more expensive than coal, even though coal prices have recently experienced a sharp rise. Under these circumstances, it will be difficult for natural gas-fired power stations to compete with coal-fired power station. It remains unclear whether CO_2 prices will permanently remain on the high level described above. From 45 Euro/t, CCS can be expected to become profitable.[40] All in all, it can be assumed that coal will keep its position in power generation and that there will be no large-scale substitution with natural gas. Natural gas will remain competitive when used for generating power during peak- or medium-load periods, for providing balancing power and for combined heat and power (CHP) plants, if there is simultaneous demand for power and heat.

Heat markets. The competitiveness of natural gas in the heat markets, i.e. the heating of buildings, warm-water-production and generation of process heat for manufacturing facilities, will be discussed using qualitative considerations. Regarding heat generation, natural gas has always competed with fuel oil and coal. From an end consumer's perspective, coal is much more economical as the fuel is much cheaper—and usually it is not necessary to heat all rooms. Due to environmental reasons and higher comfort requirements, coal has been substituted in large parts of Europe, particularly in large cities. The proportion of coal-fired heating systems remains high in the new EU member states. The main reason for customers to switch to natural gas or other energy carriers has been the increased comfort. Thus the main competitors of gas have become fuel oil, and recently also biomass or electrically-driven heat pumps. Due to the oil price fixing of gas prices, these are usually competitive in relation to fuel oil. International gas-producing companies and import companies use the so-called market-value principle in their negotiations. Due to this principle, purchasing prices for gas are linked to the prices of other fuels, particularly to that of fuel oil. This means that on the heat markets, natural gas will also in the medium term remain competitive in relation to oil.

Transport sector. In Europe, natural gas does not play any role in the transport sector yet. As mentioned above, only three EU member states have currently numbers of natural gas-operated vehicles that are worth mentioning: Italy (ca. 400,000), Germany (64,000), and France (8,000). The reason is the still missing gas-station infrastructure, on the one hand,

37 The author's own calculations based on the German transit prices from 1991 to 2008, see www.bafa.de/bafa/de/energie/index.html> (accessed July 10, 2008).
38 European Commission, Directorate-General for Energy and Transport (DG TREN), *EU Energy in Figures 2007/2008* (Brussels, 2008).
39 Leonidas Mantzos/Pantelis Capros, *European Energy and Transport. Trends to 2030 – Update 2007* (Luxembourg, 2008), p. 96.
40 See Friedrich Seefeldt/Marco Wünsch/Michael Schlesinger (Prognos AG), *The Future Role of Coal in Europe* (Berlin/Basel, 2007), p. 69.

and the limited supply of vehicles that can be operated with natural gas, on the other hand. In addition, consumers do not have the same confidence in natural gas as a fuel than they have in liquefied fuels. However, probably due to the strong increase in fuel prices and marketing campaigns of gas suppliers, the interest in natural gas-driven vehicles is on the rise.

The competitiveness of natural gas is affected by two economic factors: the purchase price of the vehicle and fuel costs. Currently, the price of a new natural gas-driven vehicle is similar to that of diesel-operated eco-models and thus is about 1,500 to 3,000 Euros higher than that of traditional petrol-operated cars. Due to the already existing bivalent drive technology, there are system-related additional costs during production, which however should decrease for larger production numbers. They will not disappear completely, though.

The utilization costs depend mainly on the prices of natural gas as a fuel: The EU commission names in its report *An Energy Policy for Europe* market prices of 230–340 Euro/t oil equivalent for natural gas as a fuel and 398–582 Euro/t oil equivalent for petrol and diesel.[41] In Germany, the Energy Tax Act ensures a lower taxation of natural gas as a fuel until the year 2018. But also the net costs for natural gas are today substantially lower than those of petrol or diesel. In the long term, a similar mechanism as in the heat markets can be expected to occur: After the successful introduction of natural gas as a fuel it will be priced in order for it to remain competitive in relation to petrol or diesel. Similar considerations could be made for the use of fuels produced from liquefied coal, which in Europe currently do not represent an alternative. Permanently high crude oil prices might open the market for coal-based fuels, though. Table 7 presents an overview of the results of the economic assessment.[42]

Table 7
Comparative Assessment (ranking) of Oil, Gas, and Coal Regarding Their Competitiveness

	Oil	*Gas*	*Coal*
Power stations	3	2	1
Heat markets	2	2	1
Transport industry (today)	2	1	(3)
Transport industry (2018+)	1	1	(1)

41 See Commission to the European Council, *An Energy Policy for Europe* (see note 33), p. 34.
42 As the goal is to find results for the individual sectors, we have not added up the ranking positions – similar to Table 2.

Summary of the Energy Policy Assessment

This chapter has analyzed to what extent an expansion of natural gas utilization in power stations, heat markets and the transport industry would be consistent with the goals that constitute the goal triangle of the EU's energy policy. The following table presents an overview of the results of this assessment.

Table 8
Total Results of the Energy Policy Assessment Regarding an Increased Utilization of Natural Gas in Europe

	Sustainability	*Energy Security*	*Competitiveness*
Power Stations	Improvement	Deterioration	Deterioration
Heat Markets	Improvement	today: Slight improvement long-term: neutral	Neutral
Transport Industry	Improvement	today: Slight improvement long-term: neutral	today: improvement long-term: neutral

The table shows that an increased use of natural gas in the heat markets and the transport sector would receive a positive assessment, from an energy policy perspective. The largest CO_2 savings can be achieved in the heat markets as the better emission factor of natural gas can be fully appreciated. For the individual case it should be analyzed though, whether other alternatives such as heat pumps or renewable energies could lead to even higher savings. If such alternatives are not available, natural gas would constitute a good choice from the society's perspective. Also in the transport sector, natural gas can contribute to a significant reduction of CO_2 emissions without other energy policy goals being jeopardized. This potential has basically not been tapped yet.

It is not recommendable to use more natural gas as a substitute for coal in the power station industry, due to the security of supply, but also because of the questionable competitiveness of using gas for power generation. In that area, emphasis should be given—in addition to a conversion to renewable energies—to efforts that commercially introduce CCS processes into the market as soon as possible.

Options for the European Energy Policy

Framework Conditions for a Natural Gas Strategy

After the positive energy policy assessment of an expanded natural gas strategy, the next question would be, whether and how such a strategy could be implemented. At first we will look at whether such increased natural gas volumes are available. The majority of current prognoses regarding the European energy demand assume an increased gas utilization. Most recent studies predict a less sharp rise than older ones. In the following presentation, we will outline examples of three reference or baseline scenarios, respectively, that represent the generally acknowledged range of the expected development of gas demand until the year 2030:

- The *European Environment Outlook* of the European Environment Agency (EEA) from 2005 develops the most ambitious scenario of the future gas demand: Assuming a withdrawal from nuclear energy, it mentions a gas demand of 638 Mtoe in the EU-25 region for the year 2030. In order to compare this scenario with the other two forecasts, it is necessary to add the gas demand of Romania and Bulgaria which according to the scenario of the National Technical University (NTU) of Athens (see below) might amount to about 23 Mtoe. in 2030. According to the EEA scenario, the gas demand of EU-27 could thus be forecast at about 662 Mtoe (+49%).[43]
- The *World Energy Outlook 2007* of the IEA mentions an EU-27 gas demand of 444 Mtoe for 2005 and raises the demand to 610 Mtoe (+37%) in the reference case. It is remarkable that power generation increases substantially (81%) whereas the increase of end energy demand is evaluated more cautiously (21%).[44]
- The most current scenario is the baseline scenario of the NTU Athens prepared on behalf of the EU Commission. According to this analysis, gas demand will only increase by 16 percent until 2030 and will then amount to 516 Mtoe. It is assumed that all sectors will use substantially more natural gas. Regarding the end energy demand, the natural gas increase is assumed to be 14 percent. For the power station industry, the number is 11 percent.[45]

Particularly the first two scenarios have in common that they were produced at a time when oil and gas prices were at least 50 percent lower than in 2008. Even the *World Energy Outlook 2007* still assumed a real stagnation of oil prices at about 60 USD/barrel. As was shown above, especially for power generation the use of natural gas depends strongly on the competitiveness of gas in relation to coal. In this context, the competitiveness of gas in power generation has clearly deteriorated after 2004. This development has been taken into account in more recent assessments and has led to a correspondingly more cautious evaluation of natural gas' growth perspectives in the power generation industry.[46]

Another reason why particularly the two first named studies are likely to have overestimated the future gas demand is that the efficiency of energy utilization might increase faster than assumed. A more detailed discussion of this issue will be provided in the following section that addresses the demand-side options of energy policy.

The following discussion of available options is based on the EU's baseline scenario according to which energy demand will increase only slightly without further political measures. An expanded natural gas strategy that starts from this premise operates within the framework of existing scenarios and should therefore not fail due to that not enough natural gas is available.

43 European Environment Agency, *European Environment Outlook* (Copenhagen, 2005).
44 IEA, *World Energy Outlook 2007. China and India Insights* (Paris, 2007).
45 Mantzos/Capros, *European Energy and Transport. Trends to 2030* (see note 39).
46 An example is the changed assumption regarding future power production from gas in the Energy Report IV of EWI/Prognos. In the mentioned oil price version—that assumes significantly higher energy prices as the reference forecast—the power production from gas reaches only 10.2% of gross power production in 2030. In 2005, the reference version still assumes 32.7%, see EWI/Prognos, *Auswirkungen höherer Ölpreise auf Energieangebot und -nachfrage* (see note 9).

A next step would be to ask what Europe has to do in order to exploit the potentials of a natural gas strategy. The starting point of such a strategy should be a consensus regarding the goal. Only if Europe largely agrees on that an increased share of natural gas is useful for a period of several decades—until the conversion to a largely CO_2 free energy system is completed—this road can be taken. Subsequently, the goal has to be substantiated by specific measures.

European energy policy has to master a balancing act between two principles: subsidiarity and centrality. On the one hand, the energy strategy[47] underlines the importance of joining forces and efforts in the energy sector. Only this way it will be possible to successfully master the challenges of sustainability and energy security. On the other hand, the action plan of the European Council from March 2007 reminds—regarding nuclear energy—that each member country has complete sovereignty to choose its energy mix. The European Union has so far mostly abstained from formulating policies regarding individual energy carriers. To a certain extent, the decision of the European Council from March 2007—that stated a compulsory goal for the share of renewable energies until the year 2020 and allocated this share to the individual countries—can be interpreted as a move away from the principle of self-responsibility. The (unexpressed) reason is the knowledge that otherwise it will not be possible to reach the challenging goals of climate protection. This means that an energy policy that states goals for energy carriers would not constitute a complete novelty.

In the following, we will show different options that would allow the EU to increase the natural gas share and at the same time avoid (or at least reduce) the undesired “risks and side effects” of such an energy policy. At first, we will present the available demand-side options. At the same time we will emphasize the importance of an increase in energy efficiency that is absolutely essential for such a strategy. A second step is a description of the supply-side options that mainly aim at risk reduction, diversification and further improvement of the climate compatibility of natural gas applications.

At the intersection of supply and demand, we find the economic policy and here, particularly, the completion of the Single Market for energy products. Only if natural gas is really traded across boarders, the security of supply, competitiveness and sustainability of the energy supply in the EU can be improved.

Demand-side Options

Heat markets

In the heat markets, the energy mix is subject to a dynamic development. The above described substitution of coal and later of oil by natural gas has proceeded with a varying intensity: In the 1970s, the European gas demand (including the gas used in power generation) still increased by 9 percent annually. In the 1980s, the growth decreased to 1.7 percent per annum. In the period 1990 to 1999, however, it rose again to 2.7 percent per annum (mainly due to the rapidly increasing volumes used in power generation) and since 2000, it has continued at a more moderate growth rate of 1.3 percent per annum.

Particularly, the fast progress regarding the efficiency increase of gas utilization, but also the high natural gas prices have resulted in a slower growth of gas consumption over the last years, and even a standstill since 2005. It is difficult to say whether this development already constitutes a break of the economic trend. It is a fact though, that—on the one hand—customers save energy and, in some countries, increasingly turn to other alternatives, such as heat pumps or biomass heating systems. On the other hand, the gas companies reduce their development activities.

The reason for this dampened business activity is the network regulation. Networks as such have to be economic. Profits are expected to decrease though, due to the forthcoming incentive regulations.[48] Therefore today, as opposed to the 1970s, energy networks will only be expanded if they comply with strict economic requirements. If the heat density in a region is not sufficient for a profitable network operation within a few years, the development will not be actively pursued. In addition, the rate of return in the regulated industry lies clearly under the profit rates that gas businesses expect and they are likely to be less willing to invest.

47 See Commission to the European Council, *An Energy Policy for Europe* (see note 33).

48 The incentive regulation allows the company to levy network fees which are only economic if grid costs are kept within certain benchmarks. As these benchmarks follow the cost structure of the best businesses, the companies have an incentive to further lower their costs.

Thus the question to be asked is whether a very restrictive incentive regulation sufficiently takes into account the potential of the energy carrier natural gas. The goals of the regulation that aim mainly at competitiveness and long-term operational security counteract—as already mentioned—a further network expansion. Politics should see to that there remain sufficient incentives for the businesses to open up new supply areas, i.e. developments beyond a pure network densification.

In addition, it would be possible, particularly on a regional or local level, to use regulatory and planning law to give priority to pipeline-bound energy carriers as opposed to other energy carriers (mainly oil). In this context, it is important to take into consideration though whether district heat is available for a possible combined heat and power supply. Neither should the political priority of natural gas counteract the conversion to renewable energy carriers.

Transport Sector

The increase of the proportion of natural gas in the transport sector requires larger efforts than those in the heat markets as there are much larger obstacles to overcome, due to the low number of existing natural gas-driven vehicles. In a Green Book from 2000 *(Towards a European strategy for the security of energy supply)*, the EU stated the goal to substitute—by the year 2020—20 percent of fuel demand by alternative options. It mentions bio-fuels, natural gas and hydrogen.[49] For natural gas, a communication of the Commission paints an "optimistic expansion scenario" according to which the natural gas share of fuel consumption might amount to 2 percent by 2010, to 5 percent by 2015 and to 10 percent by 2020. In the following years, the political discussion and legislative activities in the EU focused on bio-fuels, though. In the years 2007 and 2008, due to increasing doubts regarding the sustainability of bio-fuels, a correction of this subsidies policy was initiated.

A so-called contact group for natural gas and hydrogen was installed, whose task it was to prepare recommendations on how to increase the proportion of so-called alternative fuels. In late 2003, the contact group presented a report that predicts for natural gas a potential of a 10-percent market share of the European fuel demand by 2020.[50] Apart from that, no further specific goals or legal acts have been adopted.

Initial steps towards increasing the quota of natural gas in the transport sector would be to prepare legislative measures and to develop an implementation strategy. This study estimates the CO_2 savings potential of natural gas-driven vehicles at 39 Mt—assuming a conversion of 25 percent of the vehicles (see above p. 10). It will not be possible to reach a 25 percent share of total vehicle numbers by 2020 as the substitution rate of the vehicles is too low. However, this value seems to be feasible as a long-term goal for 2030, for instance. For now, it would not appear reasonable to aim at more ambitious goals. Only if natural gas in the future offers more savings potentials by increasing biogas mixtures, even higher shares might be feasible.

Today there are additional factors that impede the increase of the natural gas share in the transport sector: the limited number of natural gas stations,[51] the unsatisfying supply of natural gas-driven vehicles and the still insufficient faith of consumers in the gas technology as well as the fact that people know little about natural gas as a fuel. A break-through of natural gas in the transport sector can only be achieved if these obstacles are simultaneously overcome. This requires concerted efforts by a large number of EU member states. A possible initial strategy would be to focus on fleet operators as these usually use the same petrol stations. Converting large utility vehicles, such as refuse collection or public transport vehicles to natural gas might result in a massive reduction of emissions in urban centres. This will not lead to a break-through in private transport, though, and will thus not affect the mass market. However, a conversion of public transport fleets could serve as an important example for private consumers.

An increased number of natural gas stations requires that they are connected to the natural gas networks. Costs incurred for network expansion should be accepted in their entirety by the regulating authorities. In addition, petrol station operators should receive more (financial) incentives to sell more natural gas. There is a risk that petrol station operators who work in close contact with mineral oil companies decide against natural gas due to a conflict of interest

49 European Commission, *Green Book "Towards a European strategy for the security of energy supply"* (Luxembourg, 2001).

50 Alternative Fuels Contact Group, *Market Development of Alternative Fuels* (see note 13), p. 23.

51 Mid-October 2008, there were 1,047 gas station with gas pumps in Germany, Austria, and Switzerland, whereof 800 in Germany, www.gas24.de/cms/26-0-steuern-erdgas.html (accessed October 14, 2008).

with their parent companies—unless these are also involved in the natural gas business. As initial investment costs both at the gas station and for a network connection, particularly if the distance to the existing gas networks is long, will be substantial the state should support this development with investment incentives to provide financial relieve for the start-up phase. If this proves not to be sufficient, it would be possible to consider regulatory measures, such as an obligation for mineral oil businesses to offer a certain share of natural gas at their petrol station network.

Alexej Miller, *Gazprom*'s Chairman of the Board of Directors, offered in June 2008 to build up, together with European partners, a gas station network in Europe. This shows—despite all political objections towards such an offer—that the gas industry is ready to share the infrastructural costs.[52]

In addition financial incentives for vehicle owners should be created in order to promote demand for natural gas vehicles. Germany applies a reduced mineral oil tax rate to natural gas that is used as vehicle fuel. This regulation was extended to the year 2018. A follow-up solution will have to be found by around 2013. Similar measures should be taken in all EU countries. The European Union might introduce an upper limit for the taxation of natural gas as a vehicle fuel, for instance. Already today the EU defines a lower limit for mineral oil taxation, therefore also an upper limit might be possible as a market introduction tool. In addition to a limited fuel taxation based on the fuel used, it might be an efficient tool to strictly apply CO_2 emissions to determine taxation in order to promote low-emission vehicles, and thus also natural gas-driven vehicles. It would also be important to use marketing tools to increase the popular appeal of natural gas-driven vehicles. This should constitute a joint effort of vehicles manufacturers, gas industry and the governments of the EU member states.

Setting a clear and long-term EU goal, supporting petrol stations regarding an increased natural gas supply, and providing customer incentives should lead to a situation where car manufacturers supply a wider range of natural gas-driven vehicles. Currently, manufacturers do not appear to expect a break-through of compressed natural gas, though, and focus on other research and development activities. Even though most large manufacturers produce natural gas-driven vehicles, their medium- and long-term fuel strategy aims at more sophisticated synthetic fuels that can be produced from a variety of primary raw materials such as natural gas, coal and biomass.[53] The successful application of synthetic fuels would have the advantage of that the existing infrastructure at the petrol stations (and also that of the logistics chain) could also be used in the future, without any dependence on natural gas networks. This undeniable benefit is offset by the substantial production costs in comparison to traditional fuels or compressed natural gas. Even if new manufacturing technologies could substantially reduce these costs, synthetic fuel produced from liquefied natural gas or other primary raw materials will still be more expensive than compressed (gaseous) natural gas.

Currently, the EU is about to decide about compulsory mean values of CO_2 emissions for newly registered vehicles. The proposal of the Commission for a "Regulation […] on Setting emission performance standards for new passenger cars […]" from December 2007 defines the goal to limit CO_2 emissions of new cars to 130 g CO_2/km by 2012. Further measures are expected to lead to an additional decrease of CO_2 emissions by 10 g/km in order to be able to reach the EU goal of 120 g/km which was stated in the proposal COM(2007) 19.[54]

If it really became compulsory for European vehicle manufacturers to reach that value, a permanent use of natural gas in the transport sector would be enhanced.

The role of energy efficiency

Energy efficiency plays a prominent role among the demand-side options for the implementation of an expanded natural gas strategy as a more efficient energy utilization does not only have a positive effect

52 Frank Nienhuysen, "Gazprom schlägt europäisches Gas-Tankstellennetz vor. Vorstandschef Alexej Miller sieht in dem Treibstoff die einzige echte Alternative zu Benzin und Diesel", *Süddeutsche Zeitung (SZ)*, 28/6/2008, p. 30. Miller put forward his proposal at the annual share holder meeting of the holding.

53 Volkswagen, for instance, does not focus its fuel and drive strategy on CNG (compressed natural gas), but on GtL and other "synfuels", <www.volkswagen.de/vwcms_publish/vwcms/master_public/virtualmaster/de3/unternehmen/mobilitaet_und_nachhaltigkeit/technik___innovation/SunFuel.html> (accessed July 25, 2008).

54 European Commission, *Regulation of the European Parliament and of the Council on Setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles* COM(2007) 856 final (Brussels, 2007), p. 2–3.

on the energy carrier natural gas, but on all energy carriers.[55] Whereas measures for an increased natural gas share in the heat markets or in the transport sector would—without countermeasures in other sectors—lead to an increased natural gas demand, an increased energy efficiency would, at least partially, be able to compensate or even completely avoid such an increase. In Table 1 (p. 11), the additional natural gas demand of EU-27 in the context of an expanded natural gas strategy was estimated to be 33 Mtoe in the heat markets and 90 Mtoe in the transport sector. In 2007, the natural gas demand of EU-27 amounted to 434 Mtoe. The mentioned increase would correspond *ceteris paribus* to an additional demand of 28 percent.

The current baseline scenario of the EU Commission *European Energy and Transport Trends to 2030 – Update 2007* (EU Trends – Update 2007) sets the quantitative framework for the future demand of natural gas (and other energy carriers) in Europe. A look at the numbers provides an idea of the challenge that the security of the European natural gas supply poses, especially given an intensified natural gas utilization. We can also appreciate to what extent an increased energy efficiency can contribute to achieving this goal.

- The scenario assumes a natural gas demand in Europe of about 445 Mtoe (2005), which increases to 505 Mtoe (2020) and to 516 Mtoe in 2030 (16%).
- The increase affects end energy (+14%) and the power stations (+11%) to a similar extent. No significant increase of natural gas in the transport sector is assumed.
- The amount of natural gas produced in EU-27 decreases from 188 Mtoe (2005) to 85 Mtoe (2030). The import rate increases from 58 percent (2005) to 84 percent (2030).
- The demand of natural gas imported to Europe thus increases by 68 percent from 257 Mtoe (2005) to 431 Mtoe (2030). This increase of 175 Mtoe corresponds approximately to 194 billion m³. By way of comparison: The planned Nordstream pipeline is expected to have a final capacity of 55 billion m³ and the Nabucco pipeline of 31 billion m³ per year.

The mentioned analysis constitutes a baseline scenario. This means that the scenario does not include the current EU goals regarding CO_2 emissions, the share of renewable energies and energy efficiency. It only includes the policies already implemented by the member states by the end of 2006. Therefore, the strong increase in import demand does not have to be assumed to be a given value. If the EU is successful in reaching its challenging sustainability goals, the demand of natural gas imports will increase at a much lower rate than stated in the baseline scenario.

Several EU documents mention that an energy savings potential of 20 percent is feasible, among others the 2005 Green Book on Energy Efficiency. It states that Europe can save at least 20 percent of its "current" energy consumption.[56] The *Action Plan for Energy Efficiency* of the EU Commission from 2006 defines more clearly that the 20 percent refer to the baseline scenario that the NTU Athens produced in 2005 for the EU Commission (EU Trends – Update 2005).[57] As opposed to this, the proposal of the Commission *20 20 by 2020* from January 2008 mentions the goal to "decrease energy consumption by 20 percent by the year 2020".[58]

Starting from the cautious assumption that the 20 percent savings refer to the baseline scenario "EU Trends – Update 2005" and will have to be reached only by the year 2030, gas demand would then amount to approximately 437 Mtoe.

A total increased gas utilization in the heat markets and in the transport sector of 123 Mtoe—such as suggested in this study—would thus lead to a total demand of about 560 Mtoe (ca. 622 billion m³) by 2030, i.e. 2.5 percent more than anticipated in the baseline scenario 2005 or 8.5 percent more than in the updated scenario from 2007. Figure 4 (see p. 29) provides an overview of the interrelationship.

Europe has numerous options for increasing energy efficiency. For a start, the EU should end the uncertainty regarding the 20 percent efficiency goal and when appropriate relate the goal to the new baseline scenario, split it down to the level of individual member states and make it compulsory. Other legislative steps can then state in detail how to reach the efficiency goal. It is obviously not enough to require that actions plans be prepared. In September 2007, the Commission had to take breach of contract actions

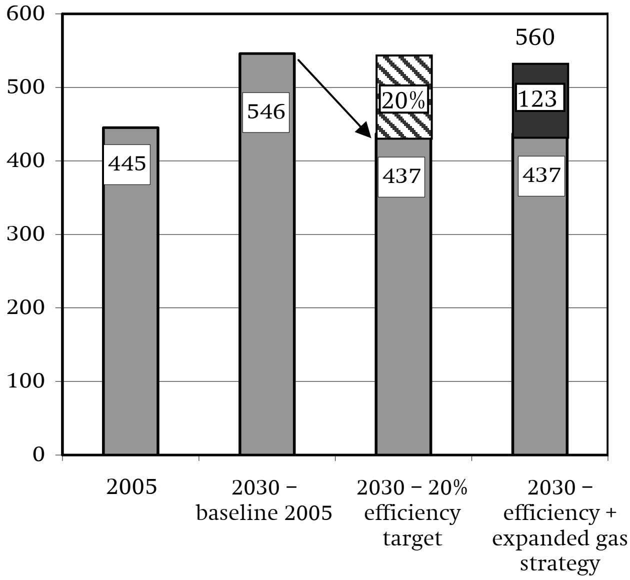
55 An example is the heat insulation of buildings, that results – independent of the used energy carriers – in a reduced energy demand.

56 European Commission, *Green Paper on Energy Efficiency or Doing More with Less* (Luxembourg, 2005).

57 European Commission, *Action Plan for Energy Efficiency: Realising the Potential*, COM(2006) 545 final (Brussels, 2006).

58 European Commission, *20 20 by 2020 – Europe's climate change opportunity*, COM(2008) 30 final (Brussels, 2008), p. 9.

Figure 4
Natural Gas Demand in the EU-27 2005 and 2030 (in Mtoe)



Source: Leonidas Mantzos/Pantelis Capros, *European Energy and Transport. Trends to 2030 – Update 2005*, Luxemburg 2006; European Commission, *European Energy and Transport. Trends to 2030 – Update 2007,* Luxemburg 2008, and estimates of the author.

against 12 member states that had not presented their action plans for increasing energy efficiency.[59]

The *Action Plan for Energy Efficiency* from October 2006 and the subsequent measures of the last years point in the right direction. The action plan mentions specific areas (e.g. appliances and facilities or buildings) for uniform efficiency requirements. The suggested regulations have still to be implemented into European law, though, in order to make the efficiency standards compulsory throughout Europe. Effective sanctioning mechanisms for non-implementation of the savings goal would put increased pressure on member states to really make use of the large and often economical potential of increased energy efficiency.

Eventually it is not Brussels that can abolish the obstacles for increasing the energy efficiency. The responsibility lies with the member states that do not implement the changes sufficiently fast.

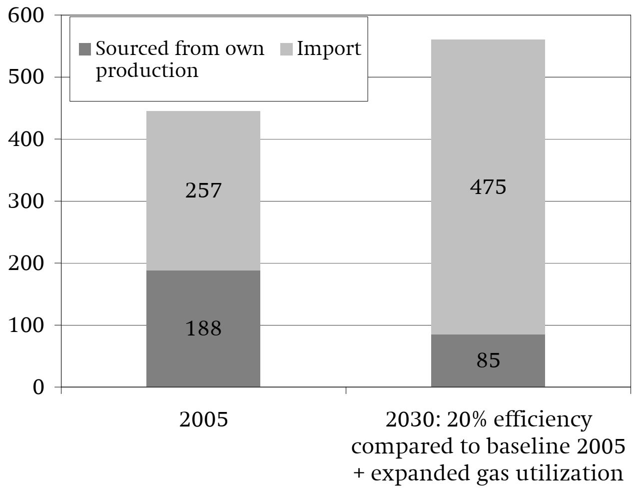
59 See Oliver Geden, *Die Implementierung des EU-Energieaktionsplans. Europäische Energie- und Klimapolitik im Spannungsfeld von Sorgfalt und Zeitdruck*, SWP-Aktuell 25/08 (Berlin: Stiftung Wissenschaft und Politik, April 2008), p. 7; Oliver Geden/Severin Fischer, *Die Energie- und Klimapolitik der Europäischen Union. Bestandsaufnahme und Perspektiven*, (Baden-Baden, 2008) (Asko Europa Stiftung [Ed.], Denkart Europa, Vol. 8), p. 102–107.

The conclusion is that there are a number of demand-side options in order to increase the share of natural gas in the heat markets and in the transport sector. An active energy efficiency policy can keep the growth of natural gas demand within acceptable limits. Nevertheless, European demand of imported natural gas will heavily increase over the next two decades as European gas production will decrease, particularly in the UK, the Netherlands and Germany.

Supply-side Options

Figure 4 has shown that for an expanded natural gas utilization, European natural gas demand will increase to about 560 Mtoe by the year 2030, given significant efficiency improvements. During the same period, European gas production will decrease from 188 to 85 Mtoe which is illustrated by the following figure.

Figure 5
European Gas Production and Import Demand of Natural Gas in EU-27 in 2005 and 2030 (in Mtoe)



Source: see Figure 4.

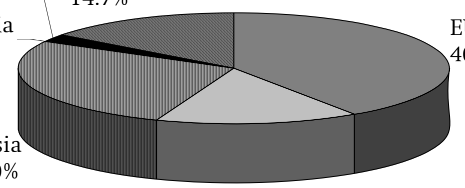
In comparison to 2005, this corresponds to an import demand increase by 218 Mtoe (242 billion m³) or 85 percent. European gas companies face the challenge to substantially increase natural gas imports from non-European countries in order to be able to meet this demand. But also national or imported biogas might contribute to supply the European demand in the medium and long term.

In the following, we will outline the supply-side options that Europe has for securing its natural gas supply in the long term.

Pipeline infrastructure and new suppliers

Europe today buys natural gas from six regions (see Figure 6). Russia, the Middle East, Africa, and Norway have potential for increased exports. Central Asia could produce more natural gas, too. It is however doubtful whether this could be used for supplying European gas demand. Due to shorter transport routes to Russia it can be assumed that Russian gas utilities have a competitive advantage over European companies regarding gas from Central Asia.

Figure 6
Market Shares of the Supplying Regions Regarding Gas Supply of the EU-27 in 2005



Source: David Bothe/Stefan Lochner, "Erdgas für Europa: Die ewiGAS$_{2008}$ Prognose", *Zeitschrift für Energiewirtschaft* 32, no. 1 (2008), p. 24.

The future importance of Russia for the European gas supply is the subject of intense political discussions. Particularly Russian activities outside its own territory, for instance in North Africa, raise mixed feelings in Europe. *Gazprom*, for instance, has suggested to Libya's government to buy off the total oil and gas exports of the country.[60] There is a fear of that Europe will become increasingly dependent on Russia regarding gas (and may be also oil) supply. If Russia really succeeds in obtaining control of a substantial part of Algerian and Libyan natural gas exports and will act as a kind of "wholesale merchant" for Europe, such fears will further increase. *Gazprom* then might be able to have a stronger influence on prices and volumes. In addition the question may arise whether the energy group does not have too many balls in the air with the commitment in these and other countries and thus possibly will neglect necessary long-term investments in the Russian gas industry. In addition, the "gas troika" formed by Russia, Qatar, and Iran in October 2008 constitutes a core of a possible future gas trust; a development that would have to be taken seriously.

Apart from *Gazprom's* activities, it is imperative from a European perspective to ensure access to the above mentioned gas reserves via pipelines (and LNG, for further details see below). Up to a distance of approximately 3000 km it is often more economic to transport liquefied gas. Therefore Europe has good chances of becoming first choice for the named gas exporting countries. The pipelines planned today are probably not sufficient to meet the heavily increasing import demand. The European gas production does decrease only slowly, though, and not all pipelines are yet necessary by 2020. The following table summarizes the most important pipelines that are planned:

Table 9
Planned Gas Pipelines into the EU

Name	*Capacity [billion m³ p.a.]*	*Country of origin*	*Target country*	*Start of operation*
Nord Stream	2 x 27,5	Russia	Germany	2011/2012
South Stream	30	Russia	Austria Italy	from 2013
Nabucco	31	Turkey	Austria	from 2013
Skanled	7	Norway	Sweden Denmark	2012
GALSI	8	Algeria	Italy (via Sardinia)	2012
Med Gaz	8	Algeria	Spain	End of 2009

Source: Company information.

The table shows that a total minimum pipeline capacity of 139 billion m³ p.a. is planned to provide gas into the EU. In addition, there is the TAP project (Trans-Adriatic-Pipeline) that intends to connect the Eurasian corridor[61]—where also Nabucco will be situated—to Southern Italy. From an EU-perspective, the TAP will not be an import pipeline as it only constitutes a connection between two EU countries (Greece and Italy).

Given "business as usual", the capacity of the planned pipelines can be assessed as follows: The

60 Claus Hecking/Wolfgang Proissl, "Kalter Krieg", *Financial Times Deutschland*, 22/7/2008, p. 23.

61 The supply route via Turkey to Southeast Europe is called Eurasian or "fourth" corridor in order to differentiate it from the gas supply from the North Sea, Africa or Russia.

EU-Trends-2007-scenario assumes that there will be an additional import demand in the European Union of about 148 billion m³ by 2020 and of 194 billion m³ by 2030. Taking into account that the capacities of some of the existing pipelines will increase due to new compressor stations, and assuming that all mentioned new pipelines will be completed within the announced timeframe, there should be enough pipeline capacity even in 2020 (today the existing pipeline capacity is not always completely utilized). For the period after 2020, additional options for natural gas supply have to be produced, though.

Reversely, this means that from today's perspective all announced pipelines will be necessary for supplying the natural gas demand, particularly if the demand will further increase based on the measures suggested in this study. The sliding timescales for putting the pipelines into operation provides an opportunity to react, to a certain extent, to current developments. This constitutes, however, also a risk for the Nabucco pipeline project. As the other projects are in a more advanced planning stage it might be difficult for Nabucco to acquire sufficient transport or gas supply contracts before it starts operation in 2013. Routing the pipeline through the Caspian Sea in order to connect it to the Central Asian gas reserve does not seem to be likely for the foreseeable future due to unresolved territorial claims. And it remains questionable whether there is sufficient gas in Azerbaijan for the respective contracts.

It might be a solution to build connecting pipelines to Iran or—something that has not been discussed sufficiently yet—to Iraq. As Iran is currently to a large extent politically isolated due to its uncompromising position in the nuclear conflict, in the medium term Iraq might become an important gas supplier and partner in the region. The country has gas reserves that are larger than those of Norway which are supposed to last for another 33 years. Iraq's gas reserves have been hardly opened up due to the missing infrastructure. Today the gas that is a by-product of oil production is mainly flared. The volumes are substantial regarding both export and climate protection potential. The *Shell* group announced in September 2008 that it had signed a framework agreement for a joint venture that plans to utilize this gas. Only in Southern Iraq, the volume of flared gas amounts to more than 7 billion m³ per annum.[62] As the country's hydrocarbon reserves have not been explored systematically for several years, it is likely that there will be more gas detected in Iraq in the future. In order to be able to adequately utilize these reserves, Iraq itself has to fulfil several prerequisites. In addition to the imperative improvement of the security situation and the long overdue adoption of the oil legislation, Baghdad should abandon its sole focus on oil and put stronger emphasis on natural gas. Europeans would be able to contribute by explicitly announcing their interest in Iraqi natural gas and, for instance, co-finance a feasibility study regarding the connection of Iraqi gas fields to the Nabucco pipeline. A key to the success of such a strategy would be to involve the Kurds in such an agreement.

The insecurity of whether there is sufficient gas for the Nabucco pipeline could prevent private investors—that are liable with their capital for the project's success—from taking the final decision in favour of the construction. If the EU wants this useful pipeline to be built it has to increase its efforts for overcoming the obstacles against this project. In addition to the suggested feasibility study and the dialogue with Iraq, this includes a continued top level "gas diplomacy" with the Caspian littoral states. It remains however doubtful whether the EU will be able to mediate in the territorial conflict regarding the crossing of the Caspian Sea. The EU should also agree on a joint position on how to deal with Iran regarding natural gas supply. These considerations should be seen in the context of the international efforts to reach an agreement in the nuclear conflict.

Liquefied Natural Gas (LNG)

Natural gas becomes liquid when it is cooled down to −162°C, its volume then decreases to one six-hundredth in comparison to the gaseous state. The liquefied natural gas (LNG) can be transported over large distances in tankers, and thus is more like crude oil than gaseous natural gas that is transported in pipelines. Today's largest LNG tankers with membrane technology have a transport capacity of 256 000 m³ of LNG; that corresponds to more than 150 million m³ of

62 Press release of Royal Dutch Shell plc, www.shell.com/home/content/media/news_and_library/press_releases/2008/iraq_shell_gas_agreement_22092008.html (accessed September 25, 2008).

natural gas. The liquefaction in the exporting country and the re-gasification in the target country require a sophisticated infrastructure, though, the dimension of which determines the respective capacity. The LNG import terminal in Rotterdam (Gas Access To Europe, "Gate"), for instance, that is currently under construction will have a capacity of 12 billion m³ of natural gas which requires more than 130 ship loads of LNG.[63] At a high utilization rate, three such terminals would be sufficient to import an annual capacity equivalent to that of the Nabucco pipeline. Currently, there is a technology under development for re-gasification of LNG onboard the tanker. This would abolish the need for re-gasification facilities in the import harbour. It would only require sufficiently strong gas pipelines for transporting the gas from the ship.

Whereas pipeline gas mainly is traded in three regional markets (America, Europe, Asia), currently a fast growing world market for LNG develops, mainly with an Atlantic and Pacific focus. LNG volumes that are traded internationally have doubled between 1995 and 2005. According to scenarios produced by Cedigaz, global LNG trade could increase until 2015 by another 75 percent.[64] In 2005, LNG supplied only 7 percent of international natural gas demand, though.

Traditionally, there is more import capacity than export terminals, with a worldwide ratio of 2.2 to 1 in 2005. This means that the importing countries compete for the scarce export capacities. This trend is further aggravated by ships with integrated re-gasification. Due to its infrastructural similarity to the crude oil market, the LNG market will increasingly adopt characteristics of the international crude oil trade. LNG will lead to a higher volatility and certain price adjustments at the natural gas spot markets as the international tradability of the merchandize can produce compensating effects between the markets. After loading, LNG tankers can be directed towards the market with the highest prices. Subsequently, the other trading places cannot but adjust the spot market prices if they do not want to lose out in the competition for LNG supplies.

LNG makes natural gas available, even if there is a long distance between the places of production and consumption. This results in new supplying relationships, to Qatar for instance, that has the by far largest international export capacities for LNG. Nigeria, too, develops into an important energy supplier. In August 2008, the German Minister of Foreign Affairs was able to sign a Declaration of Intent regarding an intensified cooperation of the two countries in the energy sector. It includes among others the supply of liquefied natural gas from the year 2014 onwards.[65]

Currently Europe supplies about 10 percent of its gas demand with LNG (2007: 47 billion m³), the import capacity amounts to approximately 100 billion m³ p.a. Europe can participate to a limited extent in the large growth of the international LNG market. Several European countries currently expand, build or plan LNG-import terminals. The total capacity that is currently in the construction or planning stage amounts to more than 110 billion m³, i.e. a doubling of the capacity is conceivable.[66] However, some of these projects have been in the books for several years without significant progress being made. An example is the project of *E.ON Ruhrgas AG* in Wilhelmshaven. Obviously, LNG supply is not necessarily profitable in Central Europe with its extensive pipeline systems. Therefore E.ON has not taken the decision to build this national project yet. On the other hand though, the company announced that it will invest in the planned LNG terminal in Rotterdam and has reserved 3 billion m³ of its total capacity of 12 billion m³.

Over the next years, the largest LNG capacities will be built in the UK. The largest European gas market needs alternatives to supply its gas demand when national production decreases. But also Italy and Spain build substantial import capacities.

It is noticeable, that there are hardly any LNG capacities in the Baltic Sea area. The only project (2.5 billion m³) which is planned by the Polish company PGNiG is likely to be built in Swinouscie. Despite the strong dependency on Russian supplies, the economic threshold for LNG projects appears to increase the closer the import terminal is located to the Russian gas wells. As Russia is considering the construction of an LNG export terminal in St. Petersburg, the

63 *E.ON Ruhrgas steigt in Gate LNG-Terminal in Rotterdam ein. Wichtiger Meilenstein für die Versorgungssicherheit Deutschlands,* 5/8/2008, www.presseportal.de/pm/55267/1240973/e_on_ruhrgas_ag/> (accessed August 11, 2008).
64 Petroleum Economist (Ed.), [Map] *The Future of LNG* (London, 2007).

65 Andreas Rinke/Klaus Stratmann, "Abkommen mit Nigeria: Berlin sucht neue Energiepolitik", *Handelsblatt*, 1/9/2008, www.handelsblatt.com/politik/international/berlin-sucht-neue-energiepolitik;2030585 (accessed September 24, 2008).
66 Terminals currently in the construction or planning stage: UK: 7 (ca. 39 billion m³), Italy: 4 (ca. 24 billion m³), Spain: 3 (22 billion m³), The Netherlands 3 (> 12 billion m³) as well as Poland, France, Germany and Croatia 1 each, www.gie.eu.com/maps_data/lng.html (accessed August 14, 2008).

Polish intention to become independent of Russian gas supplies through a national LNG terminal may finally become economically unfeasible. The reason is that all supplies from other countries than Russia would have competitive disadvantages due to the much larger distances; and a diversification would be permanently achievable only with state support. However, a Polish LNG terminal would enable a supply of natural gas from non-Russian sources even though this will not be normally the case.

The European gas industry is fast creating an LNG infrastructure, at locations that promise economic advantages. The import capacity will, by the middle of the next decade, largely exceed 200 billion m³ p.a. Due to the internal dynamics of this process, there does not seem to be the need for political actions apart from a generous project approval practice by the public authorities. Only the Polish project might require support in form of debt guarantees. Poland has to take the decision whether it wants to use guarantees to mitigate the economic risk associated with this project. However, there might be more cost-efficient solutions to improve the security of gas supply in Poland.

Despite the expansion of capacities in Europe, LNG will continue to be the "junior partner" of gas supply as pipelines in most cases will remain the more economic solution.

Biogas

Biogas is a gas mix mainly consisting of methane and carbon dioxide which can be produced from vegetable or other biogenous materials, dung or liquid manure. The production uses either a fermentation technology where the raw material is fermented with oxygen being sealed off ("anaerobic") or it applies biomass gasificaion to produce bio-synthetic natural gas (bio SNG). This technology mainly uses wood for gasification.

Biogas can be used either directly for power or heat production or as a fuel. It can also be purified and compressed into a gas with a methane proportion of 95 percent. Then it is called bio-methane; it is completely compatible with natural gas and can be—using the corresponding technology—fed into the existing natural gas networks.[67] In supply areas with a very high calorific value (e.g. North Sea gas) , it may be necessary to increase the calorific value of the biogas by mixing it with (fossil) liquefied gas (e.g. Propane, Butane) in order to maintain the combustion characteristics of the conventional gas in the gas network. The network supplies a mix of biogas and natural gas that can be used exactly like pure natural gas in all gas-operated appliances/facilities (heating, CHP, natural gas-driven vehicles etc.). Due to its compatibility with natural gas, biogas has the advantage of supplying consumers directly via the existing gas network infrastructure. As far as its application as vehicle fuel is concerned, it faces the same infrastructural challenges as described above.

The assessment of the biogas potential depends on several framework conditions. The Faction Bündnis 90/Die Grünen of the German Bundestag has commissioned the Institute for Energy and Environment in Leipzig/Germany to analyze the feasibility of a European biogas feed-in strategy. The study concludes that the potential of the EU-27 and the European successor states of the Soviet Union—provided that each country is able to produce its own food—may amount to 300 billion m³ in 2005 or 500 billion m³ in 2020. These maximizing considerations do not take into account the competition of other energy utilizations (e.g. wood production for the heat sector, rape cultivation for bio-diesel etc.).[68] Nevertheless, it shows clearly that biogas has a significant potential. If only 10 percent of this potential was utilized, at least the annual capacity of the Nabucco pipeline would be supplied as distributed production.

Due to discussions on utilization competition with food and the efficient use of scarce subsidies, in 2007 the Wissenschaftlicher Beirat Agrarpolitik (WBA) at the German Federal Ministry for Food, Agriculture and Consumer Protection has scrutinized the biomass promotion scheme. The WBA recommended focusing the German bio-energy policy on bio-energy production in heat-driven CHP or heating facilities based on wood chips, on the one hand, and on biogas from liquid manure and residual material, on the other hand. Given that politics wants to promote an increased proportion of bio-fuel, WBA recommended a consequent promotion with focus on biogas fuel and

67 In individual cases, the varying gas quality can lead to feed-in complications.

68 Bündnis 90/Die Grünen, *Möglichkeiten einer Europäischen Biogaseinspeisungsstrategie* (Berlin, January 2007), www.gruene-bundestag.de/cms/publikationen/dok/203/203923.reader_europaeische_biogaseinspeisestrat-print~1.html> (accessed August 13, 2008).

direct feed-in into the natural gas network.[69] Also the European countries dispute the appropriate bio-fuel strategy.

Against this background, it seems to be recommendable to newly adjust biomass policy throughout Europe and to increase efforts to promote biogas. The WBA recommendation to single out biogas might be a feasible way. A focus on liquid manure and residual material (such as suggested by the WBA) would lead to a total EU potential of "only" 20 billion m³, though. The large potential of energy crops and residual wood should therefore not completely remain unutilized. This study assumes that the biogas potential might amount to a minimum of 50 billion m³ p.a. by the year 2030. Feeding biogas into the natural gas networks means there is no direct increase of the biogenous proportion of fuels. However, using natural gas as vehicle fuel indirectly leads to the same goal: An increasing biogas share in the natural gas supply and a larger number of natural gas-driven vehicles will simultaneously reduce the dependence on oil in the traffic sector and decrease CO_2 emissions of the total natural gas utilization.

Natural gas storage

The underground storage of natural gas constitutes an opportunity for balancing supply and demand in the short till medium term. Strategic energy reserves, on the other hand, are a tool for managing the consequences of unforeseeable supply cuts and to keep the damages to the affected national economy as low as possible. An example are oil reserves that are calculated to last for 90 days (related to the corresponding import demand) and are stored by the IEA member states. In the case of severe supply interruptions, several mechanisms enter into force, one of them being the release of this strategic reserve. During its 30 years of existence, the IEA has only twice reacted to supply interruptions with the release of oil reserves: during the 1991 Gulf war and following hurricanes Katrina and Rita in 2005. In other cases, it was considered to be sufficient to limit consumption or to increase production in order to manage the supply crisis.

69 Federal Ministry of Food, Agriculture and Consumer Protection, *Nutzung von Biomasse zur Energiegewinnung – Empfehlungen an die Politik*, November 2007, www.bmelv.de/cln_044/nn_751706/SharedDocs/downloads/14-WirUeberUns/Beiraete/Agrarpolitik/GutachtenWBA.html, p. ii (accessed August 13, 2008).

There is no comparable mechanism for natural gas yet. On the one hand, this is due to the regional character of the gas markets in North America, Europe and Asia which makes an "intercontinental" solidarity in the gas area impossible. On the other hand, it is more costly to store natural gas than oil as it requires sophisticated technology and a specific geological formation for underground reservoirs to store large gas volumes. Despite that, the question remains whether Europe should introduce compulsory standards for a minimum storage of natural gas in order to increase the security of natural gas supply. This would correspond—provided that there is an efficient compensation mechanism in the case of a crisis—to the term of energy solidarity which is part of the EU energy strategy. The energy strategy also mentions gas storage as a possible measure for an increased security of supply. It continues though that storage has to be preceded by a detailed cost-benefit-analysis from the consumers' perspective. The Commission's package "Security of supply" will, among others, include a revision and evaluation of the EU Directive on the security of gas supply from the year 2004. This might initiate a consultation process which could result in compulsory goals for gas storage.

Gas storage has been a routine for many years in the gas industry as it allows the balancing of large differences in consumption during winter and summer. As 70 percent of the natural gas is used for (temperature-related) heat production, demand fluctuates much more between summer and winter than that of oil. Table 10 shows that a number of European countries have significant storage capacities. The 130 underground reservoirs existing in the EU have a working gas storage capacity that corresponds to 17 percent of total European demand (2006). An additional 92 reservoirs are in the planning or construction stage, some of these projects are upgraded existing reservoirs. The planned projects would have a capacity of 9 percent of European demand in 2006. This means that in total one fourth of the European demand could be stored. However, efforts in this direction vary considerably between the countries. This is mainly due to geological aspects, but also to the relative importance that natural gas has in the energy supply of the respective country.

The following suggestions should be taken into consideration for a further discussion of natural gas storage:

- In principle, the gas industry has an interest in gas storage, but not in storing "strategic" natural gas reserves.

Table 10
Working Gas Volume of Existing and Planned Gas Reservoirs in the EU (million m³)

Country	*Existing capacity*	*Planned capacity*	*Consumption 2006*	*Capacity vs. Consumption 2006*
Austria	4020	2400	8285	49%
Belgium	659	100	16659	4%
Bulgaria	350		3223	11%
Czech Rep.	2891	770	8417	34%
Denmark	1001		5040	20%
France	11860	2030	44022	27%
Germany	19138	7975	88319	22%
Hungary	3720	1600	12728	29%
Ireland	210		4459	5%
Italy	13955	8357	76872	18%
Latvia	2300		1563	147%
Netherlands	5078	3920	38107	13%
Poland	1575	1225	13747	11%
Portugal	150	30	4044	4%
Romania	2694	2350	16229	17%
Slovakia	2600		5975	44%
Spain	3829	5251	34463	11%
Sweden	1		980	0%
UK	3980	6624	90060	4%
Total EU	80011	42632	473193	17%

Note: The EU countries that are not included do not have any gas reservoirs.

Source: Gas Infrastructure Europe, Storage Map, <www.gie.eu.com/maps_data/storage.html> (accessed August 14, 2008), amended by Robert Sedlacek, "Untertage-Gasspeicherung in Deutschland", Erdöl Erdgas Kohle,123, no. 11 (2007), p. 430.

- Given the high costs of gas storage it should be analyzed which reservoirs are really necessary to increase the security of supply to the intended extent. It is preferable to build reservoirs in countries with favourable geological conditions.
- As cross-border capacities cannot be arbitrarily increased, countries (or regions) with just one gas suppliers should attempt to build additional storage capacities.
- Interruptible gas contracts—which already exist—could be an alternative to gas storage. Such contracts enable large (mainly industrial) gas consumers to interrupt the purchase of gas and temporarily use other energy carriers, such as oil or liquefied natural gas. Each member state decides individually whether it will comply with the storage obligations in its own country or whether it will secure supplies through interruptible contracts of national customers or through supply contracts with operators of reservoirs in other member states.
- Both storing and possible interruptible contracts have to be monitored in order to secure the availability of gas.
- It should be analyzed where additional transit capacities would be required in order to really allow for "solidarity" in an emergency case.
- Crisis reaction mechanisms for supply interruptions (that are nobody's fault) have to be created and formalized.

Gas Balance 2030 and Conclusions

The following table (see p. 36) summarizes the options of an expanded European gas strategy presented in this chapter. It shows clearly that the European gas supply can be secured even given an increased natural gas use. Under realistic assumptions regarding the development of the demand and the utilization, there will be no capacity shortage in 2030. It is more likely that there will be excess capacities until that time which would allow for other supply scenarios. The result confirms other studies that were able to use elaborate quantitative models.[70]

The EU's options for implementing the supply side of the described gas strategy, such as the construction of new pipelines, the diversification of sources, an increased LNG supply, a larger production of biogas and the expansion of gas storage capacities, are numerous and complement each other. If they are combined with a strategy for improving energy efficiency—which deals with the demand side—there are good prospects for a long-term security of natural gas supplies in Europe. The competitiveness of the energy supply is not affected by such a strategy. In addition, feeding biogas into the networks is not only an opportunity for substituting a part of the import demand, but for further improving the sustainability of natural gas utilization. From this perspective, an increase of the gas share does not only constitute a responsible step towards the reduction of CO_2 emissions in the heat markets and the transport sector, but also an important contribution to the European energy and climate policy.

70 Bothe/Lochner, "Erdgas für Europa" (see note 27). This study assumes a natural gas demand of 818 billion m³ in 2030 and arrives nevertheless at the conclusion that the natural gas supply can be secured through new pipelines.

Table 11
Possible Gas Balance for the EU-27 in 2030

	Bottle neck capacity		*Utilization*	*Realistic capacity*	
	Mtoe	*billion m³*		*Mtoe*	*billion m³*
Gas demand 2030 acc. to baseline-scenario 2007	516	574		516	574
(−) Demand reduction through increased efficiency	79	88		79	88
(+) Additional demand due to expanded gas strategy	123	137		123	137
(=) Gas demand 2030	**560**	**622**		**560**	**622**
European production (EU-27) (2030)	85	94	100%	85	94
Import pipelines capacity 2008	360	400	80%	288	320
LNG terminals capacity 2008	92	102	40%	37	41
Biogas potential (EU-27) 2030	45	50	90%	41	45
Planned import pipelines	125	139	80%	100	111
Planned LNG terminals	102	113	40%	41	45
Production/import capacity 2030	**809**	**898**		**591**	**656**
Capacity excess (+) or shortage (−)	248	276		31	34

Abbreviations and Glossary

BtL	Biomass to Liquid Liquid fuel produced synthetically from biomass
CCS	Carbon Capture and Storage
CNG	Compressed Natural Gas In vehicles, it is stored at about 200 bar in special tanks
CO_2	Carbon dioxide
CtL	Coal to Liquid Liquid fuel produced synthetically from coal
EEA	European Environment Agency
End energy	The energy that is used by end consumers, i.e. also private households, in businesses/trading/service facilities in the industry and in the traffic industry (see also “primary energy”)
Europe	This study always uses the term to refer to EU-27, unless explicitly stated otherwise.
EU-27	All member states of the European Union in 2008.
GHG	Greenhouse gas
GtL	Gas to Liquid Liquid fuel produced synthetically from natural gas
IEA	International Energy Agency
ktoe	Thousand(Kilo)tons oil equivalent = 41.9 Terajoule
LNG	Liquefied Natural Gas Natural gas can be liquefied by cooling it down to −162°C. Then it does not need to be compressed, but reduces its volume to about one six-hundredth of its gaseous volume due to liquefaction. Cooling is ensured through vaporization of part of the gas.
LPG	Liquefied Petroleum Gas “Car gas” also: liquid gas, not to be confused with LNG. LPG is a butane-propane-mix which becomes liquid already at 6 bar and does not need to be compressed as much as natural gas. Butane and propane are higher quality hydrocarbons that occur at mineral oil production and have an availability that is similar to that of oil. Their environmental impact lies between natural gas and mineral oil. This study has not included a detailed analysis of LPG as an option, due to its similarity to oil.
Mt	Megatons = million tons
Mtoe	Million (Mega)tons oil equivalent = 41.9 Petajoule
OPEC	Organization of the Petroleum Exporting Countries
Primary energy	Describes the total energy consumption of a national economy in its “primary” occurrence, i.e. before it is converted into power, long-distance heat, petrol or similar (end) energy products.
Synfuel	Generic term for synthetically produced fuels. It is possible to produce these fuels with a uniform high quality independent of the raw material. Synfuel has the advantage that engines can be optimized to it and thus reach a high efficiency. However, production costs of synfuel exceed those of conventional fuels by far, and even significantly that of CNG
TAP	Trans-Adriatic-Pipeline
toe	One ton oil equivalent (toe) is the amount of energy of a certain kind of crude oil and corresponds to about 41.9 Gigajoule
UNFCCC	United Nations Framework Convention on Climate Change
WBA	Wissenschaftlicher Beirat Agrarpolitik (German Federal Government)