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Current Issues

Energy prospects after the petroleum age

- In the 1990s low energy prices seemed to suggest that energy supplies were secure. But in the last two years surges in the price of oil, the number one source of energy, and power outages in North America and Europe have shown the urgent need for a renaissance in energy policy targeting secure supply.
- At the latest when discoveries of new reserves fall short of demand – which may be the case in just a few years for oil, and slightly later for natural gas – energy prices will climb significantly. The supply situation is being made more acute by the growing hunger for energy in China and India.
- This foreseeable shortage must be addressed with intelligent, future-proof strategies. In the longer run, securing energy supplies will be possible only with a broad range of measures. The needs of the moment call for the use of all available levers – the diversification of energy carriers and technologies and the mobilisation of all conservation, reactivation and efficiency-boosting strategies.
- Hopes for the modernisation of power plant parks are pinned on CO₂-free coal-fired power plants and safe fourth-generation nuclear power stations. They could trigger a renaissance in coal and nuclear energy, also in Germany. A future for energy without higher shares of renewables is inconceivable; their price competitiveness will be buoyed by the growing scarcity of fossil energies.
- Massive R&D efforts are needed to smooth the way to solar hydrogen energy. Decentralised supply structures on the basis of efficient fuel cells would reduce the risks of widespread power outages. Moreover, particularly in the private consumer sector, still too little attention is being paid to energy conservation and efficiency.
- Germany and Europe should not wait for US leadership in energy policy and ensuing geopolitics. Steps must be taken to counteract the monopolisation of pipeline routes for natural gas so that competition can unfold. The predictable intensification of competition for new energies and technologies on the part of the USA will ultimately benefit energy suppliers in all countries.
- Owing to the gradual depletion of oil and gas reserves and the need to reduce the environmental problems of energy consumption, the energy mix of the future will contain a far lower proportion of fossil energy than it does today.
- In the period to 2030 alone, the investment required to modernise and expand the energy supply infrastructure in the world will cost USD 16 trillion. The bulk of this, almost USD 10 trillion, will have to be spent on the electricity industry, more than USD 2 trillion of the total in China. Germany must replace half its total power plant capacity of 120,000 MW.

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Energy prospects after the petroleum age

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1. No prosperity without energy

Since time immemorial securing the supply of energy has been one of mankind's basic needs. Not until fire was domesticated could civilisation start taking leaps forward. Without energy there is no light, no warm meals, no protection against the cold in winter and the heat in summer, no modern tools, machinery and transportation.

Dependence shock put an end to nonchalance

The two oil price and energy crises towards the end of the last century (1973/74 and 1979/80) abruptly cut the ground from under the growth euphoria widespread at that time in the industrial countries. The security of energy supply, thrown suddenly into doubt, became the main thrust of energy policy. A raft of countermeasures were launched.

In the aftermath of the two oil price and energy crises the dependence shock elevated the security of supply to the lynchpin of Germany's energy policy. The focus was placed on measures to reduce reliance on imports. A basic consensus existed in politics and business on the need to maintain a high proportion of primary energy from domestic sources. Environmental and market criteria, though, were of minor importance. High subsidies to keep up domestic output of hard coal, for example, were – and, indeed, still are – testament to this.

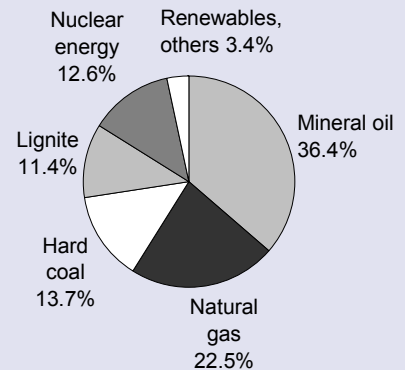
At first sight, securing energy supply now appears more problematic than it used to be. In the 1950s the Federal Republic of Germany was a net exporter of energy; today, Germany is a net importer. In 2003 it satisfied 74% of its energy requirements with imports. Net imports of energy (purchases less deliveries) cost EUR 34 bn.¹

Initial increase in security of energy supply after oil price shocks

Nonetheless, owing to a variety of energy policy measures, the supply situation at the end of the 1990s was considerably more relaxed than at the beginning of the first oil price crisis:

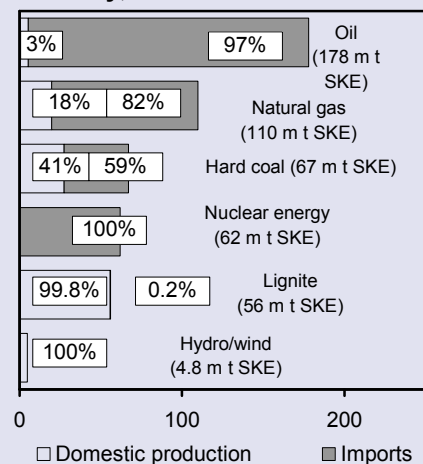
- The "away from oil" policy broadened the range of energy carriers and regionally diversified the procurement of energy, reducing reliance on potential crisis countries or regions.
- On the demand side, various different measures to boost energy efficiency have decoupled energy consumption and economic growth.
- In the oil sector, the North Sea finds of latter decades, the International Energy Agency (IEA) emergency response system, the compulsory maintenance of stocks of mineral oil products and, in the downstream sector, capital ties with the producing countries have eased the situation.
- What is more, the international energy markets are now functioning better. Whereas posted prices used to apply in the oil business, nowadays oil quotations result from the free interplay of supply and demand on special commodity exchanges. In North America this is the Nymex, in Europe the IPE, in Asia the SGX. Quotations reflect shortages on the market and provide greater transparency and calculability. Additionally, risks can be hedged on futures and options exchanges. All this indirectly increases the security of supply.

Primary energy consumption Germany, 2003



Source: Arbeitsgemeinschaft Energiebilanzen

Dependence on energy imports Germany, 2003



Source: Arbeitsgemeinschaft Energiebilanzen

¹ See Schiffer, H.-W., "Deutscher Energiemarkt 2003", ET, Heft 3, 2004.



Meanwhile similar marketplaces also exist for electricity and, in rudimentary form, for natural gas.

2. Renewed focus on securing supply

After the energy crises, for many years the security of supply had comparatively low priority as an energy policy target as the countermeasures adopted swung into effect. The price of mineral oil, the primary source of energy, remained relatively low. In the three-pronged energy concept, the two other goals – economic efficiency and environmental protection – were increasingly prioritised. The EU embarked on liberalisation of the markets for the grid-bound energies electricity and natural gas to make energy supply more cost-effective. Also, new instruments were crafted to curb the growing damage to the environment resulting from the escalation in energy use worldwide. These include support schemes to encourage regenerative energies and emission rights trading.

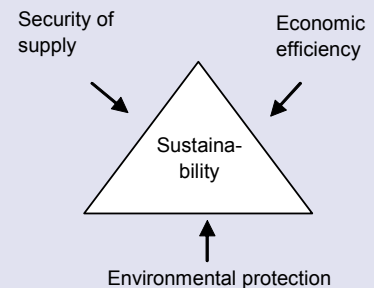
Up to the end of the 1990s the security of energy supply led a shadowy existence. Better functioning markets and lower energy prices implied a level of supply security that seemed written in stone, at least for the coming years.

Another severe blow to confidence in supply

Recently, however, confidence in the security of energy supply has been dealt several blows:

- In 2003 some industrial countries suffered **power failures** that, if at all, had previously been believed likely only in developing countries. The USA, Italy and Scandinavia were affected, making it abruptly clear that in the industrial countries, too, the electrical power supply was in need of closer scrutiny and improvement. Over a longer time frame the security of power supply is by no means a given – even in Germany, which can boast a relatively closely-knit power grid with outage times way below comparable international statistics. This signals the need for substantial investment in the modernisation of grids and power generating capacities. Added to this is the process of EU enlargement (both the recent expansion and that expected going forward), requiring more heavy investment on modernisation of the energy sector.
- As if there had been any need for proof of renewed uncertainty over energy supply and hence dependence, the price of **mineral** oil soared in the run-up to the war in Iraq at the beginning of 2003. The subsequent correction was short-lived, with oil quotations already hitting new nominal highs by 2004. **Demand push** was an important factor, with more energy being used in particular by the industrial countries (economic upswing), the Central and Eastern European countries and Russia (transition process), and the heavily populated Asian countries (as purchasing power grows throughout broader sections of the population in China and India, the hunger for energy increasingly filters through to demand). In China and India alone, which are home to more than one-third of the world population, the demand for energy is expected to double by 2020.²
- But that is only one side of the coin. On the **supply side** OPEC has proved incapable of permanently stabilising conditions in the oil market. Its influence has waned. The reliability of the

Triangle of objectives in energy policy



Emission rights trading

As part of the European Union's implementation of the Kyoto Protocol, the EU will launch trading in emission rights on January 1, 2005. The emissions trading system creates an economic basis on which to reduce emissions of the climate-damaging greenhouse gas CO₂ in the most cost-efficient way. Ecologically effective behaviour is thus put into economic practice. Business sectors, and every industrial plant affected, will be assigned specific reduction targets and allocated corresponding emission credits free of charge for the first trading period. Being tradable, the certificates serve as a kind of currency. If a company meets its targets through cost-effective CO₂ reduction measures of its own, it can sell on the certificates it does not need in the marketplace. Alternatively, if its own reduction methods would prove too expensive, it will have to purchase additional certificates on the market.

Source: Federal ministry of the environment; see also Heymann, E. "EU trade in CO₂ emissions: 2005 launch deadline at risk", DBR, Current Issues, December 2, 2003

² See also Umbach, F., "Sichere Energieversorgung auch in Zukunft", in: Internationale Politik, August 2004.

major oil exporter, Saudi Arabia, which has traditionally assumed the role of swing producer in supply emergencies by boosting or curbing oil output to balance out the market, has been cast into doubt. The fall of the House of Saud would have a markedly destabilising effect on the oil market. For quite a while now, the agreed OPEC price band has been virtually obsolete. This is one reason why international speculators have (re-)discovered the oil market. The powerlessness of OPEC and non-cartel suppliers to provide reliable market orientation is a source of growing disquiet. Moreover, political instability in important producer countries (e.g. Iraq, Venezuela, Nigeria) and global terrorism, which has identified the production facilities and transport routes of “black gold” as potential targets, are fanning fears of shortages. The danger of delivery shortfalls makes a logical case for stepping up strategic reserves.

- **Real oil prices** have not yet reached their former highs, but that is of little consolation. The longer-term price trend points upward. For months, prominent oil companies and producing countries have been revising their estimated reserves downward.³ This points to lower ranges than many experts had previously assumed, fuelling uncertainty about the longer-term supply situation and hence the price outlook. The signs are mounting that a physical scarcity of mineral oil must be expected much sooner than anticipated. Extreme forecasts predict that production of known reserves will already peak at the end of this decade.

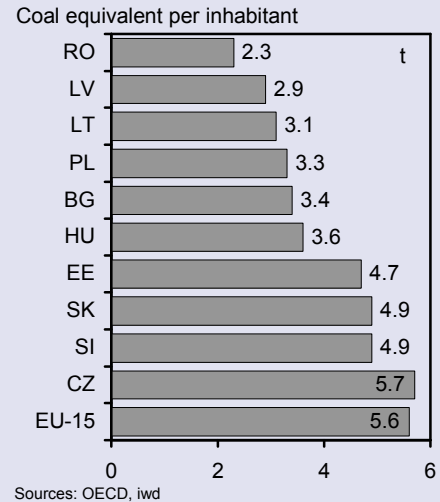
Should the forecasts on the longer-range security of supply prove correct, it is high time to ask the following fundamental questions: Just how safe is our energy supply? What will come after the oil age? What strategies must be pursued to secure our energy needs?

Renaissance in the security target also in the EU

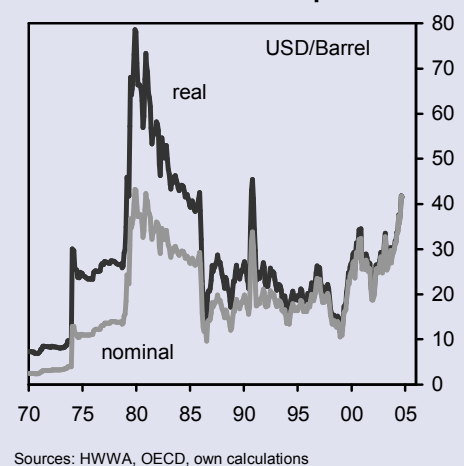
The signs are growing that the renaissance in energy policy targeting secure supply is here to stay, suggesting a change in direction. Indeed, the altered set of data on the security situation may call for a fundamental realignment of energy policy.

The European Commission gave a timely warning that the crisis in the supply situation was coming to a head. With crude oil prices having risen threefold since March 1999, at the end of 2000 the Commission presented its Green Paper “Towards a European strategy for the security of energy supply”, stating that without an “active energy policy” in the next 20 to 30 years 70% of the Union’s energy requirements would have to be met by imported products (as opposed to 50% at the time of the study). In geopolitical terms, 45% of oil imports come from the Middle East and 40% of natural gas from Russia. This increasing dependence, the Commission says, has implications for all sectors of the economy: transport, the private consumer sector and electricity generation are at the mercy of erratic swings in world market prices for oil and gas. But this certainly does not imply that the Commission is seeking to maximise energy self-sufficiency. Its aim is to achieve a balance between, and diversification of, the various sources of energy and geographical regions. Initiatives, strategies and measures are needed to increase the security and cost-efficiency of energy supply.

CEEC energy consumption, 2001



Real and nominal crude prices



³ See, for example, Porter, A., “The elusive truth about oil reserves figures”, Aljazeera, August 12, 2004.



3. Reinterpretation of secure supply

The energy policy objective of supply security goes far beyond the microeconomic perspective, i.e. the viewpoint of an individual company or private household. Rather, it focuses on securing an adequate supply of energy to lubricate and drive the global economy, so to speak.

In recent years the concept of sustainability has established itself internationally as part of the broader energy and environment issue, necessitating a wider definition of supply security. The security of energy supply should be achieved for present and future generations (intergenerational security of supply), while also accommodating the rights of the “weak” (intragenerational security of supply). Whereas the first aspect calls for the conservation of natural resources, the second is based on considerations of equity (the “right to development”) and accentuates industry’s “global responsibility” towards the emerging markets and developing countries.

Another shift in emphasis results from increasing European integration. The supply security concept can no longer stop at national borders. But a reinterpretation of the aim of securing supply in “European” terms could have far-reaching consequences. Challenges lie not least in the formulation of a common European security concept and in issues of financing and institutional jurisdiction.

4. Longer-term price increase just a matter of time

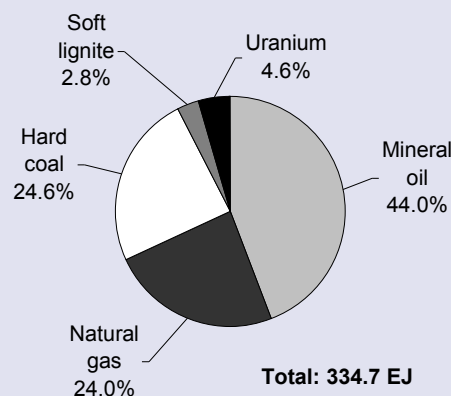
On a global scale mineral oil and natural gas are the most important sources of energy in volume terms. Together, they constitute 68% of world output of non-renewable energy-producing raw materials, and they cover 65% of non-renewable primary energy use. At 27%, coal also accounts for quite a high proportion of both production and consumption, while uranium posts shares of 5% and 7% respectively.

The lifetime of reserves is an important factor in assessing the security of energy supply. An indication is provided by the “static lifetime”, which is calculated by dividing current reserves by annual production. Data from the Bundesanstalt für Geowissenschaften und Rohstoffe, BGR (Federal Institute for Geosciences and Natural Resources) show very different lifetimes:

- Of the conventional hydrocarbons oil has the lowest static lifetime, only 43 years, whereas natural gas notches up 64 years. The reserves of lignite and hard coal, however, will each last for more than 200 years. The non-fossil energy carrier uranium has more than 40 years ahead of it.
- Adding the resources to the reserves, the static lifetimes increase (see box p. 8). Even then, though, the potential for oil is still just 67 years. However, the lifetime of natural gas is elevated to almost 150 years and that of soft and hard coal to roughly 1,500 years each. Uranium can then look forward to about 500 years.

The determinant “static lifetime” represents nothing more than a snapshot. With the passage of time demand can cause production to be stepped up, pushing up the denominator. The numerator “reserves” and “resources” can also be expanded as a result of more sophisticated extraction technologies or new exploration methods. Experience shows this to be a realistic expectation.

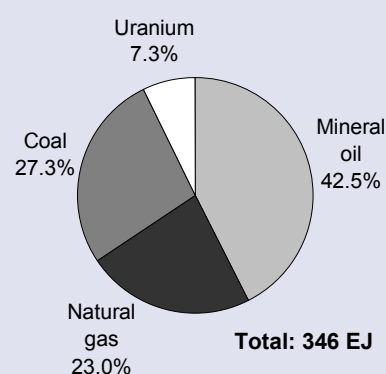
Extraction of energy raw materials*, World, 2001



* non-renewable raw materials
EJ = exajoule

Source: BGR

Consumption of energy raw materials*, World, 2001



* non-renewable energy raw materials
EJ = exajoule

Source: BGR

Static lifetimes have always been exceeded

In the past, static lifetimes have always proved too short owing to variations in the basic determinants. So far reserves have never reached the depletion stage, mainly as a result of new finds. Particularly with oil and natural gas, lifetimes have regularly been extended, partly because in recent decades the petroleum and gas industry has generally “managed” reserves for economic reasons (e.g. the high costs of exploration) in a way that keeps lifetimes for oil at around 20 to 30 years and for gas at between 30 and 40 years. That way, they could be sure of maintaining output levels without any unnecessary pressure on prices.

Among the fossil-based energy carriers, we have seen that the supply of coal is comparatively secure even in the longer term, thanks to adequate reserves and resources. In contrast, doubts are warranted with the conventional hydrocarbons petroleum and natural gas. But even here, non-conventional deposits exist that must also be taken into consideration as we look ahead:

- Non-conventional reserves of **oil** are equivalent to (only) 43% of conventional reserves. But non-conventional resources are three times higher than conventional. However, three-quarters of such resources consist of oil shale, whose use is comparatively expensive and entails environmental problems. Meanwhile, production costs for tar sands and extra heavy oil (accounting for roughly one-quarter of resources) are approximately on a par with the levels for conventional oil, as shown by projects in Canada and Venezuela. The outlook is thus far more benign than with oil shale. Even so, use is likely to remain restricted to specific regions in the coming years.
- Non-conventional reserves of **gas** are relatively low, as the technology available so far permits extraction only from porous reservoir rock and coal seams. However, the BGR reports seven times higher non-conventional than conventional resources. In contrast to its reserve estimate, the gas occurring in aquifers (gas dissolved in deepwater fields) and hydrates (ice-like crystalline solids formed from a mixture of water and natural gas) is also included here. Estimates of gas potentials still feature a high degree of uncertainty. However, consensus does exist among experts that, from a geological point of view, the supply outlook is slightly more favourable than for oil.

Hydrocarbon era coming to an end

Given the very limited availability of non-conventional stocks in the short and medium range, the hydrocarbon era is increasingly likely to be coming to an end. The BGR has calculated that, between the beginning of industrial oil production and the end of 2001, 46% of the conventional mineral oil reserves hitherto identified had already been extracted. Even including the resources expected, this is still 35% of the total conventional potential. On the assumption of constant annual output and with the given reserves, the federal agency expects the “depletion mid-point” – at which half the oil presumed to exist throughout the world has already been produced and used – to be reached within the next 15 to 20 years.

The outlook for natural gas is similarly negative, as half of all the global conventional reserves are expected to have been depleted as early as 2019. However, given the progress in exploration and production technology, new finds boosting reserves and lifetimes are more likely than with oil. The turning point will therefore presumably be reached somewhat later.

Definitions:

Reserves are the quantities economically recoverable, at current prices and with the current technology, from deposits of energy raw materials.

Resources are proved quantities of energy materials that are currently not recoverable for technical and/or economic reasons, as well as non-proved but geologically possible quantities yet to be found.

Source: BGR

Coal supply comparatively secure

Outlook for tar sand better than for oil shale

Non-conventional resources of natural gas are relatively high

End of hydrocarbons foreseeable



Trend towards climbing oil and gas prices

On a longer horizon the signs point to an increasing scarcity of hydrocarbons. If only for this reason, and setting aside any politically motivated supply crises, in a few years the price of oil (and later gas) can therefore be expected to trend upward. In all probability a battle will break out over shares in the globally diminishing reserves, particularly of oil. One major factor is that, as a rule, energy-producing raw materials also constitute important basic raw materials for non-energy uses.

Criticism of reserve lifetimes – warning of early production peak

Lately, the concept of “static lifetimes” and the “depletion mid-point” have increasingly been called into question. Although “static lifetimes” do give an impression of when production will come to an end (admittedly under status quo assumptions), the term “lifetime” implies the security of supply over a period in which the energy carrier is in reality already becoming drastically depleted and a struggle can be expected for the remaining resources. So from an economic point of view, the really interesting date is not the time at which the use of reserves comes to an end, but the time of maximum production. When output starts to decline from this peak, with demand remaining constant or even continuing to rise, strong reactions in prices and economic upheaval are possible.

The Association for the Study of Peak Oil (ASPO)⁴, a group of former petroleum geologists in the service of prominent petroleum corporations (e.g. BP Amoco), argues in favour of taking a different angle. It assumes a steep ascent in the output curve up to a peak, followed by a comparatively flat descent. The result is that the peak in production comes well ahead of the depletion mid-point, meaning that the production curve peaks far earlier than hitherto anticipated. Initially this applies to oil, and then, with a time lag, to natural gas. In its mid-2004 updated forecast for oil, the ASPO brought the peak for oil forward from 2010 to 2008.

Dramatic implications of ASPO scenario

Were the ASPO scenario to prove correct, the consequences could be dramatic: Within the space of just a few years oil supply would start to shrink in the face of trend growth in global demand, driven not least by the increasing hunger for energy in the heavily populated Asian countries. ExxonMobil expects 80% of additional global demand for energy up to 2020 to come from the developing countries.⁵ In the worst-case scenario, the already emerging widening of the supply/demand gap could trigger a shortage shock leading to a price crisis. This would also impact world economic development.

Also conceivable, though, is a more or less steady climb in the price of oil (and later also natural gas), which would tend to rein in demand for the energy carrier and encourage gradual substitution. What is more, price increases would imply an expansion of the reserve base as non-conventional reserves and current resources become more price-competitive. The peak calculated with reference to “present reserves” could then be delayed for a few more years. The possibility of realigning the energy mix without radical economic disturbance would be all the more likely, the sooner politicians,

Prices will rise

From an economic point of view the time at which the use of reserves ends is of little relevance

ASPO view

Reserves of non-renewable energy raw materials, 2001 (in EJ)

Region	Hard coal	Soft lignite
Europe	1,054	569
CIS	4,460	144
Africa	917	0
Middle East	5	-
Australasia	5,552	719
North America	5,198	522
Latin America	480	0
World	17,666	1,954

EJ = exajoule

Source: BGR

⁴ See various articles from K. Aleklett and C. J. Campbell at www.peakoil.net.

⁵ See ExxonMobil, A Report on Energy Trends, Greenhouse Gas Emissions and Alternative Energy, February 2004, p. 3.

industry and private consumers respond to the signs of the times on the markets for hydrocarbons.

Venturing to look farther forward on the supply of energy, say to the end of our century, by then the future will already be behind us, at least in terms of petroleum. The end-of-fossil-hydrocarbons scenario is not therefore a doom-and-gloom picture painted by pessimistic end-of-the-world prophets, but a view of scarcity in the coming years and decades that must be taken seriously. Forward-looking politicians, company chiefs and economists should prepare for this in good time, to effect the necessary transitions as smoothly as possible.

Averages fail to capture regional dependencies

The September 11, 2001 terrorist attacks and the second Iraq war have put the subject of regional dependence firmly back on the energy policy agenda.

Although the preceding analysis has provided valuable information with which to evaluate the security of global energy supply, a broad-brush approach does not permit any assessment of the regional and country-specific situation.

Of all the fossil sources of energy, coal is the only one exhibiting a relatively non-critical supply situation the world over. Europe, North America and Australasia all possess substantial coal reserves, while the Middle East has scarcely any stocks. The picture is quite different with regard to hydrocarbons. There, it is vital to take a more discriminating approach.⁶

- In the case of oil, longer-range world supply is considered insecure not only because of the comparatively low level of reserves. The situation is compounded by the high concentration of global oil deposits in the Persian Gulf region. This adds an element of political uncertainty.
- The six Gulf states Iran, Iraq, Qatar, Kuwait, Saudi Arabia and the United Arab Emirates (the so-called Gulf OPEC) are where two-thirds of the world's deposits are located. And moving forward, these reserves will assume even greater importance, because the IEA estimates that exploitation of the Gulf reserves is progressing at a considerably slower pace than in other important regions.
- Moreover, the production increases expected from the Caspian Sea and Russia are not enough to satisfy growing world demand for oil. Because of this, and also to balance out the probable declines in output from other regions, the Gulf OPEC will have to step up their oil production on a massive scale. The result will be even greater dependence on that region.
- The world oil market is strongly integrated on the price side. International oil quotations react with reliable alacrity to new market data and price differentials not justified by different oil qualities and transport costs (the buzzword being arbitrage). Delivery flows, on the other hand, present a more varied picture: Whereas the USA obtains comparatively little oil from the Gulf region, Europe sources more than one-fifth from there, and the share of imports from Russia is similarly high. In the event of shortages on the world market, delivery routes and relations with the producer countries can also become more important. In some regions the USA enjoys a strategic advantage.

⁶ See Müller, F., "Sicherung der internationalen Energieversorgung", Working Paper, SWP Berlin, 2003.

World oil reserves Selected regions, 2001

Region	Shares of world reserves (%)	Lifetime* (years)
OECD	8	12
Russia	5	19
Caspian region	2	32
China	2	20
OPEC	78	77
Gulf OPEC**	64	91
World	100	39

* reserves: annual production
 ** Gulf OPEC: Iran, Iraq, Qatar, Kuwait, Saudi Arabia, United Arab Emirates

Sources: BP Statistical Review of World Energy, 2002; SWP, 2003

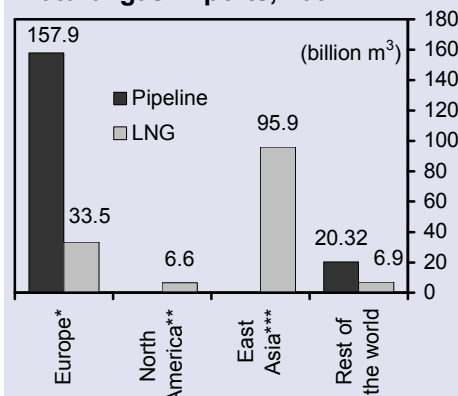
World oil production Selected regions (million barrels/day)

Region	2002	2030
OECD	21.1	12.7
Russia	7.7	10.8
Caspian region*	1.9	5.2
China	3.4	2.2
OPEC	28.2	64.8
Gulf OPEC	19.0	51.8
World	77.0	121.3
OPEC share	37%	53%
Gulf OPEC share	25%	43%

* plus other transformation countries

Sources: IEA, World Energy Outlook, 2004

Natural gas imports, 2001



* Europe west of the former Soviet Union
 ** including Mexico
 *** China, Japan, South Korea

Source: BP Statistical Review of World Energy, 2002



- International trade in **gas** requires a more sophisticated transport infrastructure than oil. This is why trading did not get underway until the 1960s. The major users so far are Russia and the OECD countries (with a share of roughly three-quarters). Whereas Europe obtains around four-fifths of its extra-European imports directly via pipelines, East Asia and North America mainly import liquefied natural gas (LNG). Given that the natural gas era is only just beginning in the fast-growing emerging markets China and India, and with North America also turning more to gas, the LNG market is expected to boom in the coming years.
- About 70% of natural gas reserves are located in the Gulf region (36%), around the Caspian Sea (5%) and in western Siberia (31%). Adding the reserves in North Africa and Europe, the total climbs to as much as 80%. In the period to 2030 reliance on imports will build up perceptibly in the major consumer regions. As regards the longer-term security of supply, it is of great benefit to Europe that roughly four-fifths of global reserves lie within a radius of 5,000 km from its centre. This geographic proximity makes transport via pipeline possible.
- So far, the organisation of European natural gas imports through pipelines has had the advantage of creating mutual dependence between the supplier and consumer countries. And, indeed, in the past there have been no interruptions in delivery (e.g. from Russia). In future gas could be transported from deposits around the Gulf (e.g. Iran). But pipeline projects are extremely cost-intensive. Favourable financing terms are obtainable only when the overall conditions can be deemed stable. Disturbances in the transport infrastructure (e.g. from attacks) could massively impair the security of energy supply, because pipeline systems are comparatively rigid structures and routing is relatively inflexible.

Strategic ellipse gaining in importance

The emerging supply and demand trends in mineral oil and natural gas highlight the fragility of our present-day sourcing structures. Seventy percent of conventional global oil reserves lie in the region extending from the Middle East to western Siberia, which geographically forms an ellipse. And extending this ellipse slightly northwards, almost 70% of the world's conventional natural gas reserves are also located there. On the supply side, we thus find a concentration of major energy sources in comparatively insecure regions, whose importance will grow considerably in future. To accentuate the region's outstanding significance for the longer-range security of energy supply, the term "strategic ellipse" has been coined for it.

5. Sustainable energy mix designed to conserve natural resources

The conservation of natural resources is increasingly coming to be recognised as an important energy policy objective. The use of fundamentally finite energy resources should therefore comply with certain rules. Before these rules can be drawn up the question of the exhaustibility and/or renewability of the energy resource must be clarified. According to the theory of natural resources, a resource is exhaustible if the pattern of its use could conceivably reduce its supply to zero. In contrast, a resource is renewable if stocks of it can be maintained despite use.

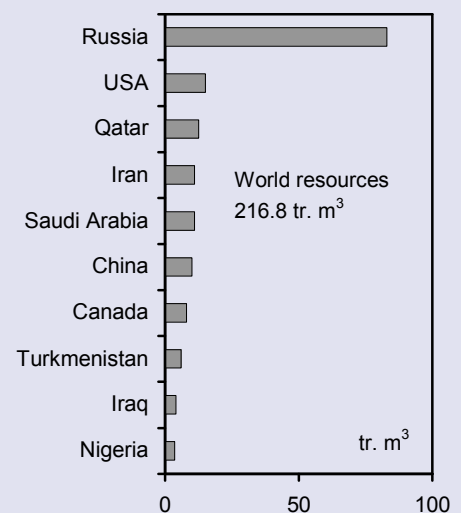
Natural gas reserves and production, selected regions, 2001

Region	Share of world reserves (%)	Lifetime* (years)
Russia	31	83
Casp./Central Asia	5	63
Middle East	36	245
Africa	7	90
USA/Canada	4	9
Europe	3	16
World	100	62

* reserves: annual production

Source: BP Statistical Review of World Energy, 2002

Conventional natural gas resources 10 major countries, 2001



Source: BGR

The following recommendations for use to help conserve resources result from the combination of resource characteristics:

- Given that biological energy resources (e.g. forests, energy grass, rapeseed) incline to depletion with excessive use, the exploitation rate should not permanently exceed the natural regeneration rate.
- Mineral energy resources (e.g. mineral oil, natural gas) are not only depletable, like biological resources, but, unlike bioenergy, also non-renewable. This disadvantage makes it advisable to use them particularly economically and to exploit them slowly, all the more so since raw materials for mineral energy that are important in terms of their quantity, e.g. crude oil, are also key components of non-energy production sectors such as petrochemicals.
- Energy sources such as solar, wind, water and tidal power do not require any special rules of use. Although man cannot renew them, neither can he deplete them.

6. Strategies for secure supply in the long run

Intelligent strategies for the future are needed to secure the supply of energy farther down the road, too. A mix of measures is particularly helpful in minimising the risks.

6.1 More renewable energies

The scarcity of fossil sources of energy looming in the longer term makes it necessary to seek alternatives. To guarantee supply security and conserve fossil-based resources, a mixture of renewable and/or non-exhaustible sources of energy would be ideal. Special rules of use (see above) need be applied only to bioenergies to ensure their regeneration (and the preservation of creation). This would, moreover, be unlikely to conflict with environmental objectives, since the energy carriers are CO₂-neutral. Of course ecologically undesirable monocultures should be avoided with bioenergies, and the entire lifecycle must be balanced.

At present the main obstacle to an energy mix of this kind is that as a rule these sources of energy are still not economical enough, particularly in the industrial countries where the demand for reliable and low-priced energy is very high. Only when this conflict of aims can be resolved by technological progress, and possibly also new basic innovations, can this ideal become reality.

Even today, renewables would automatically become more price-competitive if all sources of energy were charged with their external costs (environmental costs, intergenerational aspects). Apart from this, alternatives are likely to see their competitiveness lifted in a few years anyway, once the anticipated increasing scarcity of fossil energies is reflected in pricing. Renewables such as solar energy are already competitive in sunny, rural regions not connected to a close-knit power grid, not least in the newly industrialising and developing countries of the "sun belt", where the World Bank is supporting the installation of solar home systems in a drive to electrify rural areas. Insular solutions of this kind are economically and technically ideal for decentralised energy supply, allowing the people concerned a modicum of civilisation (e.g. clean water, information and communication). The example of "energy poverty" underscores the fact that security of supply on a global scale needs to be interpreted more broadly than the debate among the OECD countries would suggest.

Dependance on natural gas imports, 2002

Region	Net imports (billion m ³)	Share of consumption (%)
North America	0	0
OECD Europe	162	36
OECD Pacific	98	98
China	0	0
India	0	0

Dependance on natural gas imports, forecast 2030

Region	Net imports (billion m ³)	Share of consumption (%)
North America	197	18
OECD Europe	525	65
OECD Pacific	183	94
China	42	27
India	44	40

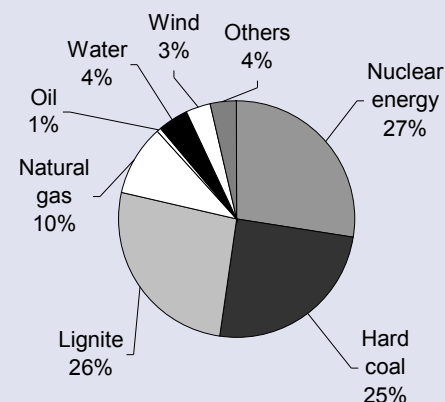
Source: IEA World Energy Outlook, 2004

Resource characteristics of energy carriers

	Depletable	Non-depletable
Renewable	Biological energy resources	
Non-renewable	Natural gas Mineral oil Coal Uranium	Tidal power Solar energy Hydro-energy Wind energy

Source: DB Research

Energy mix in power generation Germany, 2003



Source: Energy market Germany



Rising market shares in all European countries

Country-specific natural conditions form the basis for renewables to play a possible part in securing energy supply. Regenerative energy production is conditional on adequate water potential, wind speeds, length of sunshine or mean range of tides needed for tidal electric power plants. Once suitable storage media are available for alternatively generated forms of energy, distance and local conditions will become less important.

All European countries are endeavouring to achieve appreciable gains in market share for renewable energies. In Germany the new Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG) came into force mid-2004. The aim is to raise the share of renewable energies in power supply by 2010 to at least 12.5% (against 4.5% in 1997) and by 2020 to at least 20%. The EU presented a Green Paper late in 2000 as the basis for a common long-range energy strategy. It sets out to double the share of renewables in total energy consumption from 5.4% in 1997 to 12% by 2010. By 2001 just 6% had been achieved. Allowing for EU enlargement in 2004, the European Commission has set the ambitious target of ratcheting up the share of renewables in electricity consumption from 12.9% in 1997 to 21% in 2010.

Stepping up market shares for renewable energies would not be possible at present without fiscal measures. This entails fundamental dangers, such as over-subsidisation or the institutionalisation of permanent subsidies. To create incentives to boost efficiency and technological progress, sliding-scale subsidisation is absolutely vital. The highly controversial debate in Germany and Europe shows that opinions are divided, though, on the level of public funding, on the way in which it should be gradually scaled down, the choice of new energies for incentivisation and – a rather more fundamental issue – on the “right way” into a solar future.

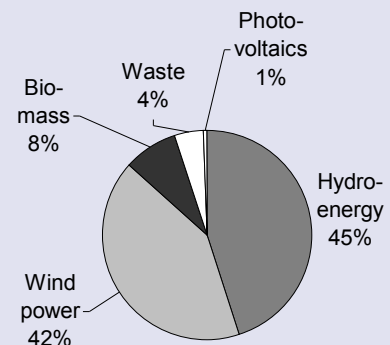
However, a certain basic international consensus is emerging with regard to the potential of renewables in securing energy supply in the long term and to the increasingly pressing issue of climate protection. In the coming years the United States is expected to reassess the climatic relevance of fossil energy consumption, and this is likely to have a huge impact on energy policy. As a result, the race to develop the necessary know-how in respect of solar energies should enter a new phase in higher gear. After all, the prospect of a global mass market in the “post-petroleum era”, if not before, beckons producers of the new technologies. Europeans would be well advised to take due note of the sea-change in the US. Already signs are surfacing of a massive build-up in research and development.

6.2 Heightened conservation effort and energy efficiency

Ultimately, the demand for energy stems from households, industry and the services sector. Energy is used in industrial production and to satisfy needs such as the manufacture and preparation of food, congenial temperatures in the home, health, mobility, information and communication. In macroeconomic terms, economising on energy and measures to improve energy efficiency help conserve scant energy resources and, in the longer term, secure supply. What is more, economical use of energy serves to protect the environment and avoid CO₂ emissions.

Economical use of energy is now high on the list of priorities, with the first “energy crisis” as the defining point in time. In latter years

Share of regenerative energies in power generation in DE, 2003



Sources: VDEW, Energiemarkt Deutschland

Renewable energies: Development targets* EU 25, %

	1997**	2010
AT	70	78
BE	1.1	6
DK	8.7	29
FI	24.7	31.5
FR	15	21
DE	4.5	12.5
GR	8.6	20.1
IE	3.6	13.2
IT	16	25
LU	2.1	5.7
NL	3.5	9
PT	38.5	39
ES	19.9	29.4
SE	49.1	60
GB	1.7	10
CY	0.05	6
CZ	3.8	8
EE	0.2	5.1
HU	0.7	3.6
LV	42.4	49.3
LT	3.3	7
MT	0	5
PL	1.6	7.5
SK	17.9	31
SI	29.9	33.6
EU 25	12.9	21

* Share of national RE generation in national electricity consumption

** For EU 10 (CZ, EE, CY, LV, LT, HU, MT, PL, SI, SK) Reference years 1999-2000

Source: European Commission, The share of renewable energy in the EU, Working Document, 2004

industrialised countries like Germany have succeeded in decoupling economic growth and energy consumption by economising on energy and using it more rationally. Even so, there is still much savings potential to be exploited in all areas of consumption. While keen international competition is compelling industry to utilise efficiency potentials, private households continue to waste too much energy.

Specific fuel input in electricity generation has already fallen markedly over the past decades. Yet efficiency could be further enhanced by new power plants or the modernisation of outdated facilities. At suitable locations, energy consumption can be lowered by cogeneration plants for the combined generation and use of heat and power. Community heating networks may be efficient in densely populated newbuild areas. Least-cost planning compares the costs of capacity increases for power utilities with savings potential on the demand side. By working together with customers to economise on consumption (e.g. better consulting, introduction of energy-efficient equipment), power utilities can avoid risky and costly investment on expansion, with benefits to both sides of the market.

With the ongoing evolution of utilities into modern service providers, customer relations no longer end at the network access point. Companies now offer more than simply “electricity” or “natural gas”, namely lighting, indoor climate and power services. The new service providers’ special expertise in the fields of planning, financing, construction, operation and economic efficiency means that dormant savings potential can be exploited.

Most importantly, the government should also encourage people to husband energy by laying down a suitable regulatory framework. This could include heat insulation regulations for residential buildings or concepts for the use of heat by large-scale industrial consumers (e.g. big bakeries). The EU directive on the integrated energy performance of buildings, with the planned introduction of an energy certificate for buildings providing information on their heating and insulation, aims in the same direction. Thermal insulation of old buildings offers enormous potential for savings.

In the transport sector, the reduction of specific vehicle consumption is the major energy saver. Automotive engineering holds out considerable potential with innovative engine concepts, lighter bodywork and reduced rolling and frictional resistance. Further savings can be obtained by shifting traffic off the road and onto the railways. This can be encouraged by the development of local passenger transport and improved services in passenger transport and goods traffic.

The range of energy-saving instruments encompasses consulting services, “carrot-and-stick” policies, and monetary incentives to conserve energy and buy energy-efficient products, but also extends to tax innovations such as Germany’s “environmental tax” designed to curb demand by putting up energy prices. A raft of promotional programmes have since been introduced by the EU, the German federal, regional and local authorities and the power utilities; all are geared to more economical and sustainable use of energy and hence better climate protection.

Least-cost planning

Utilities as service providers

Regulatory framework helpful

Great potential in the transport sector



6.3 Modern “geo-policies” required

Given the longer-term increase in regional dependence to obtain the primary energies mineral oil and natural gas, demands are also growing louder in Germany and Europe for modern “geo-policies”. Essentially, the European countries are being called on to develop a strategy of regional diversification.⁷ Europe could take its lead here from the United States, which has long implemented such a strategy as part of its security policy.

At present, though, a confusion of competences still stands in the way of a common European strategy. The ministers responsible for economic policy in the different countries insist that energy policy comes within their remit, while the power utilities competing with one another act in their own interests, so they are not the right partners.

Ultimately, responsibilities are likely to be assigned at both national and European level. The EU could assume the task of formulating overall strategy, while the member states add to it with their own special focus. This would have the advantage that historically developed country relationships are not left unexploited. One important strategic objective should be the stabilisation of supplier countries and regions. Most important is economic and political stabilisation of the “strategic ellipse” countries and North Africa, because, moving forward, these will become more important as suppliers of energy. An overall strategy should also encompass building up, developing and securing the energy infrastructure. This includes specific projects such as the construction of pipelines or port facilities.

But a geopolitics driven by energy strategy considerations must not be allowed to obstruct the establishment of competing markets in Europe. On the contrary, direct market access for suppliers from the ellipse and North Africa is an important precondition for the creation and furtherance of competition, particularly for natural gas, which in Europe will continue to be delivered mainly through pipelines.

It should be made quite clear in the dialogue between Europe and Russia that Russia will retain its position as Europe’s major energy and natural gas supplier, with long-term supply contracts providing security for investors. That said, management of the supply flows to Europe should under no circumstances be left to Russia alone. In recent months, Russia has already perceptibly increased its influence over the big deposits in Turkmenistan and Kazakhstan and the transport route across Ukraine with the recent signing of long-term contracts. There is a danger of this influence being extended to the gas-rich supplier and transit country Iran. This Russian gas policy runs counter to the European Union’s longer-range supply and competition interests. If gas transports are monopolised before they reach central Europe, a free and open market cannot arise. Without independent transports from the major supply countries, low, competitive prices and the supply of energy through diversification are hardly possible. Therefore, the EU urgently needs a modern geopolitical orientation.

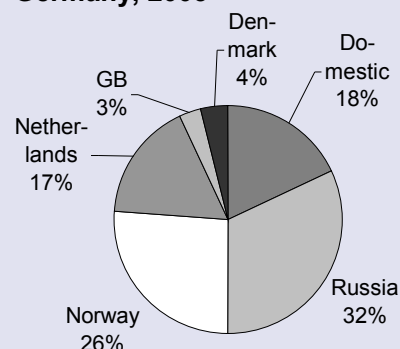
6.4 New generation of power plants

The energy mix for electricity generation in Germany and elsewhere in the world is up for discussion not least because, as technology stands at present, the use of fuels such as coal negatively impacts environmental considerations. If it were possible in future to build

Regional diversification

Responsibilities should be assigned at national and European level

**Natural gas volumes
Germany, 2003**



Sources: BV Gas u. Wasserwirtschaft, Ruhrgas AG

Two examples for new power plants

⁷ See Müller, F., “Sicherung der internationalen Energieversorgung”, Working Paper, SWP-Berlin, 2003; Müller, F., “Sicherheit der Energieversorgung: Zu kompliziert für Europas Politiker?”, FAZ, August 22, 2003.

power plants that produced no, or considerably fewer, pollutants despite the use of these inputs, the security of supply could be improved because there would be less need for imports. Here are two examples: the use of domestic coal in CO₂-free coal-fired power plants would not pose an environmental problem and more coal could be used. And a renaissance of nuclear energy (also in Germany) would be more conceivable if it were possible to develop safe power stations with "little nuclear waste".

CO₂-free coal-fired power plants

The coal industry is pinning its hopes on largely **CO₂-free coal power plants**. No source of energy pollutes the environment more seriously than coal in terms of CO₂ emissions per unit of energy. The vision of CO₂-free facilities is therefore sustained by the necessities of climate policy. Although the financial burdens of EU-wide emission rights trading planned from 2005 will initially be negligible for coal power plant operators, more stringent regulatory conditions in future could push costs up significantly.

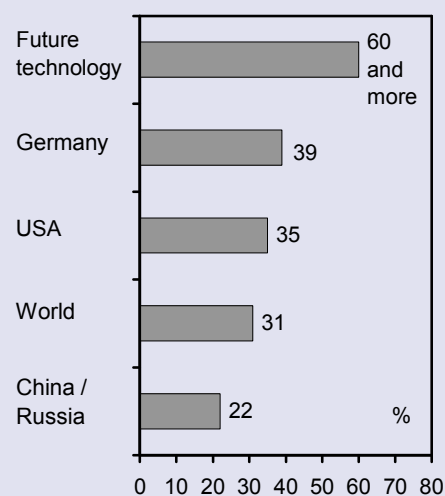
In principle, CO₂ can be isolated before or after coal combustion. Storage of the waste products is still a problem at present. Experts expect the "technological option" for CO₂-free coal power plants to be available from 2020.⁸ Using Integrated Coal Gasification Combined Cycle (IGCC) technology, hard coal⁹ is converted into gas that is then burned in a gas turbine. Pollutants are separated prior to combustion or do not arise at all. Siemens has just designed a power plant on this principle.¹⁰ Admittedly, even the new technology uses energy in the process. Environmental efficiency is not for free.

The regulatory framework for pollutant emission is critical to the economic efficiency of coal-based IGCC power plants. Meanwhile, policy-makers are also supporting initiatives geared to efficient coal power plant technology. The European Commission, for example, is sinking EUR 200 million into research on CO₂-sequestration.¹¹ Under the name Future Gen, the US government aims to develop an almost emission-free coal-based electricity and hydrogen production plant in ten years, with 80% of the USD 1 billion project coming from the public purse.¹² Importantly, technological progress also holds out considerable business opportunities, as a volume market beckons technology leaders. After all, big emerging markets such as China and India will have to satisfy much of their mushrooming electricity needs with coal-fired power plants.

In the immediate future, however, it is first a matter of further developing **conventional** coal-power technology. For example, the efficiency level of hard-coal power plants (39% at present in Germany, 31% on average for the world as a whole) could be ratcheted up to 60% and more with "technology of the future".

CO₂-free coal-fired power plants not before 2020

Efficiency levels of coal-fired power plants



Source: GVSt

⁸ See Schiffer, H.-W., "Third International Workshop on Oil and Gas Depletion – Statement", ASPO, May 2004.

⁹ IGCC systems can be designed for a wide range of inputs such as biomass, petroleum coke or liquid asphalt. Already, the petrochemical industry uses the technology to process refinery residues.

¹⁰ See VDI, "Integrierte Kohlevergasung: Auf dem Weg zum Null-Emissions-Kraftwerk?", 2004; Siemens, May 2004.

¹¹ Thought is also being given to industrial carbon management in the USA. The CO₂ is first captured at the power plants, then sequestered in depleted oil or gas fields. See Edenhofer, O., Schellnhuber, H., Bauer, N., "Der Lohn des Mutes. Gestaltungsspielräume für eine internationale Klima- und Energiepolitik", in: Internationale Politik, August 2004.

¹² See Schmitz, L./Siemens, M., "Beitrag der Steinkohle zur nachhaltigen Energieversorgung", RAG AG, 2003.



Nuclear power plants

Accounting for 7% of global primary energy consumption and 16% of world electricity generation, **nuclear energy** represents an important source of world energy supply. Mounting concern over the security of supply and climate hazards has been turning international attention to nuclear energy again in recent years. Expanding countries like China, where demand for electricity is surging and supply can fluctuate severely depending on the time of day and year, are looking to nuclear fission. But the World Energy Council expects the share of nuclear energy in energy consumption worldwide to decline up to 2020, notwithstanding the development and absolute growth in electricity generated by nuclear power (i.a. in Asia).¹³

Technological progress could brighten the prospects for nuclear energy. Further advances in plant security and the disposal of nuclear waste would be helpful here. The provision of suitable final disposal sites for radioactive residual waste has so far proved an insoluble problem. Moreover, the generation and disposal chain must be secure against accidents and terrorist activities. Finland is scheduled to take a new-style ERP ("European Pressurized Water Reactor") onstream in 2009. This third-generation nuclear power station makes better use of uranium. France is planning gradually to replace its 19 nuclear power plants with their total of 58 reactors by ERP facilities.

In Germany a new, absolutely safe generation of nuclear power stations could mean a second chance for nuclear energy in a few decades. In the meantime, the most conceivable development is a deadline extension for suitable plants going beyond the phase-out compromise reached in 2000 – but, of course, with at least an equal level of security. The USA has just extended the term for a quarter of its more than 100 power stations from 40 to 60 years. At the moment, not a single company is planning to build a new nuclear power plant in Germany. Utilities are banking mainly on gas technology. Modern gas turbine combined cycle (GTCC) plants are considered efficient, environmentally friendly and can be built comparatively quickly within the space of two years. The investment costs are far lower than for the construction of a nuclear power station, and the disposal issue does not arise. Acceptance is also greater among the public. According to the latest research, 79% of Germans are against new nuclear power stations.¹⁴ However, gas power plants are subject to certain price risks, as we have seen again recently. The farther-reaching and global deliberations we have discussed here are not yet reflected in debate in Germany.

If, moving ahead, a further generation of nuclear power stations can be developed and brought online, this may enhance the security of energy supply in Germany. Admittedly, the fuel for nuclear power stations does not come from domestic deposits. But uranium is noted for its exceedingly good storage possibilities, which are due to its extremely high energy density. For example, 1 kg of fissile uranium 235 contains two to three million times as much "energy" as 1 kg of oil or hard coal. The energy carrier owes its rating as a "quasi domestic source of energy" in Germany to the good possibilities for storage. Given new nuclear power plant technology, the "domestic" energy carrier could reduce dependence on energy

International attention turning to nuclear energy again

Third-generation power plants

No plans for new nuclear power plants in Germany

Renaissance conceivable in the long term

¹³ See World Energy Council, "Energie für Deutschland", 2004. However, in the longer term Carl Christian von Weizsäcker, for example, expects a higher share of nuclear energy than the WEC. Even so, he considers a more than 20% share of nuclear energy in world energy demand up to 2050 unrealistic (Weizsäcker, C. C. v., "Der teure Heiligenschein erneuerbarer Energien", in: Internationale Politik, August 2004).

¹⁴ See Forsa, June 2004.

imports and help secure supply. This makes a renaissance conceivable in Germany in the longer term. Given that nuclear energy enables CO₂-free electricity generation, its greater use would make an added contribution to reducing the risk of greenhouse gas emissions. The big advantage of fourth-generation nuclear power plants, apart from their improved safety, would be that they generate much less radioactive waste.

Unlike nuclear fission, **nuclear fusion**, the process by which energy is created in a reactor by combining atomic nuclei, has the quality of a backstop technology.¹⁵ So far, though, this technology exists only on paper and is unlikely to be available before the middle of this century. The upshot is that it cannot play any part in securing energy supply in the coming decades.

6.5 Decentralised energy supply

The longer-range realignment of traditional energy supply towards electricity production using fuel cells at the location where the heat created can be used offers considerable economic opportunities, not least for small and medium-sized enterprises (SMEs), the skilled trades and farmers. Essentially, what we are looking at is the creation of “virtual power stations” by interconnecting decentralised fuel cells in private and commercial buildings.

The consumer of energy also becomes its producer and supplier. For this, it will be necessary to defuse the conflict of interests between the established power grid operators and the many new and independent electricity feeders (households, small and medium-sized companies) stemming from the old way of thinking in the monopolistic era. A state regulator – and Germany is the only EU member state that does not yet have one – can create a level playing field by granting the new electricity feeders fair access to the grid with adequate remuneration. Pricing should also take into account the grid costs avoided in the long term by decentralised input. It would be in the interests of optimising energy supply – not least with regard to environmental objectives as well – if the established grid operators could stop viewing private feeders as irksome rivals and accept them instead as welcome partners. Total electricity blackouts – by no means unusual meanwhile, even in the industrial countries, for a power industry based on large power plants – would not be very likely with a more decentralised energy supply structure.

Of course, a reconfiguration of supply structures on this scale would take several decades. Consequently, substantial investment will still need to be made in conventional energy supply over the coming decades to enhance supply security.

6.6 Heavy investment necessary

The IEA¹⁶ puts the investment needed to modernise and expand the energy supply infrastructure in the three decades up to 2030 at USD 16 trillion worldwide. The agency’s estimates are based on two-thirds growth in global demand for energy. The focus of investment is in the electricity industry, with capital expenditure of almost USD 10 trillion. Of this, China accounts for more than USD 2 trillion. The oil and gas sectors each require investment of USD 3 trillion, and even the coal industry as much as USD 0.4 trillion. In the OECD

Nuclear fusion not before 2050

Virtual power stations

Decentralisation would forestall blackouts

Focus on investment in electricity industry

¹⁵ See Edenhofer, O., Schellnhuber, H., Bauer, N., “Der Lohn des Mutes. Gestaltungsspielräume für eine internationale Klima- und Energiepolitik”, in: Internationale Politik, August 2004.

¹⁶ See IEA, “World Energy Investment Outlook”, 2003; “World Energy Outlook”, 2004.



area almost one-third of investment in new power plants could go on renewables.

Immense capital requirements, with risks increasing the world over

As a result of the various energy market reforms (e.g. privatisation, liberalisation, regulation), expanding international energy trading, political upheavals and increasing religious fanaticism, the risks have tended to rise for investors in recent years. This is true at practically all levels of the energy sector: production and processing, transport and distribution. Increased uncertainty is leaving its stamp on business in the electricity industry and the markets for primary energy, most notably oil and gas. Particularly hard hit by risk premiums are the developing and transition countries – which, however, are in the greatest need of investment. For this reason, in 2030 about 1.4 billion people are still expected to be without mains connections (at present 1.6 billion).

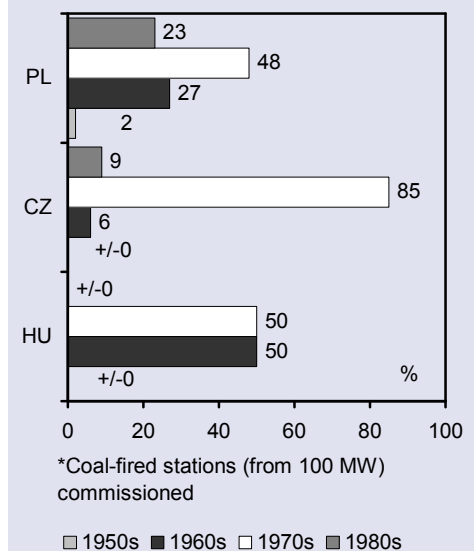
From an investor's point of view, the phasing out of nuclear energy makes Germany a special case. After all, in 2003 28% of electricity was still generated using nuclear energy. Practically all of Germany's baseload generation is based on nuclear energy and lignite. The year 2010 will mark the beginning of the "technical end" of many power plants fired with fossil fuels, and the "political end" of nuclear power stations. This means that in the period up to 2030 replacement capacities equivalent to at least 50,000 MW of power plant output must be built up. Extensive modernisation would lift capacities to 80,000 MW. In Germany total power plant capacity equals some 120,000 MW. The DIW German Institute for Economic Research calculates that an investment programme in the order of EUR 50 to 60 bn would be needed to replace around half the German capacities.¹⁷ The World Energy Council (WEC)¹⁸ expects the construction of at least 45 new power stations by 2020 and additional measures at more than 200 power stations to extend their lifetimes and boost output.

In **Europe** heavy investment still needs to be made in power plants. The WEC estimates additional demand for the EU-15 of roughly 300,000 MW by 2020. Besides, the modernisation of the energy industry in the Central and Eastern European countries (CEECs) that have already joined the EU or are about to do so calls for extremely high investment.¹⁹ With the persistent scarcity of funds in the EU budget and the member states' public budgets, the mobilisation of private-sector funding for these infrastructure projects will be pivotal.

Recent power failures have highlighted the urgent need for modernisation and expansion of the big European electricity network, the Union for the Co-ordination of Transmission of Electricity (UCTE), which provides international backup in the event of national electricity shortages. Without a reliable and efficient grid infrastructure, there is a threat of major power failures across national borders in future, with detrimental economic effects. Moreover, in the coming years attempts must be made to achieve (better) connection of the new EU neighbours in the east. For example, currently idle power generation capacities in Ukraine could be put to use for the European Union.

Investment risks have risen

Age structure: coal-fired power stations*



Source: Zittau Seminars

Need for modernisation of the European electricity network

¹⁷ See DIW, "Energiepolitik und Energiewirtschaft vor großen Herausforderungen", Wochenbericht 48/2003.

¹⁸ See World Energy Council, "Energie für Deutschland", 2004.

¹⁹ See Auer, J., "Infrastructure as a basis for sustainable regional development", Current Issues, June 3, 2004.

6.7 Embarking on hydrogen energy

Mounting concerns over supply and dangers to the climate bear witness to the fact that sustainable energy supply in the long term is not a matter of course. This is why the vision of a “solar future” or “solar hydrogen energy sector” is becoming increasingly important. Our present means of energy production is based essentially on carbons (mineral oil, natural gas, coal). In the process, however, the greenhouse gas CO₂ is created as a by-product, and its use leads to the shortage and ultimate depletion of these fossil resources. Hydrogen is a secondary source of energy, meaning that its production (like electricity) is predicated on the use of other energy carriers. The production of hydrogen by solar means rather than on the basis of fossil sources has two advantages. First, the sources of energy, such as biomass, sun, wind or water, are renewable or non-depletable, enhancing the security of supply. Second, solar production of hydrogen is carbon-independent, therefore CO₂-neutral and favourable for the world’s climate.

Hydrogen was discovered well over 200 years ago. Today, three-fifths of global hydrogen output (600 billion cubic metres) is used in refineries (for the desulphurisation of fuel oil), in the chemical industry (e.g. to manufacture fertilisers) and in the steel industry. The food industry also uses hydrogen daily as a refrigerant. But since the current level of global hydrogen production is only sufficient to satisfy half of Germany’s energy needs, the vision of global conversion of energy supply to hydrogen is still a very remote prospect indeed. What is more, the primary source of energy is entirely fossil and does not therefore offer a solution to the challenges.

So far, space travel is the only sector in which hydrogen plays a crucial part, being very high in energy. In all other important areas of use this secondary source of energy still has to penetrate the market. Looking forward, the potential of hydrogen as an energy carrier is enormous, with fuel cells playing a key role.

Hydrogen is becoming increasingly important on the markets for off-highway supplies (e.g. yachts, submarines, military purposes) and in the automotive industry (with or without fuel cells). The outlook is positive for fuel cells as a source of electricity for portable equipment (e.g. laptops) and for stationary power generation.

At present, **mobile** fuel cell systems for the automotive industry are perceived as the farthest removed from actual mass market maturity. This is, of course, partly because of the decades-long head start enjoyed by established petrol and diesel engines, which continue to gain in power and efficiency under the pressure of keen competition on the automotive market. Around 60 million automobiles are currently produced worldwide each year. Given that the replacement or life cycle of a motor car, at over ten years, is far longer than for portable equipment, market penetration will take much longer to achieve. Meanwhile, disenchantment has spread among forecasters, who are now predicting that mobile hydrogen or fuel cell drives will not account for a low double-digit percentage of total production until sometime between 2020 and 2030. An efficient infrastructure calls for substantial investment; but this is absolutely vital if fuel cells and hydrogen are ever to stand a real chance in road traffic. The evident chicken-and-egg problem – no H₂-powered cars without filling stations and no filling stations without cars – can be resolved only by cooperation between motor manufacturers, filling station operators and companies from the mineral oil and natural gas industry, possibly accompanied by regulation.

Vision of solar hydrogen energy sector

Advantages of hydrogen

- Hydrogen enables energy to be stored and made available as needed (better than batteries).
- Hydrogen also places renewables in the service of transport.
- Since the only by-product from the combustion of hydrogen (H₂) with oxygen (O₂) is water (H₂O), practically emission-free operation is possible at the place of use.
- The use of hydrogen in fuel cells produces a high level of efficiency in power generation and opens up new vistas for energy supply and transportation.

Source: Bavarian state ministry of the environment, health and consumer protection

Mobile fuel cells



Portable fuel cells for non-stationary electrical equipment such as laptops, camcorders or television cameras are poised for production and market launch.

Local hydrogen production still using natural gas

Discernible commercial prospects for fuel cells also exist on the markets for **stationary** energy generation in private households, in commercial buildings (combined heat and power systems) and for the utilities' power generation. In the home energy segment, in a ten-year time frame market penetration of fuel cells (for heating and electricity) is predicted in the low single-digit percentage range. Additionally, in the coming decade larger fuel cells are actually expected to come onto the market for buildings used commercially by small and medium-sized businesses and industry. In the household segment natural gas is most likely to be employed as a means of local hydrogen production. This has the advantage of being able to use the existing gas network infrastructure. Besides natural gas, large fuel cells can also use comparatively economical fuels such as biogas and coal gas.

Given that natural gas will continue to play a pre-eminent role in the coming years, the new technology's contribution to environmental efficiency and supply security will still be very limited. But if, in a few decades, hydrogen recoverable from regenerative energies such as hydro-energy, biomass, wind and photovoltaics could be used – cost-efficiently – a sustained improvement in our energy mix in the direction of climate protection and the security of supply could become reality.

Silicon as an intermediary for the hydrogen industry

A major obstacle to a hydrogen industry based on renewables is the problem of storage and transport. The results of recent research²⁰ propagate silicon as the "silver bullet". Silicon extracted from common sand is a perfect way of storing energy and transporting it safely. This means that wherever energy can be obtained sustainably by natural means (e.g. in the desert in the form of solar energy), sand could be reduced to the metal silicon, which would carry in it the previously harnessed energy. The benefit is evident: The mobilisation of a previously unexploited method of storing energy for an unlimited time and transporting it safely. Using suitable combinations such as water, the silicon can be turned back into sand, with the development of hydrogen as a by-product – and all this is CO₂-free. Around 20% of the energy is, admittedly, lost in the chain.²¹ However, this is negligible, given that the solar energy in the potential regions is surplus energy anyway.

For a future hydrogen industry, the use of silicon as an intermediary would have the advantage of massively reducing the still high potential dangers involved in hydrogen transport and storage and the substantial energy losses during transport. What is more, the transportation and storage of silicon requires only an infrastructure like that needed for coal. This would provide a key "missing link" to the establishment of a danger-free hydrogen industry.

Portable fuel cells

Stationary fuel cells

Not until hydrogen is produced from regenerative energies will it bring major ecological benefits

Mobilisation of a previously unexploited way

Surplus energy

A "missing link" may have been found

²⁰ See Auner, N., "Silicon as an intermediary between renewable energy and hydrogen", Deutsche Bank Research, Research Notes, May 2004.

²¹ See vwd/dowjones, "Silizium als Speichermedium für die Wasserstoffwirtschaft?", energy weekly, May 14, 2004.

7. Conclusion: Time to act

Going forward, the supply situation will become increasingly critical in the markets for mineral oil and, later, natural gas. At the latest when demand outstrips reserves, energy prices will climb significantly. This foreseeable shortage must be addressed with intelligent, future-proof strategies. In the longer run, only a broad range of measures will secure energy supply. Betting on only one card entails the risk of ultimately being left empty-handed. The needs of the moment call for the use of all available levers – the diversification of energy carriers and technologies and the mobilisation of all conservation, reactivation and efficiency-boosting strategies.

Work must push ahead on R&D geared to safe power plants (including those based on nuclear energy) and networks, renewable energies and hydrogen. Particularly in the private consumer sector, still too little attention is paid to energy conservation and efficiency. Government must continue to take action here. More decentralised supply structures would reduce the risks of widespread power outages. Political cooperation arguably stands a better chance of success than confrontation. But Germany and Europe should not wait for US leadership in energy policy and ensuing geopolitics. To enable competition on the European gas market and to better secure the transportation of natural gas, steps must be taken to counteract the monopolisation of pipeline routes. Last but not least, the emerging reorientation of US energy policy, with its greater focus on climate policy insights, should be heeded. Ultimately, the intensification of competition for new energies and technologies will benefit energy supplies in all countries.

But improved security of supply does not come for free. The political debate on the “right price” to be paid for greater security will remain highly controversial. Owing to the gradual depletion of oil and gas reserves, the energy mix of future generations will contain a far lower proportion of fossil sources than it does today. And given the climatic relevance, this is undoubtedly called for.

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Only a broad range of measures will secure energy supplies

Work must push ahead on R&D

Reorientation of US energy policy should be heeded

Improved security of supply does not come for free

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Decisions of enormous political import – such as Germany’s exit from nuclear power, ecological tax reform, and the promotion of renewable energy sources and combined heat and power generation – influence competition and lead to structural changes in the energy market. The liberalisation of the EU and German energy markets created a new regulatory framework that challenges all experience on record in the industry.

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