Facts and Figures

Electricity Generation 2005
The world population is growing by 78 million people every year. Within five decades the total world population has doubled since 1960. Currently one quarter of the world population, i.e. some six billion people, does not have access to electricity. Thus, compared to any other source of energy, the demand for electricity will increase more rapidly. It is expected that the worldwide electricity consumption will double from currently 16 100 billion kWh to a total of 31 600 billion kWh by the year 2030. About 25 % of the electricity generated worldwide, i.e. some 300 billion kWh, is consumed in the European Union (EU 25). An increase in demand of 52 % is expected by 2020.

According to experts, fossil fuels will continue to cover the major share of the increasing demand. In 2030 still 70 % of the electricity generated worldwide will be based on fossil fuels. This means for EU 25 that 60 % of the electricity generated will be based on fossil fuels. Renewable sources of energy (renewables) will play an important role in the worldwide consumption of primary sources of energy. Nuclear energy will also keep its position worldwide, and in some countries its share will even be extended.
Expected growth in electricity generation in 10^9 kWh (TWh) – in EU 25

+ 52 %

- Renewables, others
- Hydro-power
- Oil
- Gas
- Coal
- Nuclear energy

Source: E.ON Ruhrgas/IEA

Expected growth in electricity generation in 10^9 kWh (TWh) – worldwide

+ 97 %

- Renewables, others
- Hydro-power
- Oil
- Gas
- Coal
- Nuclear energy

Source: E.ON Ruhrgas/IEA
Worldwide the reserves and resources of fossil sources of energy are still sufficient, especially when taking into account unconventional deposits (resources) with hard coal and lignite having the largest deposits.

However, the uneven regional distribution of these deposits results in a growing dependence of the EU 25. Only 5% of the worldwide known fossil reserves are situated within EU 25. These deposits amount to 75 billion tce and comprise mainly lignite and hard coal. The natural gas and crude oil reserves amount to approx. 5 billion tce.

The dependence on imported coal will increase in Europe from currently 30% to 60% in 2030. The dependence on natural gas will rise to 81% and for crude oil this figure will increase to even 88%. The total share of imported energies will increase from currently 50% to some 70% by the year 2030.

The reasons for this development are due to decisions of single countries to phase out nuclear power as well as due to the less economical production of individual energies in Europe. In the long term, lignite will be the only fossil fuel that can be mined economically, i.e. at competitive prices in open-cast mines.

Reserve: Documented stock of primary energy that can be produced economically with state-of-the-art technology.
Resource: Additional stock that is documented but cannot be produced economically with technology currently available.

**Statistical range of fossil sources of energy worldwide as well as reserves and resources (in years)**

- **Oil**
  - Conventional: 43 years, Resources: 87 years
  - Non-conventional: 62 years, Resources: 157 years

- **Natural gas**
  - Conventional: 64 years, Resources: 149 years

- **Hard coal**
  - Resources: 756 years

- **Lignite**
  - Resources: 1425 years

Source: Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)
Development of dependence on imports of EU 25 between 1990 to 2030

Source: European Commission – European Energy and Transport Scenarios on Key Drivers, Brussels 2004
The electricity demand in EU 25 will increase from currently 3000 TWh to some 4400 TWh by 2020. Due to ageing of the existing power plant portfolio and the phasing out of nuclear power in Germany, the generation gap (replacement and additional demand) will amount to some 2400 TWh. Thus, the question has to be answered how to close this gap. Assuming a mean utilisation of 7500 full-load hours per year for thermal power plants and 3000 hours for wind power plants (onshore and offshore plants) as technically feasible, this would mean that approximately:

- 200 nuclear power plant units with 1600 MW each, or
- 320 lignite-fired power plant units with 1000 MW each, or
- 530 hard coal-fired power plant units with 600 MW each, or
- 800 combined cycle power plants with 400 MW each, or
- 160,000 wind power plants with 5 MW each (plus reserve capacity [80%], e.g. 425 hard coal-fired units or 640 combined cycle power units)

would be required to make up for the described gap. Alone these figures demonstrate that an energy mix is vital for a secure and reliable electricity supply in the future.

Source: EU - Energy and Transport Outlook
Power plant portfolio in EU 25 (in 2003)

Total net power plant capacity in EU 25: 688,226 MW

Source: Eurelectric, Eurostat
Electricity Generation Options

- 32% Nuclear power
- 31% Coal
- 18% Natural gas
- 10% Hydro-power
- 1% Wind

Others: 8%
## Pros and Cons of Relevant Electricity Generation Options

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| **Nuclear Power** | - Climate-compatible electricity generation without CO₂ emissions  
- Economically-priced and reliable supply without any critical dependencies on energy imports  
- High safety level of European nuclear power plants | - Not accepted by all European societies  
- Extensive nuclear licensing procedures  
- Large safety requirements are to be met  
- Disposal and final storage of nuclear fuel not yet politically decided in all societies |
| **Coal** | - Hard coal can be purchased on the world market from numerous suppliers at low prices  
- Lignite is available in Europe as safe, domestic raw material  
- Power plant technology with high potentials for further efficiency jumps | - Increasing demand for hard coal (specially from China and India) and limited transport capacities bear price risks  
- CO₂ emissions higher than in the case of natural gas  
- Flue gas cleaning requires corresponding equipment and systems |
| **Natural Gas** | - Most environmentally compatible fossil fuel with relatively low CO₂ emissions  
- Electricity generation in highly efficient power plants  
- Short erection times and favourable investment cost for new plants | - Highly fluctuating natural gas prices result in similarly fluctuating electricity generating cost  
- Dependence on natural gas imports as possible supply risk  
- Increasing concentration of deposits in politically unstable regions |
| **Hydro-power** | - Climate-compatible electricity generation without CO₂ emissions  
- Domestic source of energy, no dependency on imports  
- Favourable electricity generating cost in existing plants | - Only a limited utilisation potential in numerous European countries  
- In "low-water times" electricity generation has to be backed by thermal power plants  
- Any further potentials are hardly available in Europe |
| **Wind** | - Climate-compatible electricity generation according to wind fluctuations, thus, only utilisable in conjunction with thermal power plants  
- Further investments for reserve power plants and extension of the electricity grid necessary  
- At present economically not competitive  
- Utilisation and connection of the offshore wind plants is expensive | - Fluctuations in electricity generation according to wind fluctuations, thus, only utilisable in conjunction with thermal power plants  
- Further investments for reserve power plants and extension of the electricity grid necessary  
- At present economically not competitive  
- Utilisation and connection of the offshore wind plants is expensive |
Nuclear power plants in Germany help to avoid about 160 million tonnes of CO₂ emissions annually. This is comparable to the CO₂ emissions produced by traffic. Two scenarios established for Germany with 2020 as target horizon demonstrate the differences between the possible CO₂ reduction potentials:

1. Phasing out of nuclear power
Under the current political conditions, the energy mix in 2020 would have to comprise 20 % renewables (this requires more than a tripling of the current wind generation capacity), 75 % coal and gas and 5 % residual nuclear energy. This would result in a reduction of CO₂ emissions of 35 million tonnes annually. Besides, 30 billion Euro would have to be invested into new coal- and gas-fired power plants.

2. Keeping of nuclear power
Provided the general political conditions concerning the existing nuclear power plants were reset, this would result in an energy mix in 2020 comprising 30 % nuclear power, 50 % coal and gas and an unchanged share of renewables amounting to 20 %. This would result in a CO₂ reduction of 95 million t/a. Therefore, it can be ascertained that CO₂ reduction and phasing out of nuclear power are contradictory requirements that cannot be harmonised.
**CO₂ reduction without nuclear power in Germany**

% electricity generation = 35 mill. t (2020)

- Wind, biomass and others: 20%
- Hydro-power: 80%
- Gas: 60%
- Coal: 75%
- Nuclear: 5%

**CO₂ reduction with nuclear power in Germany**

% electricity generation = 95 mill. t (2020)

- Wind, biomass and others: 20%
- Hydro-power: 80%
- Gas: 30%
- Coal: 50%
- Nuclear: 30%
Efficient Coal- and Gas-fired Power Plants also Indispensable in the Future

The development of power plants with higher efficiencies (e.g. the VGB initiative E\textsubscript{max} [efficiency, economy and environment] with the test plant COMTES700) and the capture and final underground storage of CO\textsubscript{2} (carbon capture and storage = CCS), are often considered reasonable ways for the efficient reduction of CO\textsubscript{2} emissions that occur when converting fossil fuels. These options are frequently realised as competing possibilities, but right the opposite is true: A simple calculation demonstrates clearly that if all of the existing hard coal-fired power plants worldwide (average efficiency 30 \%) would be completely substituted by modern plants with an efficiency of 46 \%, the CO\textsubscript{2} emissions in connection with hard-coal-based electricity generation could be reduced by 35 \%. Thus, the gradual reduction of CO\textsubscript{2} emissions by advanced technology is the first option. The higher the efficiency of a power plant, the lower the expenditures for CCS.

Therefore, the development of power plants with maximum efficiencies is not only a no-regret-measure from the viewpoint of CCS, but also a necessary and sustainable pre-condition. This leads to a triple profit:
- resource savings, since less fuel is required per kWh,
- reduction of CO\textsubscript{2} emissions, and
- more electricity generated at equal fuel consumption.

Capture and storage of CO\textsubscript{2} result in an increase in fuel consumption that is taken into account for a CO\textsubscript{2}-free power plant. The coal consumption in a CO\textsubscript{2}-free power plant is by 23 \% higher than in a 700 °C-plant.
Maximum efficiencies are a pre-condition for CO₂ capture (values for coal-fired power plants)

Current German average
η = 38%

Technology currently available
η = 43 to 46%

Next step
700 °C - power plant COMTES 700
η > 50%

Power plant without CO₂ emissions (with maximum efficiencies)

270 g
700°C- technology (η = 53%)

330 g
Power plants without CO₂ emissions (η = 43%)

*Estimation, COORETEC
With 31% the European Union is worldwide the leader in nuclear-based electricity generation. Different European countries continue with the extension of nuclear energy in order to cover the growing demand for electricity sustainably and without CO₂ emissions.

Extension models for nuclear power are discussed and/or planned worldwide. Advanced developments of the proven light water reactors are preferred as Generation III+ plants in concrete plans for about 40 nuclear power plant units. They offer a maximum safety level with optimised resource utilisation and economy.

For the long-term development, the US-American Energy Ministry (US-DOE) initiated the GENERATION IV programme, with participation of Argentina, Brazil, Canada, France, Japan, South Korea, South Africa, Switzerland, Great Britain and EURATOM. The project is aiming at the development of six reactor types with improved safety, reliability and economy. Russia, India, China and South Africa are having their own developments under way.
Nuclear power has a future

**Marketable nuclear power plants**

**Generation IIIa**
Advanced versions
proven pressurised (PWR) and boiling water reactors (BWR)
- advanced PWR: EPR, AP 600/1000...
- advanced BWR: BWR-1000, ABWR, ESBWR...

**Development**
Innovative concepts for the near future
Small and medium modular reactors
- e.g. the modular pebble bed reactor - PBMR (South Africa, Japan, China)
- option for hydrogen generation

**Research**
Generation IV
Concept with special safety-engineering and economic features
- new materials
- advanced processes
- advanced fuel cycles

**Fusion**
Taking the sun as an example, inexhaustible, everywhere accessible resource
- fuel reservoir sea water
- plant type: Tokamak, Stellarator
- favourable safety and environmental characteristics
Renewables-based electricity generation has a high priority in the European Union for reasons of safety and diversification of energy supply as well as climate and environmental protection. However, it is already clear that the objective of 685 TWh in the EU 25 (= 21 %) until 2010 cannot be achieved. Instead, the share of renewables is likely to amount to 19 % at that point in time.

Among renewable sources of energy, hydro-power is the only source that can be operated economically. All the other technologies cannot compete on the market without public subsidies. The different national systems of government subsidies are to be harmonised. Apart from the necessary increase in availability, the introduction of a European-wide trading with certificates could result in a considerable increase in efficiency. One consequence would be that the renewable sources of energy that are available with regional differences could be utilised optimally.

In the medium term wind power bears the largest potential to achieve the targets of the EU. The installed capacity of wind power increased between 1999 and the end of 2004 by 250 %, i.e. to 34 400 MW. However, the climatic fluctuations and the not reliably available supply of energy impose great demands on the power plant park. According to a

Source: CEC – The share of renewable energy in the EU
study of Deutsche-Energie-Agentur (German energy agency, dena) about 36 000 MW wind capacity will be installed in Germany in 2015, however, only some 6 % of these will be reliably available then. Accordingly, approx. 94 % of the wind capacity would have to be backed-up for by conventional thermal power plants. The related economic effects have to be considered in total. Thus, a sensible energy mix is also necessary in the future.

Biomass utilisation is also contributing to electricity generation. This applies in particular to the Scandinavian countries. Co-combustion of biomass has been developing in the past years European-wide and became an important technology for CO₂ neutral electricity generation. This highly efficient form of energy conversion is mainly applied in Denmark and in the Netherlands. Fuel cells, micro gas turbines and Stirling engines can be used in combined cycle applications as decentralised small units, but one pre-requisite is the drastic reduction of the system cost in order to facilitate economic operation.
Price Risk of Primary Energy Sources

Electricity supply is the basis for economic growth, prosperity and social safety. Economically priced electricity is necessary to produce products and services at competitive prices.

An analysis of the import prices for crude oil, natural gas and coal of the last 30 years shows that the prices for crude oil fluctuated around 900 %, for natural gas around 700 % and for coal around 200 %. Additionally, there are a couple of countries that dispose of favourable lignite resources for direct electricity generation. The high price fluctuations of natural gas-derived electricity generation characterise the price risks in connection with gas. Therefore, a balanced energy mix is vital in order to generate electricity at competitive prices.

Source: Statistik der Energiewirtschaft e.V.
CO₂ Avoidance Costs

Different options with clearly different costs are available to reduce CO₂ emissions from electricity generation. The replacement of existing fossil-fired power plants by plants based on renewables results in relatively high CO₂ avoidance costs. It is much more efficient to replace or retrofit and increase the output of existing fossil-fired plants by state-of-the-art technology. New coal- and gas-fired plants can avoid CO₂ emissions at low cost.

The specific avoidance costs are an important parameter for system comparison. With the aid of this parameter it can be quantified how much costs the avoidance of one tonne of CO₂ in comparison to a reference system. With this approach it is assumed that any measure on CO₂ avoidance is much more expensive than the reference system but any measure will help to save emissions and primary energy.

Study: Professor Wagner, CO₂ avoidance cost in power plants, with renewables as well as demand-sided energy efficiency measures.

Specific CO₂ avoidance costs without certificate costs

€ / tCO₂

<table>
<thead>
<tr>
<th>Process Type</th>
<th>Avoidance Cost €/tCO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photovoltaic</td>
<td>800 – 1000</td>
</tr>
<tr>
<td>Biomass-based plants</td>
<td>90 – 110</td>
</tr>
<tr>
<td>Wind power</td>
<td>70 – 90</td>
</tr>
<tr>
<td>Hydro-power</td>
<td>60 – 70</td>
</tr>
<tr>
<td>CO₂ storage</td>
<td>25 – 70</td>
</tr>
<tr>
<td>Modern coal-fired power plants</td>
<td>15 – 20</td>
</tr>
</tbody>
</table>

Source: VGB Capture and Storage, own calculations
Utilisation Time of Power Plants

The utilisation time is an indicator for the full-load hours a plant has been operated during one calendar year. For a high utilisation time factor equipment and systems as well as sources of energy have to be available according to schedule. Thermal power plants that are operated with biomass, lignite, hard coal, natural gas or nuclear power, meet these requirements.

This does not apply to the fluctuating energy of the sunlight, wind and water that can only be used according to occurrence. In the most unfavourable case, electricity is generated when consumers do not need it or right the opposite: no electricity is generated when it is highly needed. The application of such plants (exception: pump storage plants) is therefore not according to schedule but stochastically.

From the economic point of view, the utilisation factor of a power plant should be relatively high in order to be able to distribute the operating cost per kWh to decrease the overall electricity generating cost.1 Plants that generate electricity from renewables (apart from hydro-power) above the price level of whole sale do not participate in the free competitive market. Thus, only individual regulations exist for electricity feeding into the grid.

On the German energy market, nuclear power plants, lignite-fired power plants and run-of-river plants achieve utilisation periods of 6500 to 8000 hours in base load operation. Hard coal-fired power plants in medium load operation achieve 4500 hours. They compensate the fluctuations between electricity generation and electricity consumption. Electricity peaks are covered by peak power plants (e.g. gas turbines).

1) Basic condition is the fuel cost on a level that allows generating electricity at competitive prices.
Average utilisation hours of power plants (example Germany, year 2004)

- **Nuclear power**: 7670 hours, 87.3%
- **Lignite**: 7230 hours, 82.3%
- **Hard coal**: 4460 hours, 50.7%
- **Natural gas**: 2730 hours, 31.0%
- **Run-of-river pp**: 4430 hours, 50.4%
- **Wind power**: 1600 hours, 18.2%

Source: VDEW-Stromdaten
Research and Development

The European Union initiated the technology platform "Zero Emission Fossil Fuel Power Plants" for the long-term realisation of low-CO₂, fossil-fired power plants. The constituent meeting of the Advisory Council took place in June 2005. The Council comprises members of utilities, plant manufacturers, the oil and gas industry as well as different research institutes and further interest groups (NGO’s).

In accordance with the European Commission, the Technology Platform will define the strategic research and development objectives for energy research within the EU 7th Research Programme (2007 to 2013). The initiative focuses on the further increase of power plant efficiencies as well as research into the possibilities of CO₂ capture upon electricity generation and the safe storage in geological formations.

In Germany, the EU activities are supplemented by the COORETEC-Programme. There are also research projects by European operators and manufacturers as e.g. the component plant "COMTES 700" for the development of the 700 °C-power-plant-technology as well as lignite pre-drying.

Research and development require time, thus,

• today's technologies have to be applied worldwide,
• the development of technologies for the next generations has to be accelerated,
• research into future options has to be intensified.
R & D electricity generation technologies: Today – tomorrow – the day after tomorrow

- CO₂ storage
- Hydrogen technology (e.g. fuel cell)
- Renewables
- Advanced nuclear pp

Development

- CO₂ capture
- Fuel cell (gas-based)
- 700 °C power plant engineering
- Lignite drying
- Renewables

Ready for application

- CC and gas-fired pp
- Hard coal-fired pp
- Lignite-fired pp
- Renewables (with subsidies)
- Nuclear pp

until 2020 after 2020

European technology platform

- Emission-free, fossil-fired power plants
  - Advisory board
    - Member states
    - Member organisation
    - Office
  - Steering committee or working parties
  - Platform activities
    - General assembly
Climate Policy

Climate Balance of EU 25 and Worldwide

The Kyoto Protocol agreed upon in 1997 was enforced in February 2005. According to the Protocol the participating countries are committed to decrease their greenhouse gas emissions until 2012 by a minimum of 5 % below the 1990-level.

The worldwide CO₂ emissions amounting to 23.6 billion tonnes (status: 2002) will increase annually by some 1.8 %. The share of these emissions caused by the energy industry will increase from 9.4 billion tonnes to 16.8 billion tonnes, provided the conditions assumed will prevail. Since the major increase in CO₂ emissions will stem from developing countries and the USA, a global climate policy can only result in sustainable emission reduction if these countries will also commit themselves to the Kyoto values. Today, only some 30 % of the worldwide CO₂ emissions are covered by the Kyoto commitment.

The industrialised countries are making enormous endeavours to minimise energetic losses through efficiency increases and thus to clearly reduce CO₂ emissions. Extremely high efficiency potentials exist in the developing countries. The avoidance of one tonne of CO₂ can be realised much more cost-efficiently in these countries than in countries with already high energy efficiency.

### CO₂ emissions 1990 – 2002

<table>
<thead>
<tr>
<th>Country</th>
<th>Change in %</th>
<th>-1500</th>
<th>-1000</th>
<th>-500</th>
<th>0</th>
<th>500</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia</td>
<td>-32 %</td>
<td></td>
<td></td>
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<tr>
<td>EU</td>
<td>-4 %</td>
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<tr>
<td>Germany</td>
<td>-19 %</td>
<td></td>
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<tr>
<td>Japan</td>
<td>+13 %</td>
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<tr>
<td>Australia</td>
<td>+8 %</td>
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<tr>
<td>USA</td>
<td>+16 %</td>
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</table>

**Change in millions of tonnes CO₂ equivalent**

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<thead>
<tr>
<th>-1500</th>
<th>-1000</th>
<th>-500</th>
<th>0</th>
<th>500</th>
<th>1000</th>
</tr>
</thead>
</table>

**Real development 1990 – 2002**

**Kyoto objective for 2008/12**

Source: UNFCCC 2004
CO₂ emissions in EU 25
1990 to 2030 according to sectors

Development of the worldwide CO₂ emissions
1990 to 2030 according to regions

Source: Energy Information Administration/International Energy Outlook 2004
VGB PowerTech e.V. is the European technical association of electricity and heat producers. According to its tasks, VGB Offices are divided into the competence centres:

- Nuclear Power Plants,
- Fossil-fired Power Plants,
- Renewables and Distributed Generation,
- Environmental and General Issues,
- Operational Services.

These competence centres are dealing with all issues of power and heat generation and related environmental topics in close co-operation with VDEW at national level and with EURELECTRIC at European level.

For performing its duties according to the articles of association, the VGB Board has opted for honorary committees. The VGB Technical Supervisory Board is responsible for appointing the members. Currently four general committees are active with their numerous technical and special committees as well as working panels.
VGB PowerTech e.V.

We are a voluntary association of companies that focus on power plant operation and related technologies, i.e. these fields are an important basis of the entrepreneurial activities of our members. The domicile of the association is Essen with liaison offices in Brussels and Berlin.

Our objective is the support and improvement of
- the operating safety and environmental compatibility as well as
- the availability and efficiency of power plants for electricity and heat generation, either in operation or under construction.

Currently we have 429 members in total, comprising operators, manufacturers and institutions connected with energy engineering. Our members come from 30 countries worldwide and represent an installed power plant capacity of 485 000 MW, 405 000 MW of which are in Europe.

Our tasks are to
- utilise and bundle international experience,
- offer expertise for current tasks and tomorrow’s challenges,
- represent our members’ interests.

Currently 429 companies from 30 countries are member in our association:

<table>
<thead>
<tr>
<th>Power Plant Type</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil-fired power plants</td>
<td>299 000 MW</td>
</tr>
<tr>
<td>Nuclear power plants</td>
<td>122 000 MW</td>
</tr>
<tr>
<td>Hydro-power plants</td>
<td>64 000 MW</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>485 000 MW</td>
</tr>
</tbody>
</table>

**EU 25:** 395 members in 19 countries
- Austria, Belgium, Czech Republic, Denmark, Germany, Finland, France, Greece, Great Britain, Hungary, Ireland, Italy, Luxembourg, The Netherlands, Poland, Portugal, Slovenia, Spain, Sweden

**Europe:** 24 members in 6 countries
- Iceland, Croatia, Romania, Russia, Switzerland, Turkey

**Outside Europe:** 9 members in 5 countries
- Brazil, India, Israel, Libya, South Africa

**Total:** 429 members in 30 countries
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