The global population of 7.7 billion people is increasing by 90 million people per year. Electricity consumption will grow faster, average 2000 to 2018: 66%, than any other form of energy consumption due to an increasing demand and population growth – one quarter of the global population does not yet have access to electricity. Additionally, digitisation, electromobility and sector-coupling will increase electricity demand.

The IEA estimates in all of its scenarios that in all fields and regions the annual electricity demand will increase from 26,607 billion kWh to a range of 38,713 to 42,824 billion kWh; an yearly average increase of about 2.1%.

The three scenarios are based on different targets for efficiency and emission reduction. Further scenarios e.g. by BP, ExxonMobil and the U.S. Energy Administration (EIA) and are available. According to all forecasts the worldwide electricity demand will increase by 2040 in a range of 34,000 to 43,000 billion kWh. In the EU, the expected increase in electricity demand is lower at about an average of +0.7%.

Generation capacities worldwide are increasing with +2.0% p.a., a significant increase.

The impact of the 2020 corona crisis is estimated to be low in both the medium and long term. In China, for example, electricity demand in mid-2020 is expected to rise again compared to the previous year.

EU includes the United Kingdom with respect to the data bases (before 2020).
Expected growth in electricity generation in billion (10^9) kWh worldwide

IEA scenarios (2019)
+45 to +61 %
+2.0 to 2.3 % per year

Expected growth in electricity generation in billion (10^9) kWh in the EU

IEA scenarios (2019)
+9 to 22 %
+0.5 to 1.1 % per year

Sources: IEA, BP, U.S. EIA, ExxonMobil, EU Commission, VGB (own calculations)
The EU and their member states have set binding, ambitious targets to promote the expansion of renewable energy sources. For the electricity sector, the EU expects renewables to account for 34% by 2020. Since the implementation of the EU Directive for climate protection and energy – often referred to as the “20-20-20 package” – adopted in December 2008, the share of renewables in gross final energy consumption has increased steadily. In 2018 the share reached 18.0%, almost twice as high as in 2004 (8.5%). This represents an increase of 0.5 percentage points over the previous year 2017.

At 54.6%, Sweden’s share of renewables was by far the highest in 2018, followed by Finland (41.2%), Latvia (40.3%), Denmark (36.1%) and Austria (33.4%). The lowest shares of renewable energy were registered in the Netherlands (7.4%), Malta (8.0%) and Luxembourg (9.1%). In total, twelve of the 28 EU member states have met their 2020 targets: Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, Greece, Italy, Latvia, Lithuania, Romania and Sweden.

Energy from renewables will play a key role in the years after 2020. For this reason, the member states have agreed on a new EU target of at least 32% by 2030.
Hydro power is not only a reliable renewable energy source, but also the frontrunner in Europe in the generation of electricity from renewable energy sources. With a production of more than 379 TWh – around 35.0% of the electricity generated from renewable energy sources – hydro power makes a significant contribution to achieving the EU target of 34% of electricity generation from renewable energy sources by 2020.

In addition to the predictable and constant generation of run of river power plants for base load coverage, the provision of reserve power and peak load to ensure security of supply and, in particular, control power to maintain grid stability in an increasingly flexible energy market is becoming more and more important. In Europe, these requirements are primarily met by high-efficiency pumped storage and storage hydro power plants with a total installed bottleneck capacity of more than 48,524 MW.

Hydro power is therefore not only an extremely efficient, reliable and storable form of energy, but also an indispensable renewable source of energy which has to be conserved and further developed within the framework of the energy transition.

**Target for RES-electricity in EU-28**

<table>
<thead>
<tr>
<th>Year</th>
<th>Target</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>32.9%</td>
<td>32.9%</td>
</tr>
<tr>
<td>2020</td>
<td>34.0%</td>
<td>34.0%</td>
</tr>
</tbody>
</table>

In brackets (...): Individual target; current targets achieved
In order to meet the European Union’s targets for the energy and climate package by 2020, it is also imperative to further expand the use of wind energy. In Germany at the end of 2019, around 30,950 wind turbines with a total capacity of 61,357 MW were in operation. At that time, the installed capacity of wind turbines in Europe was 204,814 MW and worldwide 650,557 MW.

A retrospective analysis of the wind turbine market reveals continuous further development of system technology, accompanied by increasing rated power, rotor diameter and hub height. From the first small plants with an average output of around 30 kW and rotor diameters of less than 15 m in the mid-1980s, offshore wind turbines with a rated power of 14 MW and more as well as rotor diameters of 222 m have been developed. Wind turbines have already paid for themselves in terms of energy after three to seven months of operation. This means that after this time the turbine has produced as much energy as is required for its production, operation and disposal. In addition to the consistent further development of system technology, the optimization of maintenance strategies in particular will play a decisive role in the future in order to increase technical availability and thus economic efficiency. Especially reliability, weight, costs and efficiency play a key role in this respect.

* Including not listed countries. Source: WindEurope
Energy production from biomass is a decisive component of the energy transition. Currently, 188 TWh of electricity is produced from biomass in Europe, which means that biomass accounts for 17.5% of renewable electricity generation. In Europe, Finland, Italy, the United Kingdom and Germany were the countries with the highest electricity production from biomass in 2018.

Biomass is used as a fuel in thermal power plants or is fermented to produce methane in biogas plants. Biomass power plants meet the same requirements for the stability of the electricity grid as fossil-fired power plants. They are suitable for base-load as well as for the supply of balancing and control power. In addition, it is also possible to convert coal-fired power plants to biomass in order to continue using existing sites. Biogas is usually used in gas engines to generate electricity or can be fed into the natural gas grid. This contributes a considerable storage potential.

Biomass power plants and biogas plants can be used both in centralised and distributed systems. Biomass, as an all-round renewable energy source, is therefore an indispensable component of future energy supply systems.
Distributed generation is an essential part of the energy transition and will increase significantly in the coming years. However, the complex system of distributed energy supply, consisting of “Security of supply – environmental protection – economic efficiency”, must be considered in its entirety.

Combined heat and power plants are mainly based on the classic reciprocating engine process. In addition, fuel cells can open up new fields of application for combined heat and power (CHP). They represent important technical innovations, as they enable the use of CHP technology, even in the very small power range. This applies in particular to applications in the local heating sector, but also in the commercial and industrial sectors.

In combination with the increase in distributed energy generation, these systems will increasingly have to offer the necessary network services in the future, including the provision of control power.

To support the necessary measures, smart metering will now also be introduced in Germany. With intelligent information networks, energy production and consumption can be efficiently linked and balanced. The central component of an intelligent metering system is the Smart Meter Gateway as a communication unit.
Efficient system integration of variable renewable energies and distributed generation requires a high degree of flexibility. This flexibility can be provided by controllable generation, storage and sector coupling solutions.

Storage systems can be divided into centralised storage power plants, decentralised small-scale storage facilities, short-term or long-term storage facilities. Furthermore, there is the possibility to store electrical or thermal energy. Hydrogen is a central key to achieving climate neutrality. The technologies for producing climate-neutral hydrogen are already available today. However, climate-friendly hydrogen technologies must be developed and strengthened quickly and international cooperation must be expanded. Since it is currently the only application that can link all sectors (electricity, industry, heating and transport) and at the same time ensure the over-seasonal storage capacity of energy, power-to-gas (PtG) is taking on the role of a key technology for sector coupling.

Market-driven framework is required for the use of the various storage technologies. The only mature technology currently available is the use of hydropower in the form of pumped storage power plants. Large battery systems have already demonstrated their technical suitability.
Today, volatile energy resources such as photovoltaics and wind contribute about 10% to global electricity generation – according to IRENA, their share will grow to about 60% by 2050. This will also increase the need for flexibility in the energy system, which arises from fluctuating residual loads. The more flexible an energy system is, the better the integration of increasing shares of photovoltaics and wind will succeed. System flexibility is essentially ensured by the four options of controllable generation, energy storage, grids and demand-side management.

Dispatchable generation technologies currently form the backbone of system flexibility – in Europe, for example, they account for 80% of available flexibility capacities (IEA, World Energy Outlook 2019). Controllable generation mainly includes thermal power plants and hydropower plants. Their flexibility can be characterised by three parameters: Minimum load, load gradient and start-up and shut-down times. The minimum load represents the lowest load at which a power plant can be operated under stable conditions. The load gradient indicates how quickly a power plant can change its output in a given time. The start-up time indicates the time from the start of power plant operation until the minimum load is reached; the shut-down time indicates the time until complete shut-down.

The increasing share of volatile energy resources requires not only a high degree of flexibility in the energy system, but also special attention to security of supply. It must be ensured that electricity demand is covered at all times and in all places. Fluctuations in the feed-in of wind and photovoltaics must be balanced not only in the short term, but also in the long term. In Europe, for example, there are meteorological situations in which there is no wind and no sunshine for several days or weeks. During this period, controllable generation capacities and/or energy storage facilities must guarantee security of supply.

New and appropriately upgraded thermal power plants can contribute to the integration of renewable energies into a modern power supply system through their flexible operation. The focus of technical developments is on the exploitation of the existing potential for flexible plant operation. Against the backdrop of the expansion targets for renewable energy throughout Europe, a broad and flexible thermal power plant portfolio will continue to be indispensable in the future in order to ensure economic efficiency and security of supply at all times.

FLEXIBLE GENERATION – GUARANTEEING SECURITY OF SUPPLY

FACTS AND FIGURES   ELECTRICITY GENERATION 2020 | 2021
Flexibility parameters of controllable generation plants:
High load gradients, low minimum load, short ramp-up times

<table>
<thead>
<tr>
<th>Plant type</th>
<th>Hard coal</th>
<th>Lignite</th>
<th>CCGT</th>
<th>Gas turbine</th>
<th>Nuclear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load gradient in % per minute</td>
<td>2/4/6</td>
<td>2/4/6</td>
<td>4/8/12</td>
<td>8/12/15</td>
<td>2/5/10</td>
</tr>
<tr>
<td>... in the load range of %</td>
<td>40...90</td>
<td>50...90</td>
<td>40^a...90</td>
<td>40^a...90</td>
<td>40...100</td>
</tr>
<tr>
<td>Minimum load in % of nominal capacity</td>
<td>40/25/15</td>
<td>60/40/20</td>
<td>50/40/30^a</td>
<td>50/40/20^a</td>
<td>40^b/40^b/40^b</td>
</tr>
<tr>
<td>Ramp-up time in hours (h), hot start &lt; 8 h</td>
<td>3/2/1</td>
<td>6/4/2</td>
<td>1.5/1/0.5</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Ramp-up time in hours (h), cold start &gt; 48 h</td>
<td>7/4/2</td>
<td>8/6/3</td>
<td>3/2/1</td>
<td>&lt;0.1</td>
<td>36/36/24</td>
</tr>
</tbody>
</table>

^a) As per emission limits for nitrogen oxides (NO\textsubscript{x}) and carbon monoxide (CO).
^b) Limited by minimum load of the steam turbine.

Sources: VDE, VGB (own studies).
NEW FRAMEWORK FOR THE OPERATION OF CONVENTIONAL POWER PLANTS

Electricity generation in Europe has changed in recent years. These include the development of renewable energies, the reduction of electricity generation in conventional – thermal – power plants, the different European energy policies and the development of the electricity market. An efficient tool is needed to help make decisions and to assess the various influences.

With the objective of evaluating, comparing and optimising the operation of power plants and the plants (systems & components) themselves, VGB has been collecting data on e.g. the availability and utilisation of different power plants since 1970 according to uniform definitions and procedures, using the Power Plant Information System (KISSY – Kraftwerksinformationssystem).

The following trend diagrams show the comparison between European coal-fired power plants (276 plants) and gas turbines (151 plants) over the period 1998 to 2019. The number of power plants shown per year vary because typical behaviours such as decommissioning, new plants, power plant modifications, transfer to grid and capacity reserve or safety readiness have to be considered.

The performance-weighted characteristic values of energy availability and energy utilisation as well as of planned, disposable and not disposable availability and especially of unavailability show interesting developments over the 22 years which reflect current trends such as liberalisation and the energy turnaround.

The unplanned unavailability reflects the short-term technical failures of the power plants. While for coal-fired power plants this has been increasing steadily over all these years, for gas turbines it has only increased sharply in the last 3 years, with the same fluctuations in maintenance measures over the last 10 years.

Sources
Technical and Commercial Key Indicators for Power Plants, VGB-S-002-03-2016-08-EN, VGB PowerTech, ISBN 978-3-86875-934-1 (eBook, free of charge)
Energy availability of European power plants

- Energy availability, coal
- Energy availability, gas
- Energy utilisation, coal
- Energy utilisation, gas

Unavailability (UA) of European power plants

- UA planned, coal
- UA postponable, coal
- UA not postponable, coal
- UA planned, nat. gas
- UA postponable, nat. gas
- UA not postponable, nat. gas.

Source: VGB data base KISSY (Power plant information system, data: 2019)
In 2019, electricity generation from nuclear power plants was around 2,587 billion kWh, slightly higher than in 2018, due to excellent operating results of the plants as a whole, the first commissioning of new units mainly in Asia and the recommissioning of 8 units in Japan in recent years. The share of nuclear energy in the total global electricity generation was 10.5% in 2019. In Western Europe, electricity generation from nuclear energy remained almost constant compared to 2018 at around 750 billion kWh. After North America, Western Europe is the second strongest economic region with nuclear power generation.

Since the first commercial nuclear power plants were commissioned in Calder Hall, England, in 1956, a cumulative total of about 83,900 billion kWh of electricity has been produced. This corresponds to about three times today’s worldwide annual electricity demand.

The greatest increase in nuclear power generation was in the 1980s, when the large nuclear power plant projects with unit capacities above 1,000 MW, which were started in the 1970s, went into operation.

After the events in Japan in 2011, the availability of work increased slightly to a global average to the high value of almost 80%.
Worldwide, 444 nuclear power plants with a total capacity of 419,797 MW were operated in 31 countries (status: December 2019). 52 nuclear power plant units are currently under construction and the trend of new projects in the countries of Asia as well as in newcomer countries, also in Africa, the Middle East and South America – with substantial participation of the supplier countries – is increasing.

In the years 2018 and 2019, for example, a total of 9 new nuclear power plant units started commercial operation for the first time in China, among them Taishan 1 and 2, the first European pressurised water reactors (EPR). With a gross capacity of 1,750 MW each these are currently the most powerful nuclear power plant units worldwide.

Thus, 15,600 MW of nuclear power plant capacity have been added worldwide, but also 9 older power plant units, mostly with lower capacity, have been permanently shut-down.
A part from the further development of the reliable light water reactor technology, innovative modularly designed reactors of small and medium capacity up to approx. 600 MW are developed. These “Small Modular Reactors” (SMR) and other concepts belong to the so-called Generation IV reactors. The USA and Canada in particular are involved in this, but projects are also starting in Great Britain, China and Finland.

These concepts are characterised above by the following properties:

- Highest safety standards through passive systems or physically inherent safety features.
- Modular design. i.e. a step-by-step investment-optimised construction of the units according to requirements is possible.
- “Modular principle”, i.e. production in the manufacturer’s factory with all advantages of series production is aimed for.
- Long maintenance intervals and operating times for the nuclear fuel loading over several years lead to lower operating costs.
- Partial erection of the modules in underground caverns and thus also close to the consumers. This enables not only the generation of electricity, but also the supply with district or process heat.
- Self-supply of remote areas in island operation.

SMALL MODULAR REACTORS (SMR)
Assuming an average lifetime of 60 years for a nuclear power plant, approx. 300 plants will be shut down worldwide by 2030. Since the decision for the phase-out of nuclear energy in 2011, the German plant operators and the nuclear industry, which has also prepared itself for the dismantling, have gained extensive knowledge on planning, organisation and implementation of the dismantling. Of the 30 prototype, pilot and power reactors decommissioned to date, three have been completely dismantled to the “greenfield site”. The dismantling work at other plants has started well and is well advanced according to the shutdown date.

Apart from Germany, nuclear power plants are also decommissioned and dismantled in other European countries such as Belgium, France, Sweden, Lithuania but also outside Europe.

The increased international interest leads to the fact that international organisations like WANO, WNA, OECD/NEA are increasingly dealing with the decommissioning and dismantling of nuclear power plants.

Within the framework of the EU project Horizon2020 SHARE (Stakeholder-based Analysis of Research for Decommissioning), the EU, in cooperation with relevant stakeholders, is also identifying a Strategic Research Agenda for the decommissioning and dismantling of nuclear installations.
For more than two decades, European electricity generation has been investing predominantly in renewable energy sources and gas-fired power plants, whereas in the 1970s and 1980s, investments focused on conventional coal-fired and nuclear power plants. This structural change is above all the result of various financial support systems for renewables in the individual European countries.

Conventional power plants in Europe, mainly coal-fired and nuclear power plants, have therefore now reached a technical age at which future decommissioning is foreseeable. The typical technical lifetimes of coal-fired power plants are about 40 years, those of nuclear power plants about 60 to 80 years, and those of hydroelectric power plants about 100 years. In addition, it is also foreseeable that in the coming years, renewables capacities will increasingly reach the end of their technical operating life; the service life of wind power and photovoltaic systems is considered to be 20 to 30 years.

Based on typical service life data and individual political decisions (e.g. phasing out nuclear power in Germany by 2022), it can be estimated that by the year 2030 around 30% of the electricity generation capacities currently in operation in Europe will be decommissioned. By 2050, this figure will be around 80%.

This estimate makes it clear that with today’s time horizons for planning, construction and commissioning of power generation plants of 10 years and more, suitable replacement capacities for a secure electricity supply will have to be prepared in good time – now.
The need to replace existing power generation capacities in Europe has led many companies to plan new construction projects. Despite the massive expansion of energy from renewables, coal, natural gas and nuclear energy continue to be the most important primary energy sources for reliable available power generation. Highly efficient new plants are replacing less efficient power plants. In addition to a significant reduction in CO$_2$ emissions, new power plants will also reduce further emissions and their increased flexibility will contribute to a secure electricity supply and the integration of renewable energy into the supply system. However, due to a lack of long-term political framework conditions across Europe, investment in new capacities is stalled.

According to the updated VGB PowerTech new construction statistics, the technology of gas-fired power plants accounts for the largest share of the available capacity of disposable conventional plants at around 30%. With a share of approx. 14% these are followed by hard coal and lignite power plant projects, particularly in Eastern European countries. The low-emission sources nuclear and hydropower account for 12.3% and 9.2%. Projects based on non-schedulable generation technologies continue to focus on wind power plants with a capacity share of approx. 34.5%.

Within a decade, the projected and announced new build capacities gathered have declined considerably, from 277,884 MW in 2010 to 96,563 MW in 2020.

**Projected and announced power plant capacities in Europe**

- **Gas** (28,403 MW, 29.4%)
- **Oil** (0 MW, 0%)
- **Hard coal** (12,200 MW, 12.7%)
- **Lignite and peat** (1,160 MW, 1.2%)
- **Nuclear** (11,800 MW, 12.2%)
- **Hydro** (9,013 MW, 9.3%)
- **Wind** (33,279 MW, 34.5%)
- **Biomass** (300 MW, 0.3%)
- **Residues and waste** (120 MW, 0.1%)
- **Other renewables** (300 MW, 0.3%)

* without photovoltaic, oil: no projects., incl. averages

Source: Data base VGB, state: 2020
Climate Policy: Global Approach Needed

Between 1990 and 2018, the total greenhouse gas emissions (GHGE) in the European Union (EU-28) decreased by 23.2% (World Bank, EU, state: 2018). Targets for climate and energy policy were revised by the EU Commission in November 2018. The objective is to reduce EU emissions by at least 40% below 1990 levels by 2030.

For the stabilisation and actual reduction of GHGE emissions, action, based on the principle of effectiveness and cost efficiency, has to be taken worldwide. Cost-efficient measures such as insulation of buildings, fossil-fired power plants with higher efficiencies, the application of CCU (Carbon Capture and Utilisation), expanded use of renewables or further use of technologies with low GHGE like nuclear energy must be applied with priority and without prejudice in order to mitigate the globally increasing amount of GHGE.

The International Energy Agency (IEA) has developed a stabilisation concept, “Sustainable Development”, which, compared with the reference scenarios “Current Policies” – unchanged energy policy – and “Stated Policies” – taking into account announced measures for a more sustainable energy policy – aims to stabilise energy consumption and the CO₂ concentration in the atmosphere through a bundle of instruments.

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2040 (in billion (10^6) t CO₂)</th>
<th>2040</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ emissions worldwide, total, energy sector</td>
<td>33,243</td>
<td>41,302</td>
<td>35,589</td>
<td>15,796</td>
</tr>
<tr>
<td>Coal</td>
<td>14,664</td>
<td>16,609</td>
<td>13,891</td>
<td>3,424</td>
</tr>
<tr>
<td>Oil</td>
<td>11,446</td>
<td>14,053</td>
<td>12,001</td>
<td>6,433</td>
</tr>
<tr>
<td>Natural gas</td>
<td>7,134</td>
<td>10,639</td>
<td>9,697</td>
<td>6,032</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>thereof electricity generation</th>
<th>2018</th>
<th>2040</th>
<th>2040</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>10,066</td>
<td>11,813</td>
<td>9,641</td>
<td>1,552</td>
</tr>
<tr>
<td>Oil</td>
<td>692</td>
<td>497</td>
<td>418</td>
<td>200</td>
</tr>
<tr>
<td>Natural gas</td>
<td>3,060</td>
<td>4,284</td>
<td>3,775</td>
<td>2,123</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>thereof other final energy consumption</th>
<th>2018</th>
<th>2040</th>
<th>2040</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>17,809</td>
<td>22,561</td>
<td>19,895</td>
<td>11,037</td>
</tr>
</tbody>
</table>

IEA scenarios for the reduction of greenhouse gas emissions. Share of energy sources.

* incl. upstream and downstream sector

Source: IEA, World Energy Outlook 2019
### CO₂ emissions total and per capita from fossil fuel combustion for selected regions for 2018 and changes from 1990 to 2018

<table>
<thead>
<tr>
<th>Region</th>
<th>Change 1990 to 2018</th>
<th>CO₂ emissions (billion t CO₂ per year)</th>
<th>CO₂ emissions (t CO₂ per capita)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU-28</td>
<td>-18 %</td>
<td>3,518</td>
<td>6.1</td>
</tr>
<tr>
<td>India</td>
<td>+313 %</td>
<td>2,650</td>
<td>1.96</td>
</tr>
<tr>
<td>USA</td>
<td>+1 %</td>
<td>5,410</td>
<td>16.56</td>
</tr>
<tr>
<td>China</td>
<td>+347 %</td>
<td>7,05</td>
<td>4.14</td>
</tr>
<tr>
<td>World</td>
<td>+61 %</td>
<td>33,114</td>
<td>4.14</td>
</tr>
</tbody>
</table>

Sources: U.S. Department of Energy’s (DOE) Environmental System Science Data Infrastructure for a Virtual Ecosystem (ESS-DIVE) 2020, and IEA: CO₂ emissions from fuel combustion

### CO₂ emissions from different power plants in g CO₂ equivalent per kWh, calculated for the life cycle of the power plant

<table>
<thead>
<tr>
<th>Power Plant</th>
<th>CO₂ Emissions (g CO₂ per kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignite</td>
<td>950 to 1,230</td>
</tr>
<tr>
<td>Hard coal</td>
<td>790 to 1,080</td>
</tr>
<tr>
<td>Oil</td>
<td>890</td>
</tr>
<tr>
<td>Natural gas</td>
<td>640</td>
</tr>
<tr>
<td>Gas combined cycle</td>
<td>410 to 430</td>
</tr>
<tr>
<td>Photovoltaik</td>
<td>35 to 160</td>
</tr>
<tr>
<td>Nuclear</td>
<td>16 to 23</td>
</tr>
<tr>
<td>Wind</td>
<td>8 to 16</td>
</tr>
<tr>
<td>Hydro power</td>
<td>4 to 13</td>
</tr>
</tbody>
</table>

Result range due to different methods of calculation and different site implications.

Sources: PSI Paul Scherrer Institut/Switzerland, ESU-services, VGB (own calculations)
**VGB POWERTECH E.V.**

VGB PowerTech e.V. is the international technical association for generation and storage of power and heat with head office located in Essen (Germany).

Currently VGB has 436 members, comprising operators, manufacturers, and institutions connected with energy engineering.

Our members come from 34 countries and represent an installed power plant capacity of 303,000 MW located in Europe.

The activities of VGB PowerTech comprise:

- Provision of an international platform for the accumulation, exchange, and transfer of technical know-how.
- Acting as “gate-keeper” and provider of technical know-how for the member companies and other associations of our industry.
- Harmonisation of technical and operational standards.
- Identification and organisation of joint R&D activities.
- Exclusive member access to qualified expert knowledge.
- Representation of members’ interests.

VGB is performing these tasks in close cooperation with Eurelectric on European-level and further national and international associations.

**Structure of the VGB membership:**

<table>
<thead>
<tr>
<th>Category</th>
<th>Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil-fired power plants</td>
<td>227,500</td>
</tr>
<tr>
<td>Nuclear power plants</td>
<td>32,500</td>
</tr>
<tr>
<td>Hydro power plants and other renewables</td>
<td>43,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>303,000</strong></td>
</tr>
</tbody>
</table>

**EU: 410 members in 20 countries**

Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Luxembourg, The Netherlands, Poland, Portugal, Romania, Slovenia, Spain, Sweden

**Other Europe: 14 members in 4 countries**

Russia, Switzerland, Turkey, United Kingdom

**Outside Europe: 12 members in 10 countries**

Argentina, Canada, China, Israel, Japan, Malaysia, Mongolia, Morocco, Saudi Arabia, South Africa

**Total: 436 members in 34 countries**
VGB PowerTech e. V. supports its members with all technical issues of generation and storage of electricity and heat in order to further optimise:

- Safety
- Efficiency
- Environmental friendliness
- Economic efficiency and
- Occupational safety and health protection

The competence areas “Nuclear Power Plants”, “Power Plant Technologies”, “Renewables and Distributed Generation”, and “Environmental Technology, Chemistry, Safety and Health” are dealing with all aspects of nuclear, conventional and renewable generation. They are cooperating closely to fully exploit the synergies.

The engineering services of the “Technical Services” with engineering consulting, materials and oil laboratory and water chemistry, the VGB Research Foundation, data bases, and publications, e.g. the technical journal VGB POWERTECH perfectly round off the portfolio of expertise of VGB PowerTech.