Electricity Generation **2023|2024**

Facts and Figures

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Electricity Generation **2023** | **2024 – Facts and Figures**

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DEVELOPMENT OF THE GLOBAL AND EUROPEAN ELECTRICITY DEMAND

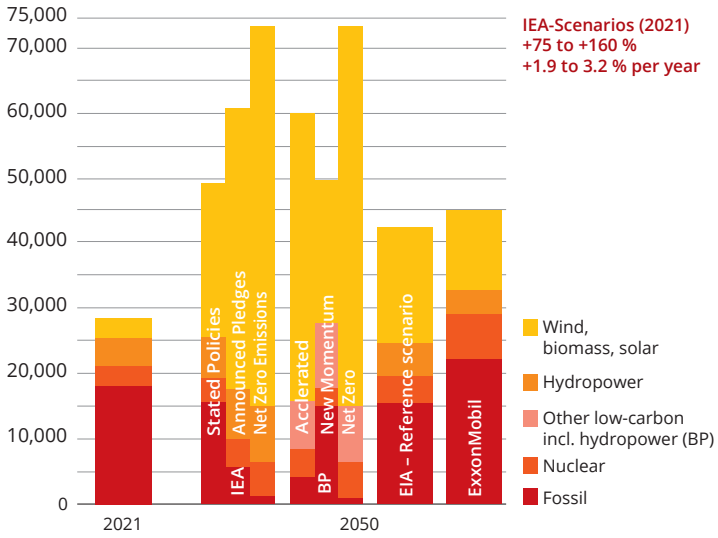
The global population of 8.0 billion people (United Nations, mid-November 2022) is increasing by approx. 80 million people per year. Electricity consumption will grow faster and thus simultaneously generation, average 2000 to 2021: +84 %, than any other form of energy consumption due to an increasing demand and population growth – one quarter of the global population does not yet has access to electricity. Additionally, digitilisation, electromobility and sector-coupling will increase electricity demand.

The IEA estimates in all of its three scenarios that in all fields and regions electricity generation will increase from 28,334 billion kWh in 2021 to a range of 49,845 billion kWh to 73,232 billion kWh in 2050; an yearly average increase of approx. 1.9 % up to 3.2 %. The scenarios are based on different policies and targets for efficiency and emission reduction. The so-called "Net Zero Emmissons Scenario" is based on no climate effective emissions in 2050. 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 2050 in a range of the IEA´s scenarios. In the EU, the expected increase in electricity demand is lower at about an average of +1.0 % to 3.5 %. Generation capacities worldwide are increasing with +3.1 % to +5.0 % p.a. from 8,185 Gigawatt in 2021 up to a range of 19,792 Gigawatt to 33,878 Gigawatt in 2050 – according to IEA´s scenarios – a significant increase.

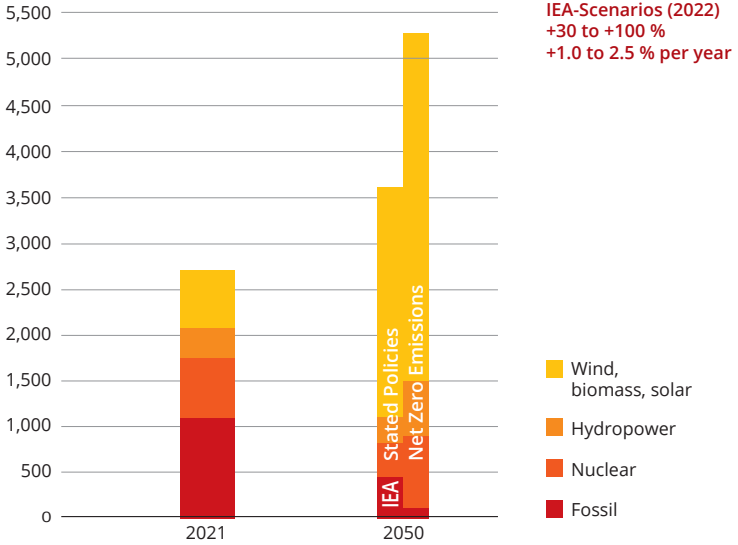
The impact of the 2020 Corona crisis and the Russian war on Ukraine is estimated to be low in both the medium and long term. In China, for example, electricity demand in 2021 has risen again compared to the year 2019 level – before Corona. Russian oil, gas and coal are now exported to other regions than before the war.

EU data no longer include the UK due to stated projections after 2020.

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



Expected growth in electricity generation in billion (10^9) kWh in the EU-27



Sources: IEA, BP, U.S. EIA, ExxonMobil, EU Commission, own calculations

RENEWABLES – EU’s targets

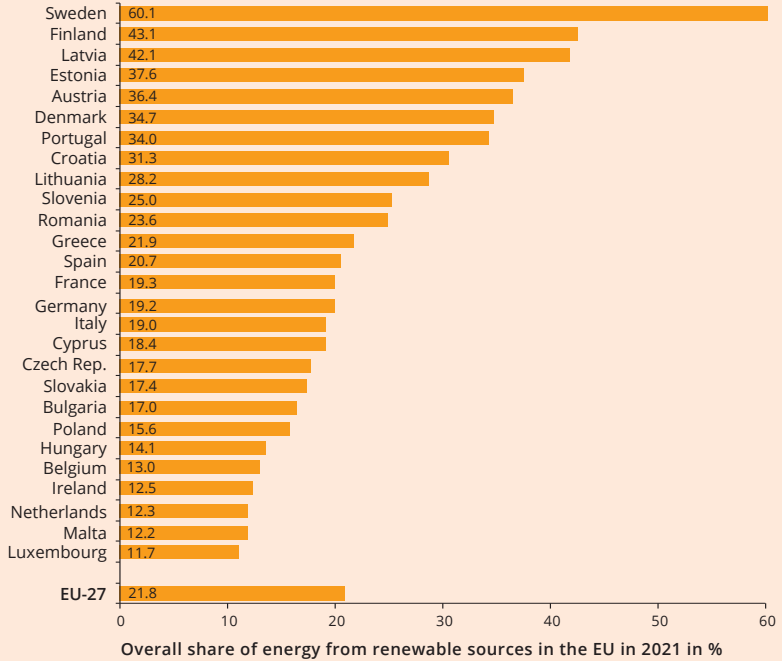
The European Union (EU) has been pioneering the transition to renewable energy sources, solidifying its commitment through the Renewable Energy Directive (RED). This directive outlines the EU's ambitious targets and policies aimed at promoting renewable energy adoption across the region to make Europe the first climate-neutral continent by 2050. For the intermediate 2030 goals, the European Commission recently came to a provisional agreement to increase its target share of renewable energy to at least 42.5 %, reinforcing its dedication to combatting climate change and fostering a sustainable future.

The RED outlines specific measures to ensure member states' compliance with the renewable energy targets. These measures include National Renewable Energy Action Plans (NREAPs), which serve as comprehensive roadmaps for each member state to outline their renewable energy strategies and contributions towards the collective EU goals. Additionally, the directive has put forth binding 10-year targets for each member state, providing a clear framework for progress evaluation and accountability.

The most recent EU data from 2021 puts the share of gross final energy consumption from renewable sources in the EU at 21.8 %. This was a 0.3 percentage point decrease from 2020 and the first-ever recorded decrease. 21.8 % is still far away from the lofty targets set by the European Commission and puts further pressure on underperforming countries to reach their targets.

vgbe energy, along with its close partners such as Eurelectric, maintains a watchful eye on the renewable energy situation at a European level. As the targets set out in these directives and regulations at a European level affect how national and local governments and bodies regulate their energy sector.

Overall share of energy from renewable sources in the EU in 2021



Source: Eurostat 2023 (Data: 2021)

Hydro power – an indispensable source of energy

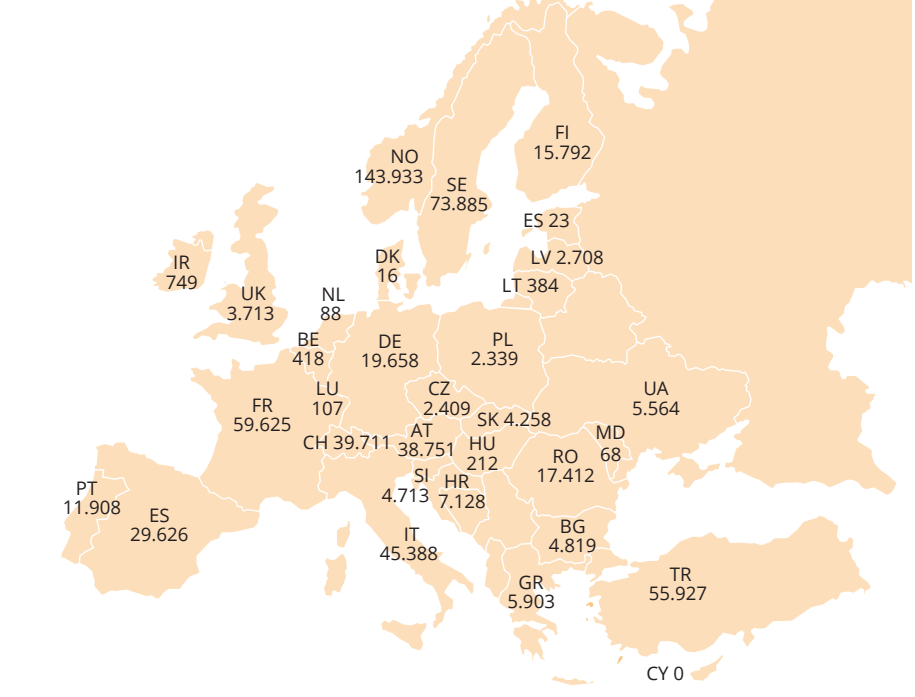
Hydropower is not only a reliable renewable energy source but is also one of the leaders in Europe in the generation of electricity from renewable energy sources. With a generation of around 348 TWh – about one third of the electricity generated from renewable energy sources.

As seen on the map, hydropower is utilised in nearly every European country. In particular, the Nordic countries as well as the Alpine are relying on this trusted energy source.

In addition to the well-predictable and constant generation in run-of-river plants for base load coverage, the importance of providing reserve power and peak load to ensure security of supply and, in particular, control energy to maintain grid stability is increasing in an ever more flexible energy market. In the EU, these requirements are predominantly ensured by the highly efficient pumped storage and storage hydropower plants with a total installed capacity of nearly than 46,000 MW.

Hydropower is therefore not only an extremely efficient, reliable and also storable form of energy, but also an indispensable renewable energy that must be preserved and further promoted in the context of the energy transition.

Despite the importance of hydropower in the European energy mix, both today and in the future, this sector faces numerous challenges and hurdles. From needing a clear regulatory framework and level playing at the European level to technical challenges related to an ever-changing climate and hydrologic cycle, hydropower faces a tough road ahead if it is to remain the reliable and stable energy source Europe needs in the future.



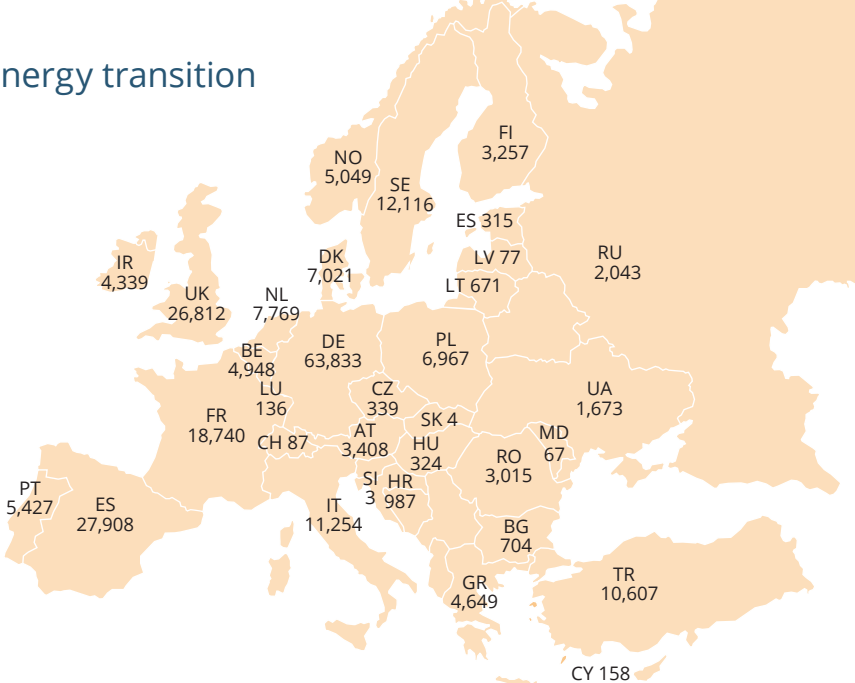
Gross electricity generation of run-of-river and reservoir storage hydropower in European countries in 2021 in billion (10^9) kWh

Sources: (1) eurostat; (2) CH Bundesamt für Energie BFE;
(3) UK Department for Business, Energy & Industrial Strategy

Wind energy – A supporting pillar in the energy transition

Wind energy plays a crucial role at the European level in achieving the desired climate neutrality by 2050 under the "Green Deal". The Parliament adopted the EU Climate Law on 24th June 2021, thereby legally binding the goals of reducing emissions by 55 % by 2030 and achieving climate neutrality by 2050.

As seen on the depicted map of Europe, the installed capacity for onshore and offshore wind energy for the 27 EU member states was 188,371 MW (EU-27 + UK 215,183 MW).



Wind energy: Total capacities in Europe end of 2022 in MW

Source: EUROSTAT (2023)

Compared to the previous year, this represents an increase of 11,312 MW. Europe as a whole thus has an installed capacity of around 236,000 MW. With 437 TWh of electricity generated, wind energy accounted for approximately 15 % of the electricity consumption of the 27 EU Member States + UK in 2021. In Europe Germany leads with an undisputed 63,833 MW of installed capacity, followed by Spain with 27,908 MW and the UK with 26,812 MW.

The wind energy sector remains dynamic and innovative. Technological advances continue: higher rated capacities are being achieved offshore, and onshore new concepts are being tested to further optimise operation and maintenance. Finally, the focus is on improving sustainability (keyword recycling).

All of these are topics on which members at vgbe energy, an international association for plant operators, exchange ideas. vgbe places its focus on all techno-economic and ecological aspects regarding the construction and operation of wind energy plants and relies on its strong network of industry experts.

Looking at the current installation figures, it is clear that we still have a long way to go to achieve the politically defined climate targets. Only through a collaborative approach can we achieve these objectives.

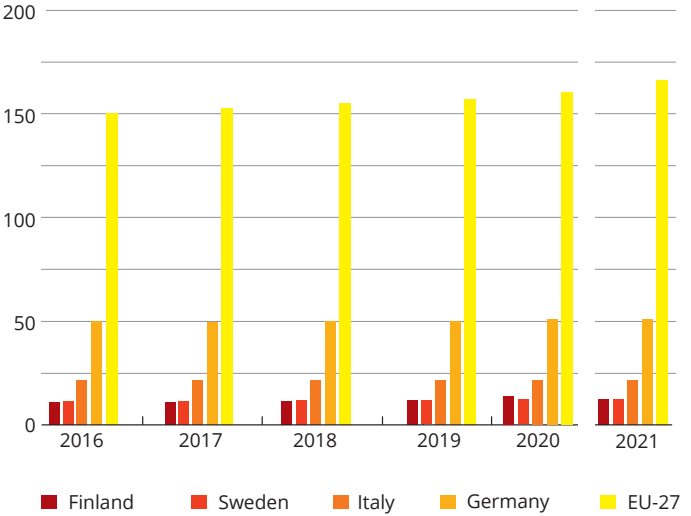
Biomass – The multitalent

Energy generation from biomass is a crucial component of the energy transition. Currently, 163 billion kWh of electricity are generated from biomass in Europe, which means that biomass (solid, liquid, gaseous) accounts for 15 % of renewable electricity generation. In Europe, Finland, Italy, Sweden and Germany were the countries with the highest electricity production from biomass in 2020.

Biomass is used as fuel in thermal power plants or is fermented into methane in biogas plants. Biomass power plants fulfil the same tasks for the stability of the electricity grid as fossil-fuelled power plants. They are both base-load capable and suitable for the provision of balancing and control energy. In addition, there is also the possibility of converting coal-fired power plants to biomass so that existing sites can continue to be used. Biogas is either directly converted into electricity in gas engines or processed into biomethane and fed into the existing natural gas grids. This is also associated with considerable storage potential.

Biomass power plants and biogas plants can be used both centrally and decentrally. As a multitalent among renewable energies, biomass is thus an indispensable component of future energy supply systems.

Biomass: Development of electricity generation in selected countries and the EU-27 (in billion (10^9) kWh)

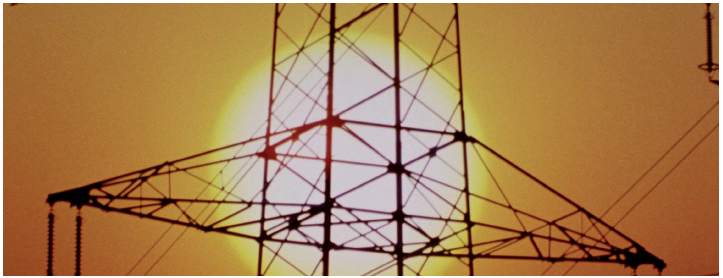


Source: Eurostat (2023)

Distributed power generation – New supply system structures

Distributed energy resources play a critical role in the transition of the traditional energy industry into a distributed decarbonised system.

The growth rates for distributed generation are expected to significantly outpace that of centralised generation in all regions through 2030.



This shift away from centralized generation requires innovative technologies and solutions on the part of grid operators, including advanced software and hardware that enable greater control and interoperability across heterogeneous grid elements.

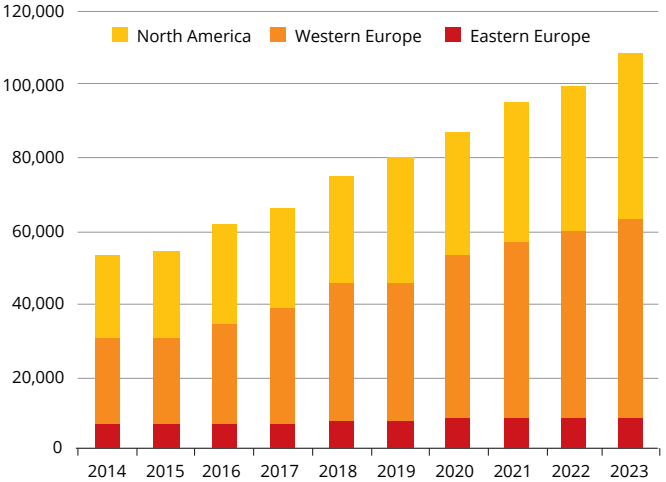
Distributed energy technologies grouped in parts of the value chain that generate, manage, and consume electricity.

It is expected to have steadily growing demand over the next decade until 2030, by residential and other end consumers including commercial, industrial, community/multifamily, institutional, and remote (island) installations.

The use of large heat pumps will also make an important contribution to the decarbonisation of the heating sector in the future.

The available heat sources are diverse, ranging from the use of environmental heat from air, soil and water up to the use of industrial heat recovery. Since the environmental heat sources are emission-free and the electricity will be drawn purely from renewable energies in the future, the heat pump will operate in a completely climate-neutral manner. To support the necessary measures, smart metering is also being introduced across Germany. The introduction of smart metering systems is the starting signal for the digitalisation of the energy transition in Germany. With them, consumers and companies can manage their electricity consumption or the feed-in of their electricity better and more conveniently.

Total annual installed capacity of distributed energy resources by technology, selected regions: 2014 to 2023 in MW



Distributed generation, including small hydropower, biomass, biogas, solar energy, wind power and geothermal energy & decentralised storage systems & charging load management of electric energy management systems & energy efficiency

Source: Navigant Research

Storage technologies – An important component of system stability

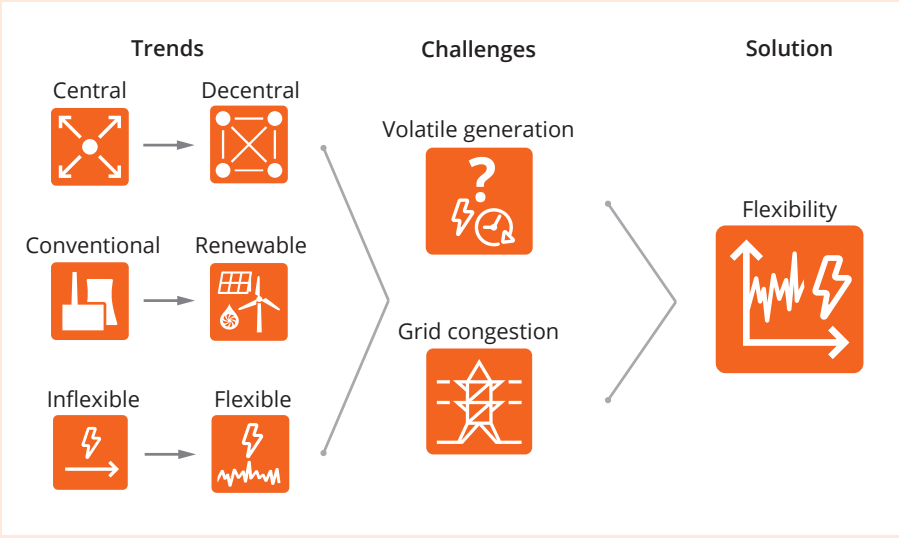
Efficient system integration of variable renewable energies (VRE) and decentralised generation require a high degree of flexibility.

This flexibility can be provided by controllable generation as well as storage and sector coupling solutions.

Globally Growing need to modernise global electricity grids and the evolution of business cases for deploying energy storage are likely to ensure continued market growth.

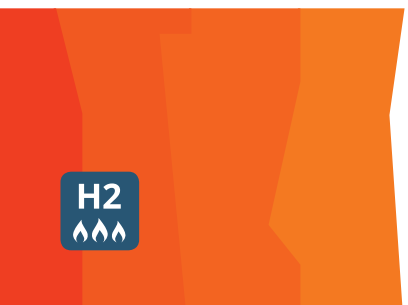
As global electricity grids embrace the new energy economy, energy storage is becoming a necessity in grid infrastructure. In recent years, the landscape for this technology has grown increasingly sophisticated.

Several key factors continue to increase the global need for energy storage deployments. The restructuring of electricity markets will enable valuation of the flexible benefits of energy storage deployments, while variable generation sources such as solar PV and wind that are connected to power grids will require increased load balancing against demand. Areas with unstable grids and frequent outages will benefit from distributed energy storage systems (DESSs) and microgrids with storage, and load profiles are expected to play a critical role in the structure and operation of the power grid, which will influence the development of energy storage markets.


Trends
Challenges
Solution
Central
Decentral
Conventional
Renewable
Inflexible
Flexible
Volatile generation
Grid congestion
Flexibility

Hydrogen as key to sector coupling

The advantage of hydrogen (H_2) is that it can be used as an energy carrier in almost all sectors – such as transport, heat generation and industry. If H_2 is produced in a climate-neutral way, it can make a significant contribution to climate neutrality. Technologies for the production of climate-neutral H_2 are already available today and are constantly being further developed through intensive R&D activities.



The worldwide demand for H_2 will increase strongly in the future. Many countries have already developed hydrogen strategies. In view of the long-term international efforts required for decarbonisation by 2050, most national strategies focus on the use of green H_2 produced exclusively from renewable energies. The emphasis on green H_2 is particularly pronounced in the EU. In some countries, such as Australia, Japan and Russia, other types of low-carbon hydrogen are also seen as one way to provide the required quantities of H_2, reduce technology costs and boost the H_2 economy.

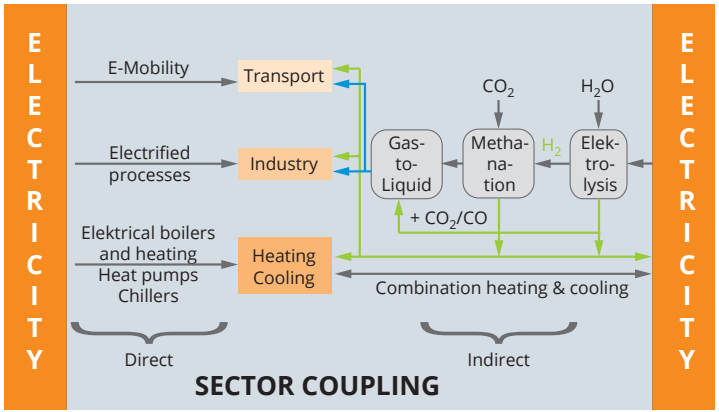
Refineries and the chemical industry will become the first major H_2 markets in the medium term. They are already large H_2 consumers today. The gradual replacement of fossil-based "grey" H_2 with green or low-carbon H_2 is one element of several strategies. As a result, large electrolysers are already being planned in and around European refineries. When comparing countries with relevant automotive production, the expected use of H_2 in fuel cell

cars and trucks is more pronounced in Asia than in Europe. While in Japan, South Korea and China the use of fuel cell vehicles is planned in all road transport sectors, European strategies focus mainly on heavy-duty vehicles.

Similarly, fuel cells play a much more pronounced role in the building and energy sector in Asia than in Europe.

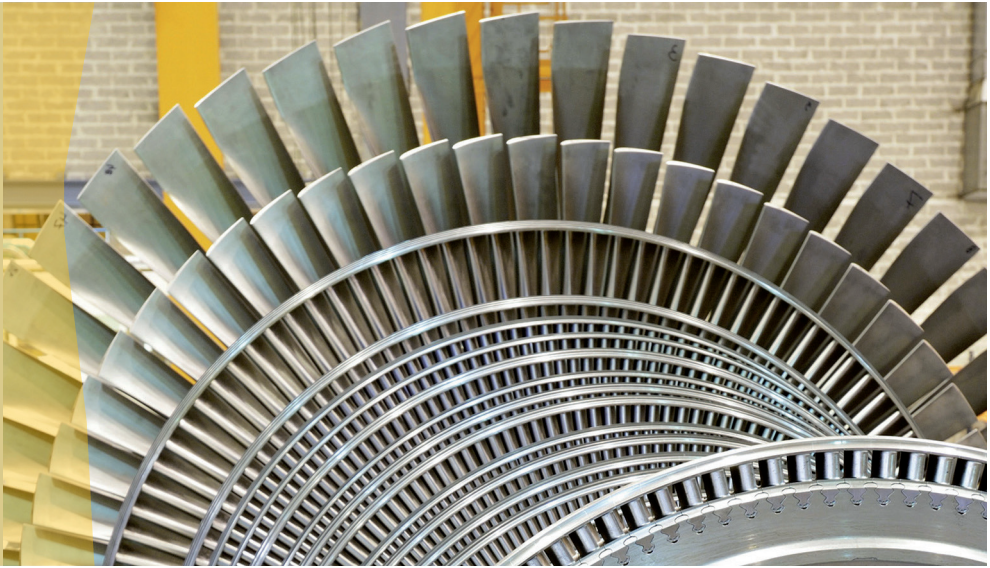
H2@VGBE: With its expertise in operating energy plants, our sector plays an important role in the development of the H_2 economy. Our members operate or plan to operate demonstration projects for H_2 generation and sector coupling. vgbe supports them with technical exchange of experience, standardisation and R&D activities as well as with laboratory and consulting services. The vgbe Technical Committee "Future Energy System" coordinates these activities.

Sector coupling



[1]: Source: https://www.weltenergierat.de/wp-content/uploads/2020/11/WEC_H2-Strategie_Executive-Summary_DE_final.pdf

Flexible generation – Guaranteeing security of supply



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.

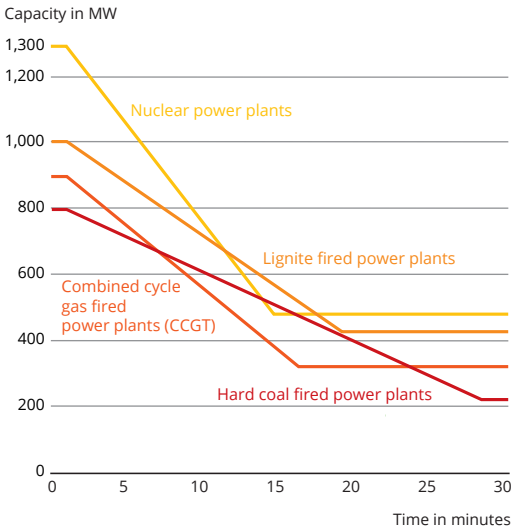
Dispatchable generation technologies currently form the backbone of system flexibility – in Europe, for example, they account for 80 % of available flexibility capacities (IEA, World Energy Outlook 2019). Controllable generation mainly includes thermal power plants and hydropower plants. Their flexibility 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.

Flexibility of thermal power plants - state of the art



Source: VDE and own studies

Flexibility parameters of controllable generation plants
– High load gradients, low minimum load and short times to ramp up.

Power plant type	Black coal	Lignite	CCGT	Gas turbine	Nuclear
Load gradient in % per minute	2/4/6	2/4/6	4/8/12	8/12/15	2/5/10
... in the load range of %	40 ... 90	50 ... 90	40[a] ... 90	40[a] ... 90	40 ... 100
Minimum load in % of nominal capacity	40/25/15	60/40/20	50/40/30 [a]	50/40/20[a]	40 [b]/40 [b]/40[b]
Ramp-up time in hours (h), hot start < 8 h	3/2/1	6/4/2	1,5/1/0,5	<0,1	<0,1
Ramp-up time in hours (h), cold start > 48 h	7/4/2	8/6/3	3/2/1	<0,1	36/36/24
	Usual value / State-of-the-art / Further potential				

[a]) As per emission limits for nitrogen oxides (NOx) and carbon monoxide (CO)..
[b]) Limited by minimum load of the steam turbine

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, vgbe 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 – Kraftwerks-InformationSSYstem).

The following trend diagrams (data as of August 2023) show the analysis and comparison between European coal-fired power plants (277 plants) and gas turbines (142 plants) over the period 2000 to 2022. 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 23 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 years, with the same fluctuations in maintenance measures (planned) over the last 10 years.

Definitions

Energy availability: Energy availability is a measure of the energy that a plant can produce in view of its technical and operational condition. Unlike time availability, it also takes account of partial unavailabilities.

Energy unavailability: The unavailable energy is the energy which cannot be generated for reasons which are inside the plant or cannot be influenced by the management.

Sources

Basic Terms of the Electric Utility Industry, 11th edition 2019, (Former VGB-RV 809)
VGB-S-002-01-2019-05-EN, VGB PowerTech, ISBN 978-3-96284-168-3 (ebook, free of charge)

Hydropower – Definitions and Key indicators –
VGB-S-002-02-2014-06-EN, VGB PowerTech, ISBN 978-3-86875-811-5 (ebook, free of charge)

Technical and Commercial Key Indicators for Power Plants,
VGB-S-002-03-2019-10-EN, VGB PowerTech, ISBN 978-3-96284-174-4 (ebook, free of charge)

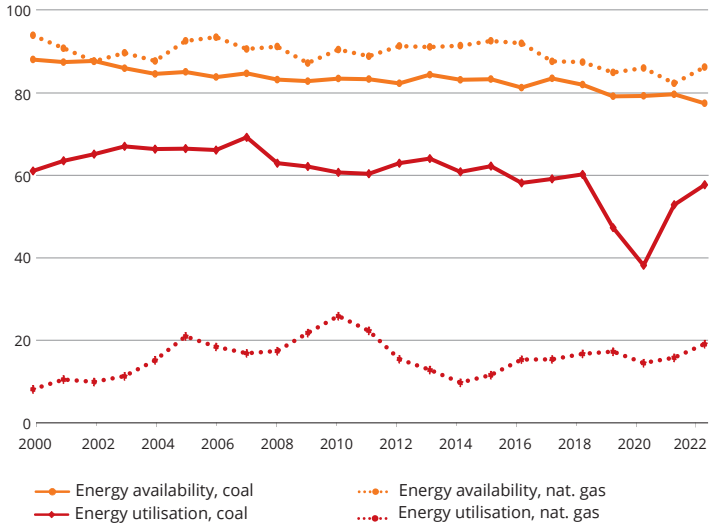
VGB-Standard Annex to VGB-S-002 Series,
VGB-S-002-33-2016-08-EN, VGB PowerTech, ISBN 978-3-96284-933-4 (ebook, free of charge)

Availability of Power Plants 2012 – 2021,
VGB-TW 103Ve, Issue 2022, vgbe energy e.V., ISBN: 978-3-96284-311-3

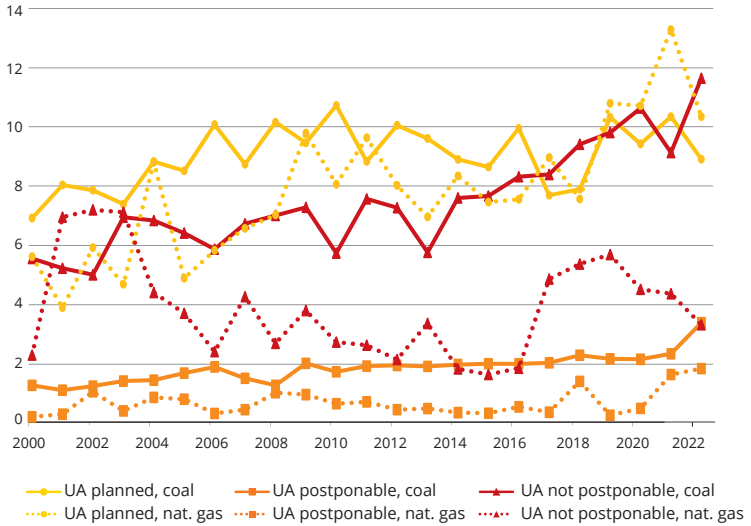
Analysis of Unavailability of Power Plants 2012 – 2021,
VGB-TW 103Ae, Issue 2022, vgbe energy e.V., ISBN: 978-3-96284-313-7

Source: vgbe data base KISSY (Power plant information system, data: 2023)

Comparison of energy availability of European power plants (in %)



Comparison of energy unavailability (UA) of European power plants (in %)



Nuclear Power – Continued expansion worldwide

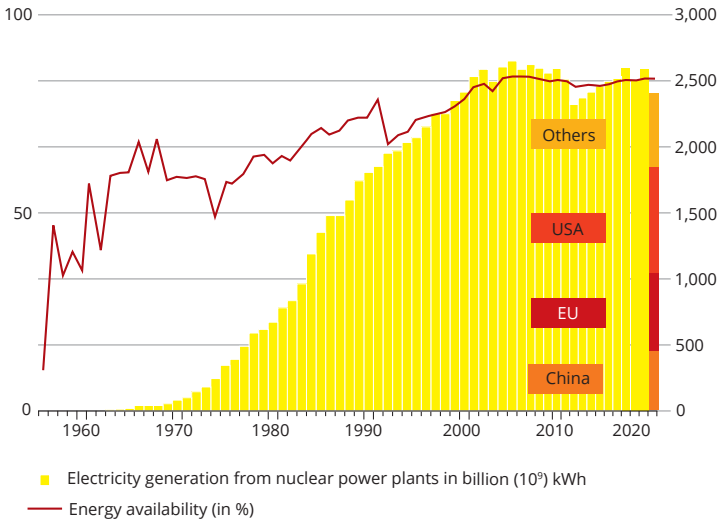
In 2022, electricity generation from nuclear power plants worldwide was around 2,486 billion kWh, lower than in 2021 with 2,653 billion kWh (both data net generation, gross in 2022 about 2,710 billion kWh). The missing production (data) from the 15 nuclear power plants located in the Ukraine with an average annual production of approx. 70 billion kWh and maintenance work in some countries had a significant influence.

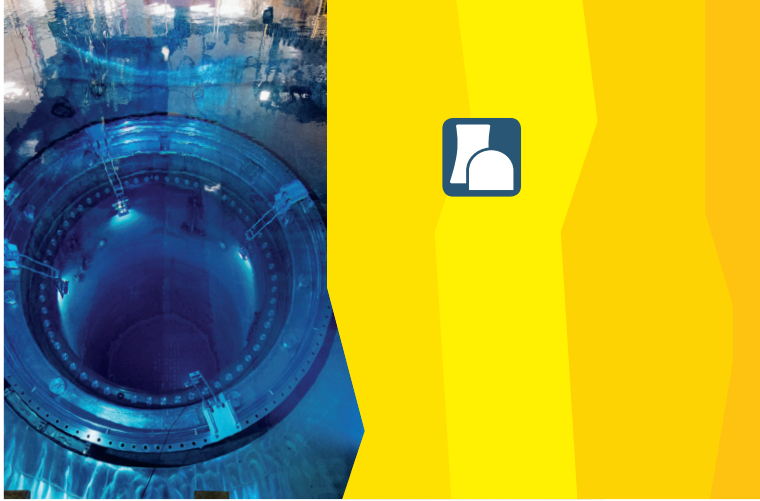
The share of nuclear energy in the total global electricity generation was 10.0 % in 2022. In the European Union (EU-27), electricity generation from nuclear energy was at around 572 billion kWh in 2022, visible lower than in the previous decade due to the incremential shut-down of plants in Germany. Following North America, Western Europe incl. further four countries with an electricity production of about 141 billion kWh 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 90,600 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.

Development of electricity generation from nuclear power worldwide from 1956 until 2022





Source: IAEA, vgbe energy)

Nuclear power: Plants, planned shutdowns, new plants and projects

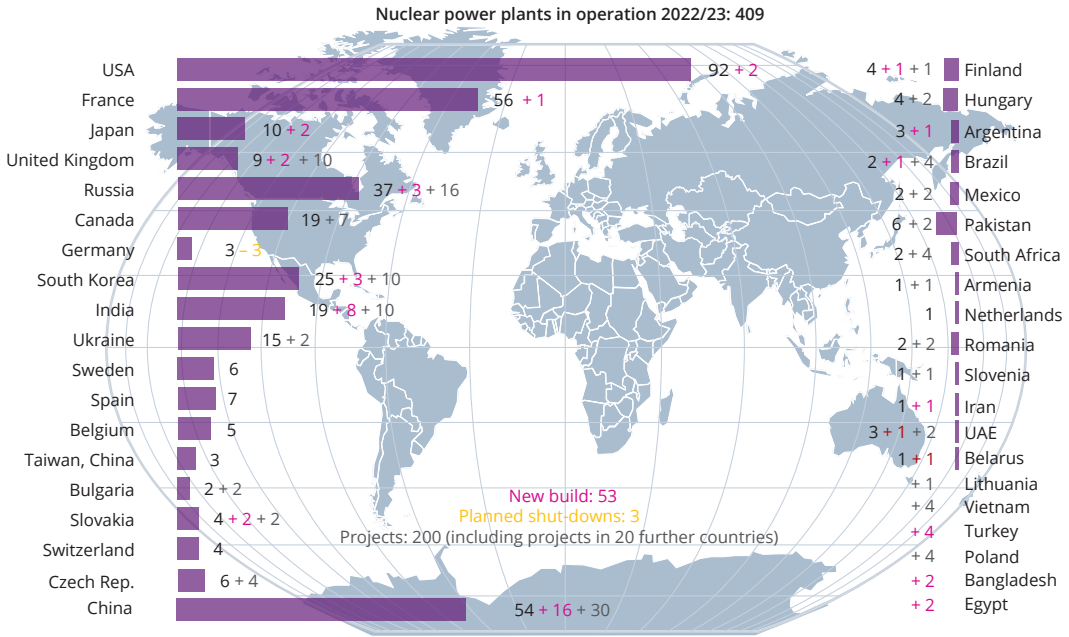
Worldwide, 409* nuclear power plants with a total gross capacity of 387,469 MW were in operation in 33 countries (as of December 2022). 53 nuclear power plant units are currently under construction in 18 countries. The trend of new projects is growing in Asian countries as well as in "newcomer" countries, also in Africa, the Middle East and North and South America – substantially with the participation of supplier countries.

There is a growing interest in so-called small modular reactors (SMR) in a capacity range of up to approx. 300 MW_{el}. Modular design, advanced, simple safety features, flexible operation and the option for a serial-production are some main characteristics.

Worldwide, 7,500 MW of 6 NPP capacity was added, however, 5 power plant units with approx. 3,400 MW capacity were permanently decommissioned or shut-down due to political decisions.

* The number of power plants in operation decreased significantly in 2022 due to the redefining of 27 nuclear power plants in Japan and 3 in India from "in operation" to "operation provisionally suspended".

USA, Vogtle Unit 3 and Unit 4 in the background: Photo: Georgia Power Company



Source: IAEA, vgbe energy, Status: 12/2021

Nuclear power plants – Decommissioning and dismantling

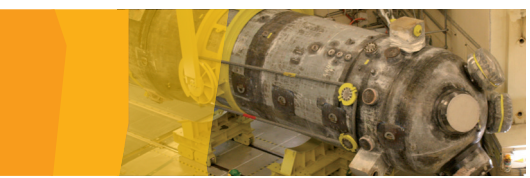
Assuming an average lifetime of 60 years for a nuclear power plant, approx. 300 plants will be shut down worldwide by 2030.

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 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.



Removal of a steam generator and underwater loading of casks during dismantling.

Repurposing of coal-fired power plants: Research for sustainable solutions

In 2022, coal-fired power plants accounted for 15.8 % of net electricity generation in the European Union. In order to prepare for the coal phase-out already decided by many European countries, 13 power plant operators and research institutes looked into the continued use of the sites in the project "Re-purposing Coal Power Plants during Energy Transition (RECPP)" from June 2020 to July 2022. In the project coordinated by the vgbe energy, 300 coal sites were identified and 70 % of them were analysed on the basis of surveys.

The project partners investigated more than 20 technical solutions – from conversion to renewable energy technologies such as PV, to fuel conversion to biomass, to conversion to storage and hydrogen plants. The solutions were characterised in terms of technical and economic parameters, clustered and evaluated according to the procedure shown in the figure. The following location factors proved to be particularly advantageous: Connection to the electricity and district heating network, access to water and the presence of a water treatment plant, landfill and storage areas, and proximity to industrial areas. The piloting of selected solutions is planned in follow-up projects.

RECPP
RE-PURPOSING COAL POWER PLANTS

European Commission

Research Fund for Coal & Steel

This project has received funding from the Research Fund for Coal and Steel under grant agreement No 899512

Climate policy: Global approach needed

Between 1990 and 2020, the total greenhouse gas emissions (GHGE) in the European Union (EU-27) decreased by 34.3 % (-1,939 million tonnes CO_2-equivalents, EEA, EU, state: 2022). Targets for climate and energy policy were revised by the EU Commission. The objective is to reduce EU emissions – Fit for 55 – by at least 55 % – hitherto 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 concept, “Net Zero Emissions”, which, compared with the reference scenarios “Stated Policies” – unchanged energy policy – and “Announced Pledges Scenario” – is focusing on a zero-emissions target and aims to stabilise energy consumption and the CO_2 concentration in the atmosphere through a bundle of instruments.

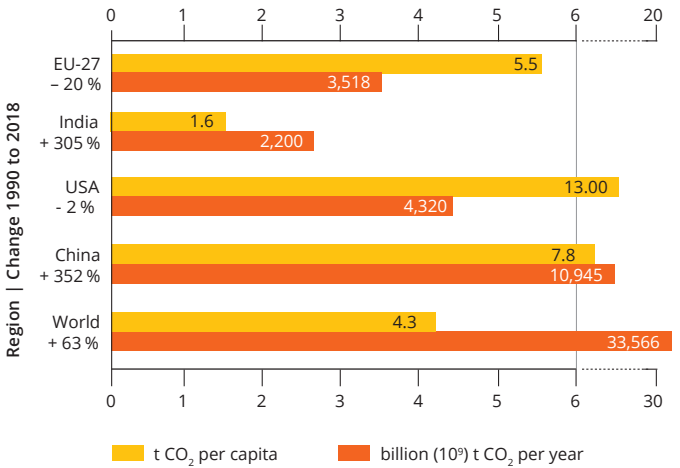
Picture: Mont-Soleil. sun and wind power plant. Source: BKW Energie AG

	2021	Stated Policies 2050	Net Zero Emissions 2050
CO_2-emissions worldwide, total, energy sector in million (10^6) t CO_2			
Total [1]	**36,639**	**31,979**	**-**
Coal	15,106	9,863	114
Oil	10,850	11,094	722
Natural gas	7,520	7,629	405
Thereof electricity generation			
Coal	10,507	5,938	27
Oil	574	260	2
Natural gas	3,195	2,842	42
Thereof other final energy consumption			
Total	20,468	21,056	1,005

IEA scenarios for the reduction of greenhouse gas emissions. Share of energy sources.
[1] inkl. upstream and downstream sector

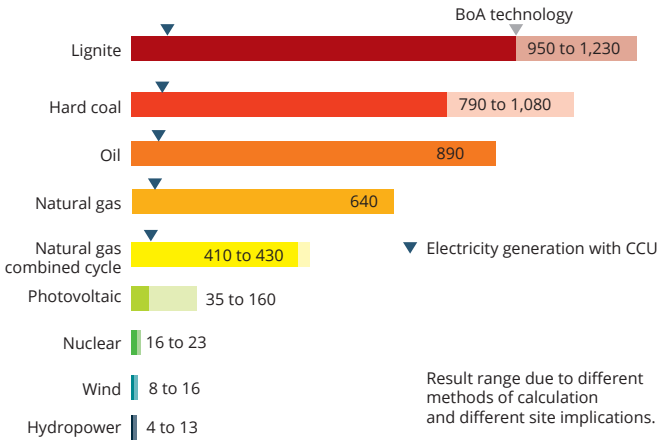
Source: IEA, World Energy Outlook 2022

CO_2 emissions total and per capita from fossil fuel combustion for selected regions for 2020 and changes from 1990 to 2020



Source: World Bank (2023)

CO_2 emissions from different power plants in g CO_2 equivalent per kWh, calculated for the life cycle of the power plant



Sources: PSI Paul Scherrer Institut/Switzerland, ESU-services, own calculations

vgbe energy e.V.

vgbe energy e.V. is the technical association of energy plant operators. Since its foundation in 1920, vgbe energy has become the technical centre of competence for the operators. The membership is open for companies and institutions active in the whole power business.

Our mission:

- Support our members in their operational business.
- Support our members in strategic challenges.
- Be a key contact for international energy stakeholders.

Our objectives:

- Keep operational and plant safety at a high standard.
- Ensure high availability and reliability of power plants.
- Ensure environmental compatibility of power plants.
- Secure occupational health and safety.
- Ensure cost-effective power plant operation.

Current structure of the vgbe energy membership:

Thermal, fossil-fired power plants	217,000 MW
Thermal, nuclear power plants	32,000 MW
Hydro power plants and further renewables	43,000 MW
Total	292,000 MW

EU: 400 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: 6 members in 4 countries
Norway, Switzerland, Turkey, United Kingdom

Outside Europe: 5 members in 5 countries
Japan, Jordania, Malaysia, Mongolia, South Africa

Total: 411 members in 29 countries

Tasks & benefits of the International Technical Association vgbe energy e.V.

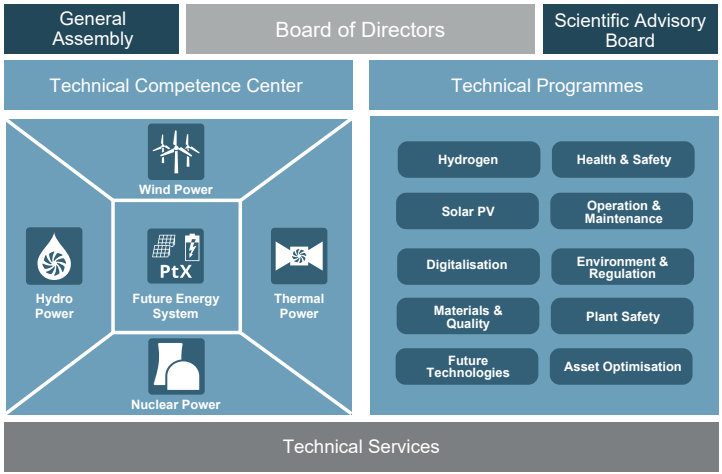
vgbe energy e.V. is the technical association of energy plant operators and the international competence centre for the generation and storage of electricity, heat, hydrogen and energy carriers based on them as well as sector coupling.

... acts as a gatekeeper and provider of technical know-how for members and relevant partner associations.

... generates technical and operational standardisation in close cooperation between operators and suppliers.

... offers technical services, engineering consulting and construction supervision.

... guarantees access to a pool of expert knowledge.



vgbe energy e. V.
Deilbachtal 173
45257 Essen | Germany

t +49 201 8128–0
e info@vgbe.energy

Editorial: Oliver Then (responsible),
Mario Bachhiesl, Thomas Eck,
Stefan Prost and Christopher Weßelmann

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be connected **www.vgbe.energy**