2021

BGR ENERGY STUDY

Data and Developments Concerning German and Global Energy Supplies

BGR

24

BGR ENERGY STUDY 2021

Data and Developments Concerning German and Global Energy Supplies

Hannover, August 2022

Imprint

Editor: Federal Institute for Geosciences and Natural Resources
(Bundesanstalt für Geowissenschaften und Rohstoffe – BGR)
Department B1.3, Geology of energy resources, polar geology
Stilleweg 2
30655 Hannover, Germany
email: energierohstoffe@bgr.de

Authors : Dieter Franke, Stefan Ladage, Rüdiger Lutz, Martin Pein,
Thomas Pletsch (coordination), Dorothee Rebscher, Michael Schauer,
Sandro Schmidt, Gabriela von Goerne.

Contributions by: Andreas Bahr, Uwe Benitz, Jennifer Bremer

Acknowledgements: The authors thank Christian Ostertag-Henning for his assistance
in creating this study.

Data status: 2020

Photo credits
title page:

Picture 1 Topic Renewable energy resources © pixaby.com

Picture 2 Topic Hydrogen © pixaby.com + Wasserstoffstrategie BMWi

Picture 3 The Troll C platform in the North Sea © EQUINOR / Øyvind Hagen

Picture 4 Topic Natural gas © pixaby.com

Cite as: BGR – Bundesanstalt für Geowissenschaften und Rohstoffe (2022): BGR Energy Study 2021 – Data and Developments Concerning German and Global Energy Supplies (24). – 175 p.; Hannover; doi:10.25928/es-2021-en

ISBN-PDF: 978-3-9823438-4-6

Federal Ministry for Economic Affairs and Climate Action

The Federal Institute for Geosciences and Natural Resources (BGR) is a technical and scientific agency of the Federal Ministry for Economic Affairs and Climate Action (BMWK).

Prof. Dr. Ralph Watzel
President of the Federal Institute for Geosciences and Natural Resources

At the World Climate Conference in Glasgow, almost 200 countries struggled to limit global warming to 1.5 °C through binding measures. It is becoming increasingly clear that achieving this goal by transforming energy systems within a few decades will require the greatest efforts. The growing world population in combination with rising living standards in emerging countries has resulted in a further increase in global energy demand, which was only briefly interrupted in 2020 due to the pandemic, only to rise again in 2021.

In Germany, achieving the Paris climate goals goes hand in hand with a considerable expansion of renewable energies and the exploitation of further energy-saving potential. In light of the global dimension of the challenge, it is therefore also worth looking beyond the national horizon, especially at China. The country is on its way to achieving its self-imposed goal of becoming the world‘s largest economy.

According to the IEA, global CO_2 emissions amounted to around 34 billion tonnes in 2020. Germany‘s CO_2 emissions amount to around 0.74 billion tonnes and thus account for slightly more than 2 % of global CO_2 emissions. In comparison, the CO_2 emissions of China, whose primary energy supply is based on around 57% coal, amounted to around 10 billion tonnes.

In 2020, around 80 % of global primary energy consumption was covered by fossil fuels and around 16 % by renewable energies. Hydropower and biomass accounted for the largest share, while solar and wind energy had a share of around 2.4 %. The total share of renewable energies in global electricity generation was about 29 % and was mainly generated by hydropower. Wind power, photovoltaics and biomass together had a share of around 9 %

The share of renewable energies in Germany was slightly above the global average in primary energy consumption at around 17 % and significantly above the global average in electricity generation at around 44 %. In 2020, wind power and photovoltaics dominated electricity generation from renewable energies; the share of wind power in the electricity mix was 27 % and was thus larger than the share of lignite for the first time.

China was the leader in terms of absolute figures, accounting for around one third of global installed renewable energy capacity (908 GW). Hydropower accounted for 370 GW, wind power for 282 GW and photovoltaics for 254 GW. The share of renewable energies in China was slightly below the global average in electricity generation at around 28 % and very significantly below the global average in primary energy consumption at around 9 %.

With its new energy study, the Federal Institute for Geosciences and Natural Resources wants to contribute to a better understanding of the current situation and a fact-based energy policy discussion. The study presents data and facts on the worldwide availability, production, import and export of energy resources and the growing share of renewable energy sources worldwide. Due to the political decisions to build a hydrogen economy, we devote a special focus to this energy carrier.

Yours

Ralph Watzel

Table of contents

List of figures

DEFINITIONS

List of tables

1 Summary

The year 2020 was dominated by the Covid-19 pandemic, with some significant impacts, including on energy systems. Globally, reduced demand and consumption of energy commodities led to around 7 percent lower CO_2 emissions compared to 2019.

Demand for crude oil fell sharply for the first time since 2009, by more than 9 percent. For the first time in history, there were negative prices on the crude oil markets for the Western Texas Intermediate (WTI) grade. Nevertheless, crude oil remained the most important energy source worldwide with a share of 31 percent of primary energy consumption (PEV) and crude oil consumption is at a high level (Fig. 1-1). Globally, coal production also decreased by about 5 percent, although regionally unevenly distributed. China produced more than half of the global hard coal and Asia accounted for four-fifths of global coal imports. Coal remained the second most important energy source after crude oil, accounting for 27 percent of global PEV. The percentage share of natural gas in global PEV increased, although absolute consumption fell by 1.5 percent. For the first time, more natural gas was traded between the individual regions in the form of liquefied natural gas (LNG) than through pipeline transport. Although there is growing interest in the energetic use of nuclear fuels in numerous countries, especially in Asia, the production of uranium declined sharply by minus 12 percent.

In order to reduce their greenhouse gas emissions, almost all countries are now pushing the expansion of renewable energies. With 261 gigawatts (GW) worldwide – of which almost 45 percent (117 GW) in China alone – the expansion of renewable energies set a new record in 2020. In terms of newly installed power generation capacities, the annual increase in renewable energies also exceeded that of conventional power plant capacities. Eleven countries already cover more than 20 percent of their electricity demand from wind energy and photovoltaics.

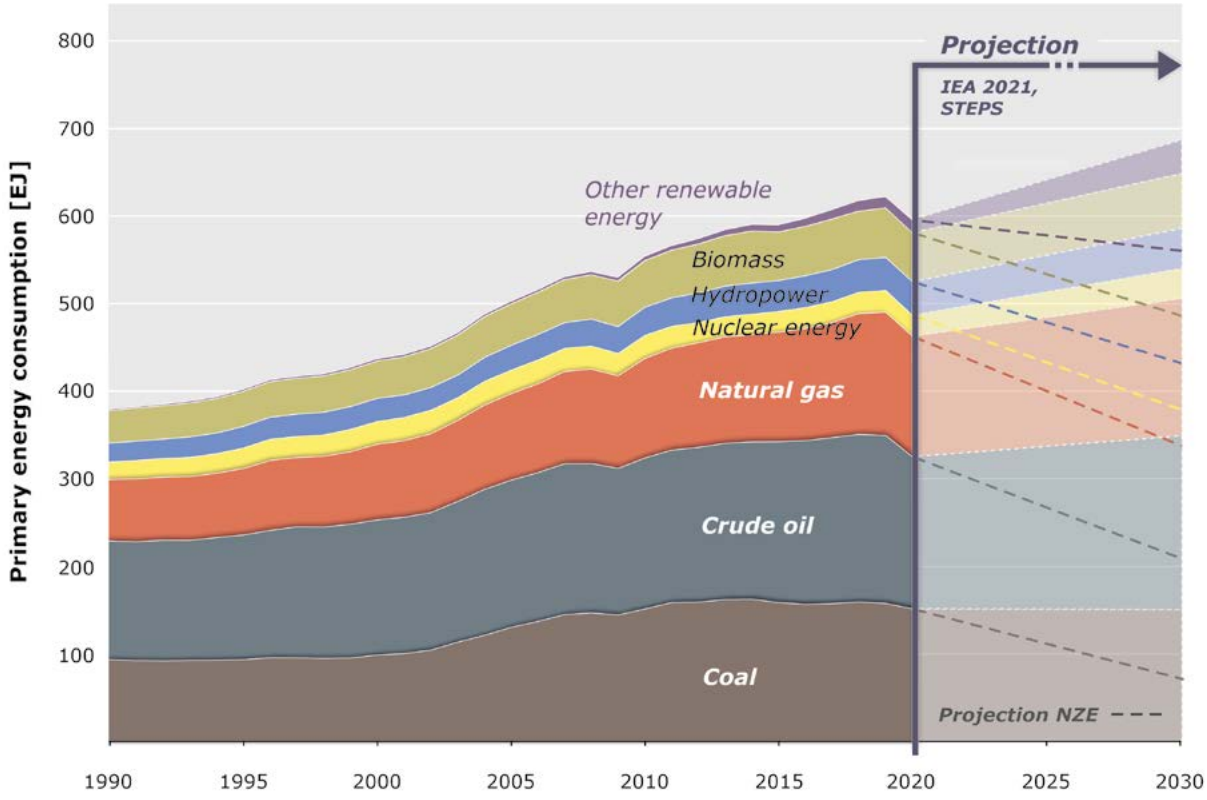


Figure 1-1: Development of german primary energy consumption from 1990 to 2020 according to energy sources and scenarios of the International Energy Agency until 2030 (IEA 2021a). Stated Policies Scenario (STEPS): future energy consumption based on existing and specific policies announced by governments around the world by the end of 2020. Net Zero Emissions (NZE) Scenario: pathway for the global energy sector to achieve net zero CO_2 emissions by 2050.

Plans for the use of hydrogen as an energy source gained momentum across Europe in 2020. The EU‘s hydrogen strategy envisages the development of an electrolysis capacity of 40 GW by 2030. In addition, projects for the production of blue hydrogen are in advanced planning stages in individual member states. Despite efforts to produce hydrogen regionally, there will foreseeably be a high demand for imports.

In Germany in 2020, there were temporary restrictions on the production, expansion and maintenance of renewable energies, but this had little impact on electricity generation (Fig. 1-2). The share of renewables in Germany‘s energy supply increased and the CO_2 reduction targets were achieved in 2020. For the first time, more electricity was produced from renewable energies, especially biomass, wind power and photovoltaics (share of 44 percent) than from all fossil energy sources combined (share of 40 percent).

The share of coal in German primary energy consumption fell by about two percentage points to around 16 percent. Hard coal imports were even down by almost a quarter. The production and consumption of lignite also fell by almost a fifth. Despite the 9 percent drop in crude oil consumption due to the pandemic, crude oil remained the most important primary energy source in Germany with 34 percent. With a share of about 27 percent, natural gas, Germany‘s second most important energy source, is at an all-time high in its share of primary energy consumption. However, domestic natural gas production has continued to decline and covers about 6 percent of domestic demand.

Even though renewable energies have become the most important source of electricity, Germany‘s dependence on imports in the energy sector remained very high at over 71 percent. This can also be attributed to the further declining shares of domestic production of fossil energy sources of around 5 percent compared to the previous year.

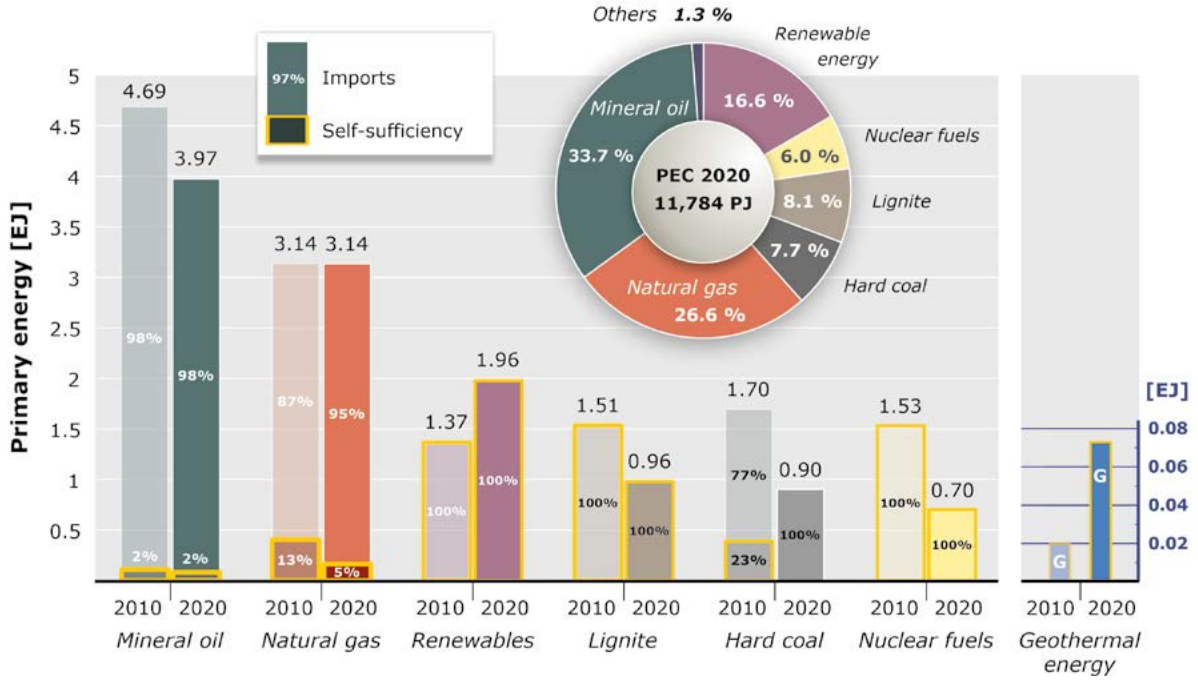


Figure 1-2: Import dependency and self-sufficiency level in Germany of some primary energy resources in 2010 and 2020. Pie chart: Share of individual energy resources of German primary energy consumption (PEC) in 2020 (Data: AGEB 2021).

Methodologies – The content of the current energy study of the Federal Institute for Geosciences and Natural Resources (BGR) is data and analyses on the situation of the energy resources crude oil, natural gas, coal, nuclear fuels and renewable energy sources including deep geothermal energy and hydrogen as of the end of 2020. The study contains estimates of the geological inventory of energy resources with information on reserves and resources. It also looks at the commodity markets with regard to the development of production, export, import and consumption of energy and fossil energy commodities. The energy study serves to advise the Federal Ministry for Economic Affairs and Climate Action (BMWK), the German economy, the scientific community and the public on resources management.

The datasets published in the BGR Energy Study are a classified and evaluated extract of the BGR energy commodity database. They were compiled from specialist journals, scientific publications, reports from industry, specialist organisations, political bodies and from BGR‘s own studies. Data not taken from the BGR energy resources database are marked. In the following, key developments in the individual energy resources and energy sources are presented in alphabetical order, first for Germany and then worldwide. Country-specific data on resources, reserves, production and consumption as well as imports and exports are summarised in the appendix.

2 Energy situation in Germany

2.1 Natural gas

Natural gas is Germany's second most important energy source with a share of around 27 % (AGEB 2021).

Natural gas production in Germany, which had already been declining for over 17 years, continued to fall in 2020 (Tab. 1). However, the significant 15 percent decline in production compared to the previous year is primarily due to the nine-week outage of a natural gas processing plant (LBEG 2021). The slight decrease in natural gas consumption compared to the previous year is primarily due to lower consumption in the industrial sector (LBEG 2021).

Compared to other federal states, Lower Saxony has the largest natural gas reserves, accounting for almost 99 % of total proven crude gas reserves, and it also accounted for the largest share of German production of around 97 %. In the reporting year, 73 natural gas fields were in operation (LBEG 2021). The largest natural gas production company in terms of domestic production output was ExxonMobil Production Deutschland GmbH, with over half of the total production (BVEG 2021).

Table 1: Natural gas metrics for Germany 2020, and year-on-year change
(LBEG 2021, DESTATIS 2021a)

Production	5.7 Bcm	-15 % ↓
Proven reserves	22.3 Bcm	-10 % ↘
Consumption	90.8 Bcm	-1.3 % →
Natural gas imports	159.7 Bcm	-1.6 % →

The natural gas production of German companies abroad is mainly provided by Wintershall Dea AG. The company is active in Northern Europe, the Russian Federation, North Africa and Latin America.

>> *Share of natural gas in primary energy consumption at a new all-time high of just under 27 %*

The total amount of natural gas resources not recoverable as of today economically in Germany is estimated at 1.36 trillion m³ (BGR 2020). These are made up of 0.02 trillion m³ of conventional natural gas, 0.45 trillion m³ of coal seam gas, 0.09 trillion m³ of natural gas from tight gas deposits (BGR 2020) and natural gas from shale gas deposits, which is in the order of 0.32 to 2.03 trillion m³ (on average 0.8 trillion m³), based on a depth between 1,000 and 5,000 m (BGR 2016).

In the reporting year, natural gas imports were about 1.6 % below those of the previous year (DESTATIS 2021a). The total volume (imports, own production and storage balance) was 5.76 EJ in 2020 (BAFA 2021a). Almost half of the imported natural gas was re-exported to neighbouring European countries. According to preliminary calculations, the average cross-border price for natural gas in 2020 decreased by around 21 % compared to the previous year to 3,410 €/TJ of natural gas (BAFA 2021b). In the second half of 2021, however, there was a significant increase in cross-border prices. In September 2021, they already reached 7,727 €/TJ natural gas (BAFA 2021b).

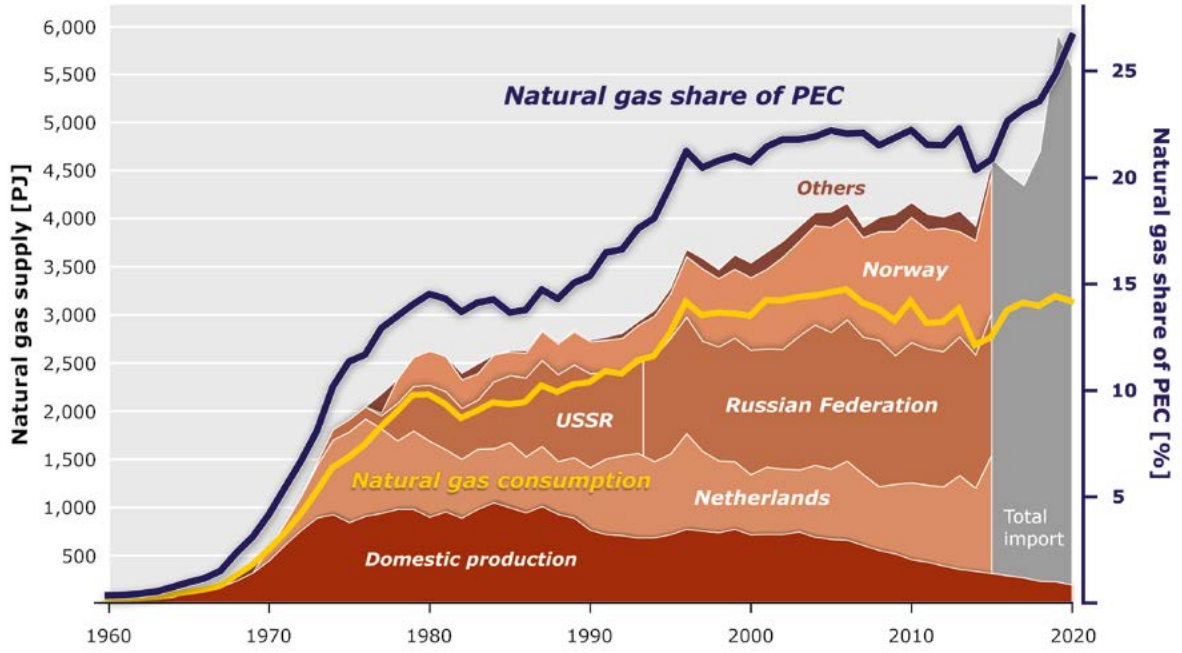


Figure 2-1: German natural gas supplies from 1960 to 2020, and natural gas proportion of PEC. The yellow curve shows the calculated German natural gas consumption (BAFA 2021a). For data protection reasons, the Federal Office of Economics and Export Control has not published information on supply volumes from the countries of origin since 2016.

2.2 Crude oil

In 2020, crude oil was by far the most important energy source in Germany, accounting for just under 34 % of primary energy consumption (AGEB 2021). As in recent years, domestic crude oil production declined and was just under 1.9 million tonnes (LEBG 2021).

>> *Crude oil remains the most important primary energy source with 34 %*

Petroleum products are predominantly used in the transport sector. Around 94 % of final energy consumption in the transport sector was accounted for by petroleum products in recent years (AGEB 2020). In addition, petroleum is an important base material for the organic chemical industry. Mineral oil consumption declined sharply by 9 % as a result of the COVID-19-related restrictions on mobility.

Germany‘s proven oil reserves amount to about 17.9 million tonnes (Tab. 2). Most of the oil reserves are located in the North German Basin, especially in Schleswig-Holstein and Lower Saxony. At the end of 2020, 49 fields were in production. Almost 90 % of the total production came from the ten fields with the highest production, whereby the largest German field, Mittelplate/Dieksand, already covered 57 % of the total production with almost 1.1 million tonnes. Tertiary extraction measures accounted for 10 % of total production (LBEG 2021).

The largest oil production company by far in terms of operational domestic production output was Wintershall Dea AG, with a share of about two-thirds of total production (LBEG 2021).

Due to the lower oil and gas prices compared to the previous year, the lower production and, in some cases, lower production levy rates, the production levies of the oil and gas producers fell significantly to around € 52 million (minus 74 %). Around € 42 million of this was attributable to oil production (BVEG 2021). Domestic drilling activity fell to an all-time low in 2020 with only seven active wells (LBEG 2021). In 2020, the German crude oil and gas industry employed 7,281 people; 975 fewer employees than in the previous year (BVEG 2021).

As one of the largest mineral oil consumers worldwide, Germany is almost entirely dependent on imports. Compared to the previous year, crude oil imports fell by just under 4 % to around 83 million tonnes (BAFA 2021c) (Fig. 2-2). Although the imports originated from 32 supplier countries, the most important countries for the German crude oil supply are the Russian Federation, the United Kingdom, the USA and Norway (BAFA 2021e). These countries already covered around 67 % of German crude oil imports.

Table 2: Metrics for the German oil sector in 2020, and year-on-year change
(LEBEG 2021, BAFA 2021c, BAFA 2021d)

Production	1.9 Mt	-1.4 %	→
Proven reserves	17.9 Mt	+12.5 %	↑
Consumption	93.7 Mt	-9 %	↘
Crude oil imports	83 Mt	-3.8 %	→

>> *Decrease in mineral oil consumption by 9 % , mainly pandemic-related*

Due to the dependence on imports, compulsory stockpiling was introduced as early as 1966 and has been legally anchored since 1978 by the Petroleum Stockpiling Act (Erdölbevorratungsverband 2008). The legally prescribed level of stockpiling in Germany corresponds to at least the daily average net imports for 90 days in relation to the last three calendar years prior to the reference period. Crude oil and mineral oil products are held in stock. These are stored in caverns, tank farms and refinery storage facilities, among other places (BMJV 2019). As of 31 March 2020, stocks of crude oil and petroleum products amounting to 23.3 million tonnes of crude oil equivalent were held (EBV 2020). Although stocks are held in all federal states, they are concentrated in the north-west of Germany due to the possibility of cavern storage there. Important cavern storage facilities are located in Wilhelmshafen-Rüstlingen, Heide, Bremen-Lesum and Sottorf.

The cross-border prices for crude oil imported into Germany reflect the decline in oil prices. In 2020, an average of € 278.38 was paid per tonne of imported crude oil. This was about 35 % or € 149.49 less than in the previous year (BAFA 2021c). The total cost of German crude oil imports amounted to around € 23 billion.

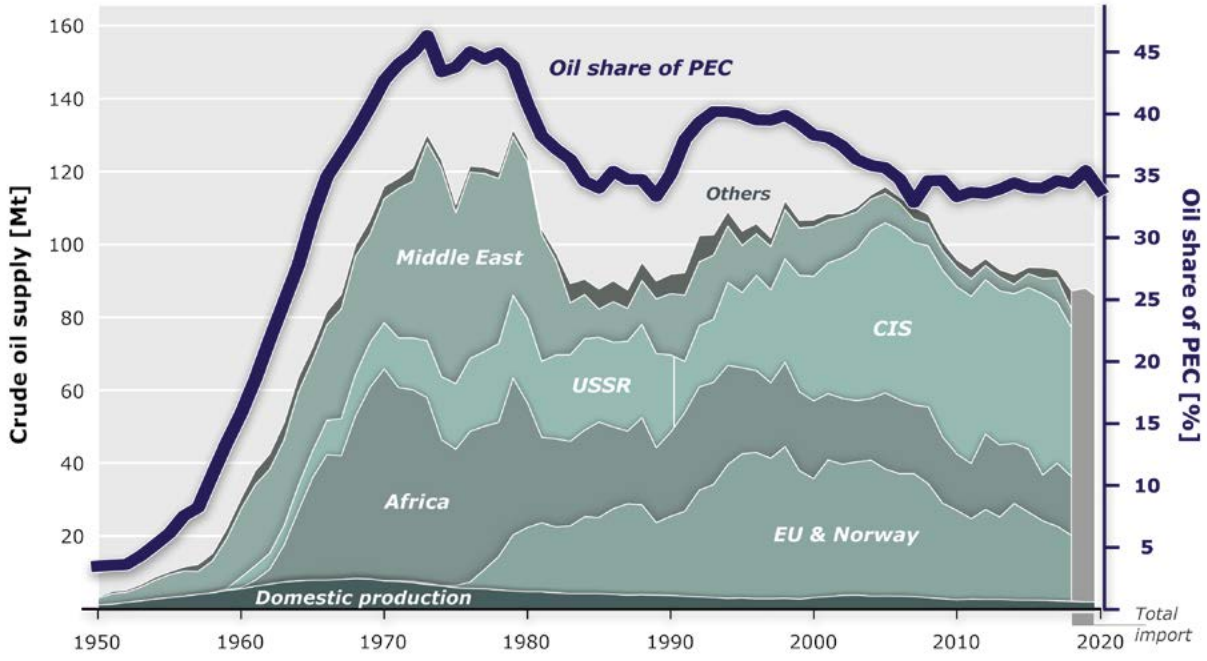


Figure 2-2: German petroleum supplies from 1950 to 2020.

2.3 Renewable Energy

The year 2020, which was marked by the COVID-19 pandemic, saw hardly any negative impact on the market for renewable energies in Germany. On the contrary, their share of Germany's energy supply increased further. Although there were temporary restrictions in the renewable energy sector, for example in production and construction, which delayed the expansion of renewable energies, this had hardly any influence on electricity generation. For the first time, more electricity was produced from renewable energies, especially biomass, wind power and photovoltaics (share 44 %) than from all fossil energy sources together (crude oil, natural gas, coal – share 40.4 %) (UBA 2021). The basis for the growth of renewable energies is the Renewable Energy Sources Act (EEG) introduced on 1 April 2000, which was last reformed in 2021. The goal is to generate all electricity in Germany before 2050 in a greenhouse gas-neutral manner.

By 2025, the share of renewable energies in electricity generation should be around 40 % to 45 % and 65 % by 2030 (BMWi 2017). The target share of 18 % renewable energies in gross final energy consumption for 2020 was exceeded at 19.3 %, also due to the general decline in energy consumption caused by the COVID-19 pandemic. Both the increased share of renewable energies in electricity generation and the increased sales of biodiesel were decisive for this. In addition to the expansion of renewable energies, energy efficiency is the second pillar of the energy transition. By 2050, Germany's primary energy demand is to be reduced by 50 % compared to 2008 (BMWi 2019).

So far, the development of renewable energies has focused primarily on the electricity sector. In 2020, around 44 % of electricity in Germany was generated from renewable energies. Wind energy, biomass and solar energy are the most important energy sources for electricity generation. Hydropower and geothermal energy make additional contributions to meeting demand.

>> *44 % of electricity generation and 19 % of of gross final energy consumption from renewable energies*

A total of 131 billion kWh of electricity was generated from wind power (onshore and offshore), making it the prime electricity producer ahead of lignite for the first time, with a share of 27 % of the electricity mix (AGEB 2021). The expansion of onshore wind energy remained at a low level in 2020 after a sharp decline in 2018 (BGR 2019a). This is mainly due to problems in approval and tendering procedures. In total, onshore wind turbines with a total capacity of 1,227 MW were newly commissioned (UBA 2021). Despite the comparatively low expansion, onshore wind turbines generated 103.7 billion kWh of electricity, 2 % more than in the previous year, due to favourable wind conditions.

The offshore plants also generated 10 % more electricity than in the previous year. In addition to good wind conditions, this is mainly due to the addition of new capacity in recent years. In the second half of 2019, this addition was comparatively strong, while in 2020 it was low at only 219 MW. While offshore electricity generation was still 1.4 billion kWh in 2014, it was already 27.3 billion kWh in 2020. In total, Germany has more than 60,940 MW of installed capacity from wind turbines (onshore and offshore) (Table A-44 in the appendix).

Power generation from solar energy (photovoltaics) is also being intensively expanded in Germany and, after wind power, has the highest installed capacities among renewable energies. After a decline in the expansion volume in recent years, the growth rate has now increased significantly. In 2020, the expansion of installed photovoltaic capacity amounted to around 4.8 GW and exceeded the expansion framework of 2.5 GW per year set out in the Renewable Energy Sources Act (UBA 2021). A total of 53,848 MW of installed capacity from photovoltaics is currently available in Germany (Tab. A-44 in the appendix).

Electricity generation from this source increased by 9 % to 50.6 billion kWh in 2020, primarily due to favourable weather conditions.

>> *Wind power and photovoltaics the most important renewable energies for electricity*

Biomass is the third most important renewable energy source for electricity generation. In 2020, 44.9 billion kWh of electricity was produced from biogenic energy sources (solid, liquid and gaseous biomass) from almost 9,000 MW of installed capacity. In addition to biogas, this also includes landfill and sewage gas, sewage sludge, and biogenic waste in waste-fired power plants (AGEB 2021). The share of biomass in the electricity mix was 8 %. While there were hardly any changes in the installed capacity of solid and liquid biomass, investments are currently being made especially in increasing the capacity of existing biogas plants, but also in the construction of new plants (UBA 2021).

>> *Photovoltaic electricity on highest level due to expansion and strong solar year*

The share (15.2 %) of renewable energies for heat generation remained almost stable in 2020 compared to the previous year. Due to the mild weather as well as the general decrease in energy consumption due to the COVID-19 pandemic in 2020, the total final energy consumption in Germany decreased slightly, so that the consumption of solid biomass (especially wood) in households also decreased. At around 85 %, solid biomass (incl. biogenic waste) has the most significant share of renewable energies in heat generation. Wood use generates about two-thirds of renewable heat in Germany; pellets contribute a total of 6.4 % of the renewable share. Increased sales of heat pumps (up 40 % compared to 2019) and solar thermal systems had a positive impact on the share of renewables in the heat market. In particular, heat use from solar thermal systems increased by 3 %.

>> *7.3 % of the German fuel demand from renewable energy*

Biofuels such as bioethanol, biodiesel and biogas make up the main share (88 %) of renewable energies in the transport sector (UBA 2021). Sales of biodiesel in particular rose by around 35 % in 2020. In addition to biofuels, more and more electrical energy (12 %) is being used in the transport sector.

The fleet of purely battery-powered electric vehicles increased significantly from 83,175 (2018) to 194,163 in 2020 and thus, after plug-in hybrids, has the highest growth in new registrations. However, compared to the total of 54.4 million registered motor vehicles in Germany in 2020 (KBA 2021), the share of electrically powered vehicles remains low.

With regard to the share of renewable energies in primary energy consumption (PEC) according to fields of application, the use for electricity generation dominates with 57 %. The second largest area of use is heat generation, whereby privately used systems (wood-burning stoves, solar thermal systems, heat pumps, etc.) clearly predominate with a share of 24 %. The use for heat generation in industrial power plants, on the other hand, is only 6 %. A further 6 % is used in the transport sector as an admixture for petrol and diesel fuels, and another 6 % is used by industry (AGEB 2021). Biomass is the dominant form of energy among renewables with a share of almost 51 %, followed by wind energy (24 %), solar energy (11 %), waste (7 %), geothermal energy (4 %) and hydropower (3 %) (Fig. 2-10).

>> *Germany‘s primary energy consumption decreased by 8 %*

Germany‘s PEC has slightly decreased by 8 % in 2020 compared to the previous year to 11,784 PJ. Compared to 2001, primary energy consumption in Germany has decreased by 20 % from 14,679 PJ (2001) to 11,784 PJ (2020), while at the same time the share of renewable energies in the PEC

has quadrupled from 427 PJ (2001) to 1,961 PJ (2020). The individual renewable energy sources contributed to this to varying degrees (Fig. 2-3). With the exception of hydropower, the share of all renewable energies in PEC increased significantly over the last 19 years. With the planned expansion of renewable energies in Germany, their share will continue to grow in the future. At the same time, weather-related fluctuations in energy production will increase due to the fluctuating nature of most renewable energies in Germany.

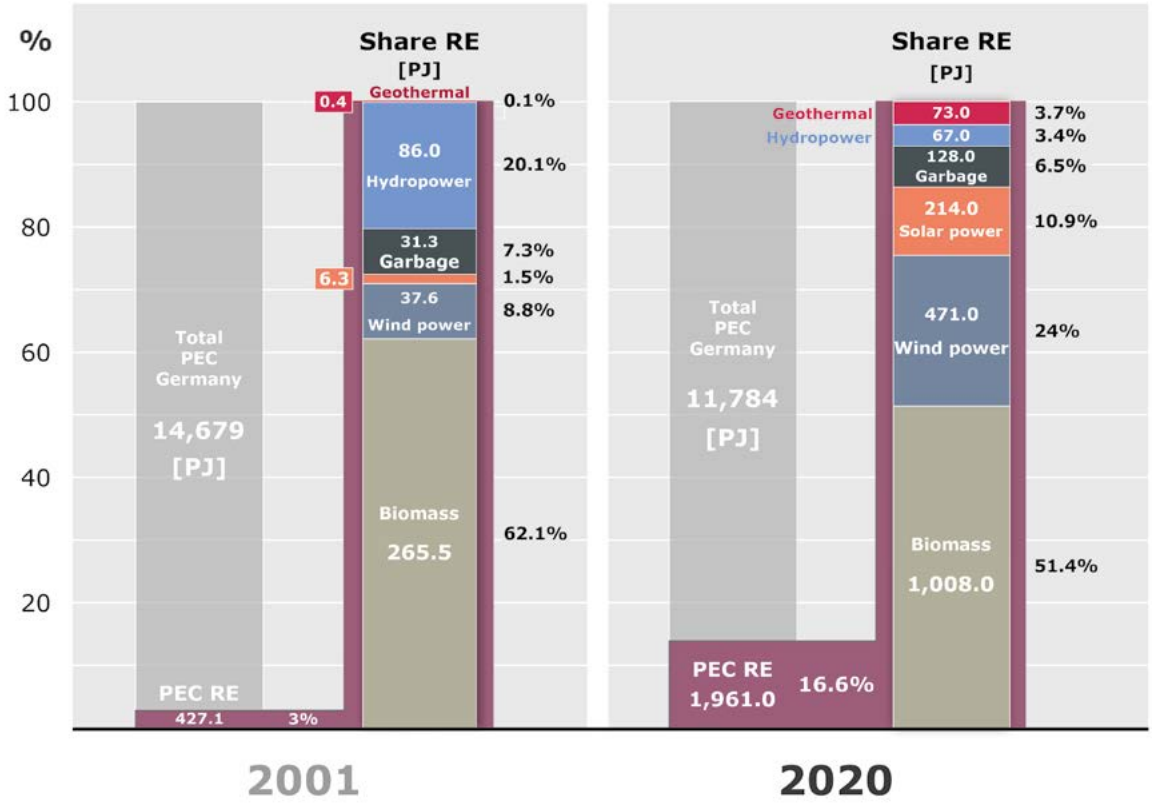


Figure: 2-3: Primary energy consumption in Germany in 2001 and 2020, as well as a comparison of the share of individual renewables (Data: AGEB, UBA).

2.4 Geothermal energy

In Germany there are three main regions with geologically favourable conditions for deep geothermal energy, the North German Basin, the Upper Rhine Graben in the west and the Molasse Basin in the south. In 2020, electricity was produced at eight geothermal sites in Germany. Namely, with the year of commissioning in brackets, these are Dürrnhaar (2013), Grünwald/ Laufzorn (2014), Holzkirchen (2019), Insheim (2012), Kirchstockach (2013), Landau in der Pfalz (2007), Sauerlach (2013) and Traunreut (2016). Together, they had an installed electrical capacity of about 41 MW_e in 2020 and their produced electricity volume amounted to about 190 GWh_e/a (LIAG 2021). The two new plants in Munich (Schäftlarnstraße) and Garching a. d. Alz are scheduled to go online shortly.

>> *Two new electricity-generating geothermal power plants are to be connected to the grid in Germany shortly*

For the German heating sector, the total installed thermal capacity of deep geothermal energy in 2020 remained unchanged from the previous year at 404 MW_{th}. In 2020, a total of 191 GWh_{th} of heat was produced geothermally (LIAG 2021).

The use of heat pumps for heating newly built residential buildings also increased in 2020. In the reporting period, about 69 % of these residential buildings were heated at least partially with renewable energy sources (DESTATIS 2021b). The rising trend towards the installation of heat pumps in the form of geothermal and environmental thermal energy continues and formed the most common heating type of all new residential buildings in 2020 with just under 46 % (DESTATIS 2021b).

>> *Heat production by deep geothermal energy in Germany unchanged. Heat pumps in almost half of all heating systems in new private residential buildings*

2.5 Nuclear fuels

With the 13th amendment to the Atomic Energy Act on 6 August 2011, the German government decided to end the use of nuclear energy for commercial electricity generation in the nuclear power plants built since 1962 by the end of 2022 at the latest. Currently, six nuclear power plants are still in operation, of which Grohnde, Gundremmingen C and Brokdorf will be shut down by the end of 2021, and Isar 2, Emsland and Neckarwestheim 2 by the end of 2022.

The contribution of nuclear energy to primary energy consumption decreased to 702 PJ in 2020 (2019: 819 PJ). It thus had a share in primary energy consumption of 6.0 % (2019: 6.4 %). In electricity supply, nuclear energy was in fourth place with a share of 11.3 %, behind renewables (43.9 %), lignite (16.1 %) and natural gas (16.1 %).

At 572.2 TWh, electricity generation was slightly lower than in the previous year (minus 6.1 %; 2019: 609.4 TWh). The share of nuclear energy in gross electricity generation decreased to 64.4 TWh (2019: 75.1 TWh). By the time eight nuclear power plants were shut down in 2011, 17 nuclear power plants with a gross capacity of 21,517 MW_e had been installed. The six nuclear power plants remaining in 2020 are connected to the grid with 8,545 MW_e (gross). The natural uranium quantity of 1,012 t U required for fuel production was mainly covered by long-term contracts with producers in Canada and the Netherlands, as well as from stocks.

2.6 Coal

>> *Coal's share of German primary energy consumption fell by almost two percentage points to 15.8 %*

In 2020, coal (hard coal and lignite) was Germany's fourth most important energy source, with a share of 15.8 %, after crude oil, natural gas and renewable energies (AGEB 2021). According to the Act to Reduce and End Coal-fired Power Generation and to Amend Other Laws (Coal Phase-out Act) passed by the German Bundestag in August 2020, coal will continue to contribute to Germany's energy supply until 2038 at the latest (Fig. 2-4). The coalition agreement (2021) between SPD, Bündnis 90/Die Grünen and FDP provides for an accelerated phase-out of coal-fired power generation, ideally by 2030. Both the production (Fig. 2-5) and the consumption of lignite and hard coal decreased significantly in the year under review (Tab. 3). In addition to the main use of coal for electricity generation, there are other areas of application for coal. In Germany, the use of coke, produced from coking coals, for the production of pig iron in the steel industry is particularly noteworthy, as it is not yet fully substitutable.

Figure 2-4: Currently active lignite and hard coal mining areas in Germany and those that have been closed down since 2010.

Table 3: Metrics for the German lignite and hard coal sector in 2020, and year-on-year change
(AGEB 2021, DEBRIV 2021, VDKI 2021, SdK 2021)

	Lignite		Hard coal	
Production	107.38 Mt	-18.2 % ↓	-	-
Imports (incl. Products*)	0.04 Mt	+11.9 % ↑	31.82 Mt	-24.7 % ↓
Exports (incl. Products*)	1.07 Mt	-19.0 % ↓	-	-
Consumption	32.6 Mtce	-17.8 % ↓	30.8 Mtce	-16.6 % ↓
Reserves (End of 2020)	35.700 Mt	-0.6 % →	-	-

* Products like dust, briquettes und coke

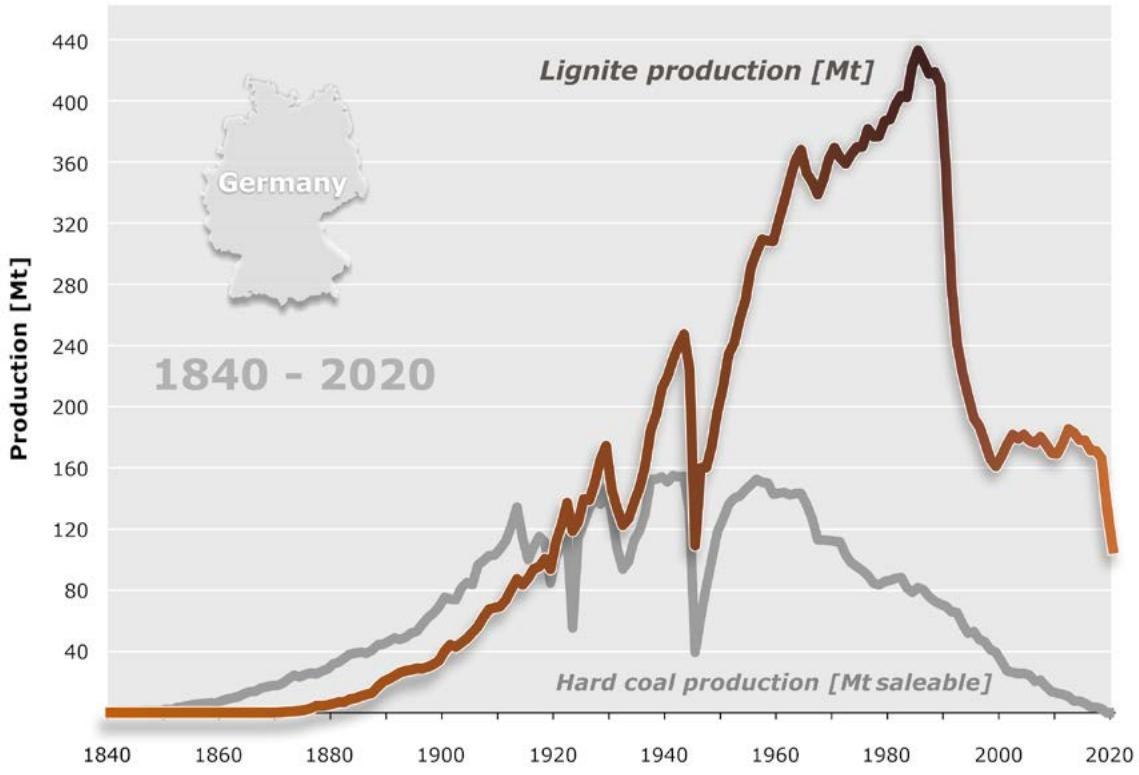


Figure 2-5: Development of German coal production from 1840 to 2020 (after SdK 2021).

Hard coal

At the end of 2018, the last two German coal mines ceased production (BGR 2019a). Due to the end of German coal mining, Germany has since covered its entire demand for hard coal through imports.

Compared to 2019, **hard coal consumption** in Germany decreased significantly by one sixth to around 30.8 million tce in the reporting year, according to preliminary data. The share of hard coal in primary energy consumption thus fell to 7.7 %, after 8.5 % in the previous year (AGEB 2021).

>> *Hard coal imports down by almost a quarter due to reduced demand*

Imports of hard coal and hard coal products decreased by around a quarter compared to 2019 to 31.8 million t (Fig. 2-6). In 2020, the Russian Federation was again the largest supplier with around 14.5 million t (45.4 %), followed by the USA (18.3 %) and Australia (12.3 %). Imports from Poland, the only remaining significant EU-27 coal exporting country, decreased to 1.2 million tonnes. Of this, coke accounted for around 1 million tonnes (VDKI 2021).

Price developments

The annual average price for imported steam coal (updating of the BAFA transition price by the VDKI from 2019) amounted to around 64 €/tce in 2020 and was thus noticeably lower than in the previous year (minus 20.7 %). The annual average price for coking coal decreased significantly by 25.6 % compared to the previous year to 125.51 €/t. The price for coke amounted to 208.47 €/t (minus 21.6 % compared to 2019) (VDKI 2021).

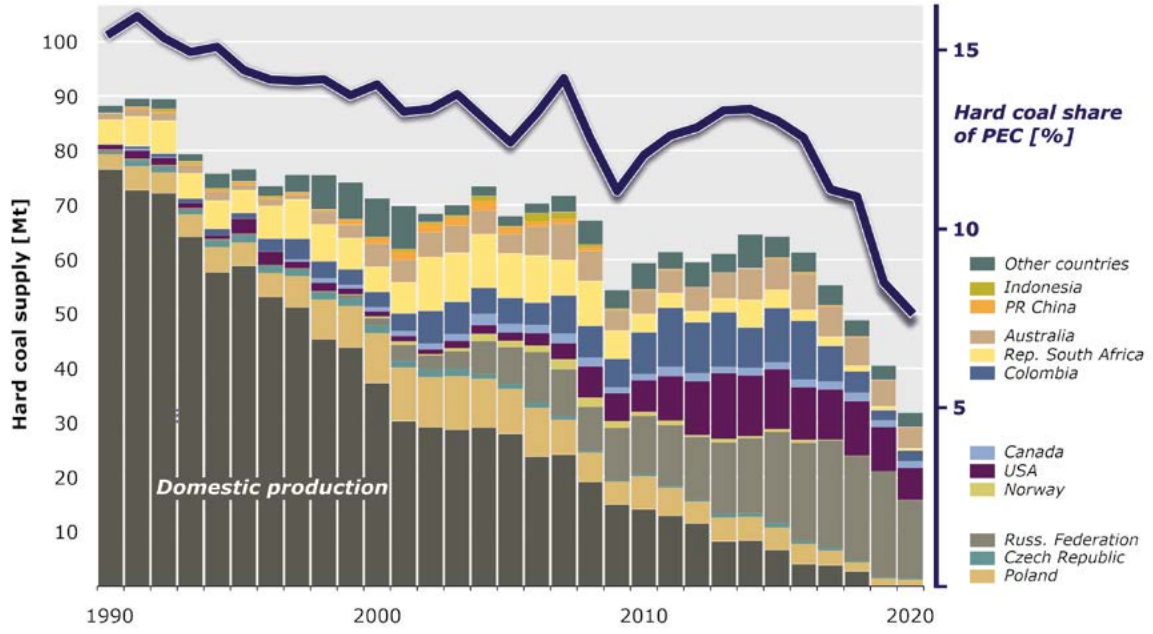


Figure 2-6: German coal supplies from 1990 to 2020 (AGEB 2021, SdK 2021, VDKI 2021).

Lignite

>> *Lignite production and consumption down by almost a fifth*

Lignite is mined in three fields in Germany (Fig. 2-4). In the **Rhenish lignite field** in North Rhine-Westphalia, production fell by around one fifth to 51.4 million tonnes. In the Central German and Lusatian lignite fields in Brandenburg and Saxony, production also fell significantly by 15.8 % to 56 million tonnes. Nationwide, the total in 2020 was 107.4 million tonnes (SdK 2021, Fig. 2-5). Around 1.95 billion t of lignite reserves are accessible in Germany via developed and specifically planned surface mines. Further reserves amount to about 34 billion t. The resources comprise 36.5 billion t.

In the **Rhenish lignite field**, RWE Power AG operates three surface mines – Garzweiler, Hambach and Inden. The Frimmersdorf, Neurath and Niederaussem power plants are supplied with lignite from the Garzweiler surface mine. The Frimmersdorf power plant was transferred to stand-by mode for security of supply reasons on 1 October 2017, units E and F of the Niederaussem power plant on 1 October 2018 and unit C of the Neurath power plant on 1 October 2019. The latter means that the power plant and the units will no longer be used on the regular market and start-up is only permitted at the request of the transmission system operator, which is responsible for the system stability of the transmission and electricity grids. The Hambach surface mine supplies lignite to the Niederaußem and Goldenberg power plants and to Gas- und Elektrizitätswerke Köln. The Weisweiler power plant is supplied by the Inden surface mine.

Production in the **Lusatian lignite field** is carried out by Lausitz Energie Bergbau AG from the four surface mines Jänschwalde, Welzow-Süd, Nochten and Reichwalde. The Jänschwalde (Block F in stand-by mode for security of supply reasons since 1 October 2018 and Block E since 1 October 2019), Boxberg, Lippendorf/Block R and Schwarze Pumpe power plants are operated by Lausitz Energie Kraftwerke AG. Both companies – formerly Vattenfall Europe Mining AG and Vattenfall Europe Generation AG & Co. KG – have been operating under the shared brand name LEAG since autumn 2016 and belong to the Czech energy group Energetický a Průmyslový Holding (EPH) and its financial partner PPF Investments.

The two surface mines Profen and Vereinigtes Schleenhain of Mitteldeutsche Braunkohlengesellschaft mbH (MIBRAG), which has been fully owned by the Czech holding EP Energy since 2012, and the surface mine Amsdorf of Romonta GmbH are in operation in the **Central German lignite field**. Most of the lignite from the first two surface mines is used to generate electricity in the Schkopau and Lippendorf power plants. On the other hand, the lignite from the Amsdorf surface mine is used for the production of **raw montan wax**.

The total **volume** of lignite sold fell by 18.2 % to 107.4 million tonnes in the year under review due to the sharp reduction in production. Its share of primary energy consumption thus fell from 9.1 % in the previous year to 8.1 % in the year under review. Around 87 % of German lignite production was used in general supply power plants to **generate electricity**. The share of lignite-fired power plants in gross electricity generation was 16.1 % in 2020, on a par with the share of natural gas. In the reporting period, the number of employees decreased slightly. Nationwide, 14,867 people were employed in lignite mining, 4.3 % less than in the previous year (AGEB 2021, Maassen & Schiffer 2021).

2.7 Hydrogen

Hydrogen is a colourless and odourless gas that is currently primarily a feedstock for the chemical industry. In the future, this energy sources will also play a significant role in the decarbonisation of energy and economic systems in other industrial applications as well as in the transport sector and heating markets.

>> *Electrolysis capacity in Germany to be expanded to 5 GW by 2030*

The **national hydrogen strategy** (BMWi 2020) envisages installing around 5 GW of electrolysis capacity in Germany by 2030 to produce around 0.4 million tonnes (4 billion m^3, 14 TWh) of hydrogen (BMWi 2020). The National Hydrogen Council advises aiming for an even significantly higher electrolysis capacity, backed up by the expansion of additional renewable energies (NWR 2021). In addition to the massive expansion of renewable energies in order to be able to provide the required energy quantities, there is likely to be a considerable import requirement for hydrogen, as a hydrogen demand of 2.7 to 3.3 million t (30 to 37 billion m^3, 90 to 110 TWh) is expected by 2030 (BMWi 2020). The level of import demand will depend not least on how much hydrogen will be produced in Germany. Germany's hydrogen demand is currently around 1.65 million t (18 bcm, 55 TWh) and is mainly produced from natural gas (see „Hydrogen: Fundamentals" in the appendix).

According to IEA (2020), the German electrolysis capacity was 46 MW_e in 2019 (Tab. 4). However, the actual electrolysis capacity is probably higher, as not all small-scale plants were recorded. The share of production from electrolysis processes (mainly chlor-alkali electrolysis, ALK) in total production is above average in Germany compared to other countries.

More than 62 large-scale hydrogen projects and several hundred smaller projects are planned in Germany (BMWi 2021). The largest current hydrogen project is the AquaVentus initiative, which aims to use offshore wind power from the German North Sea to produce green hydrogen on a large scale in the future. The plan for the project off Heligoland envisages electrolysis plants of around 10 GW by 2035.

>> *High future hydrogen import demand*

One of the Federal Government's instruments for developing a hydrogen infrastructure in Germany are the real-world laboratories, which are operated by partners from science and industry. These are usually pilot projects limited in time and place in which innovative technologies, products, services or approaches are tested under real conditions. Of the 20 winners of the real-world oratory competition in Germany, about half have currently started testing hydrogen technologies and sector coupling.

Table 4: Installed electrolysis capacity 2019 for hydrogen production and expansion targets according to Wietschel et al. (2021) [GW]

	Installed electrolysis capacity	Electrolysis capacity until 2030	Expansion targets for installed electrolysis capacity		
			2030	2040	2050
Germany	0.046	5	1.7-10	up to 35	43-63

Hydrogen production from discarded electricity production

At times when the German power grid is at its maximum capacity and wind and solar power cannot be fed into the grid, this power is discarded to maintain grid stability. The energy that is not generated is referred to as „discard production“. Even though the amount of discard production will foreseeably decrease as the grid expands, the question arises to what extent discard production could be used to produce hydrogen and what quantities of hydrogen would be involved.

In Germany, around 6,146 GWh of electricity (1 % of total generation, primarily onshore wind power) was discarded in 2020 (Bundesnetzagentur 2021; Fig. 2-7). Assuming an electricity demand of 55 kWh for the electrolysis of 1 kg H_2, 112 kt of hydrogen could theoretically be produced from this amount of electricity. However, the currently installed electrolysis capacities are not sufficient to produce these quantities of hydrogen.

With the currently installed domestic electrolysis capacity of around 46 MW_e (of which around 26 MW_e are in operation) (IEA 2020), around 3.3 kt of hydrogen could theoretically be produced from discard production power at 4,000 full load hours. These calculations are based on the data on realised electricity and balancing quantities (discard production power) (Bundesnetzagentur 2021). Not taken into account are maintenance times or other outages at electrolysis plants, seasonal fluctuations in which disceard production could theoretically be used, and energy losses during processing, liquefaction, transport and electricity exchange with neighbouring countries.

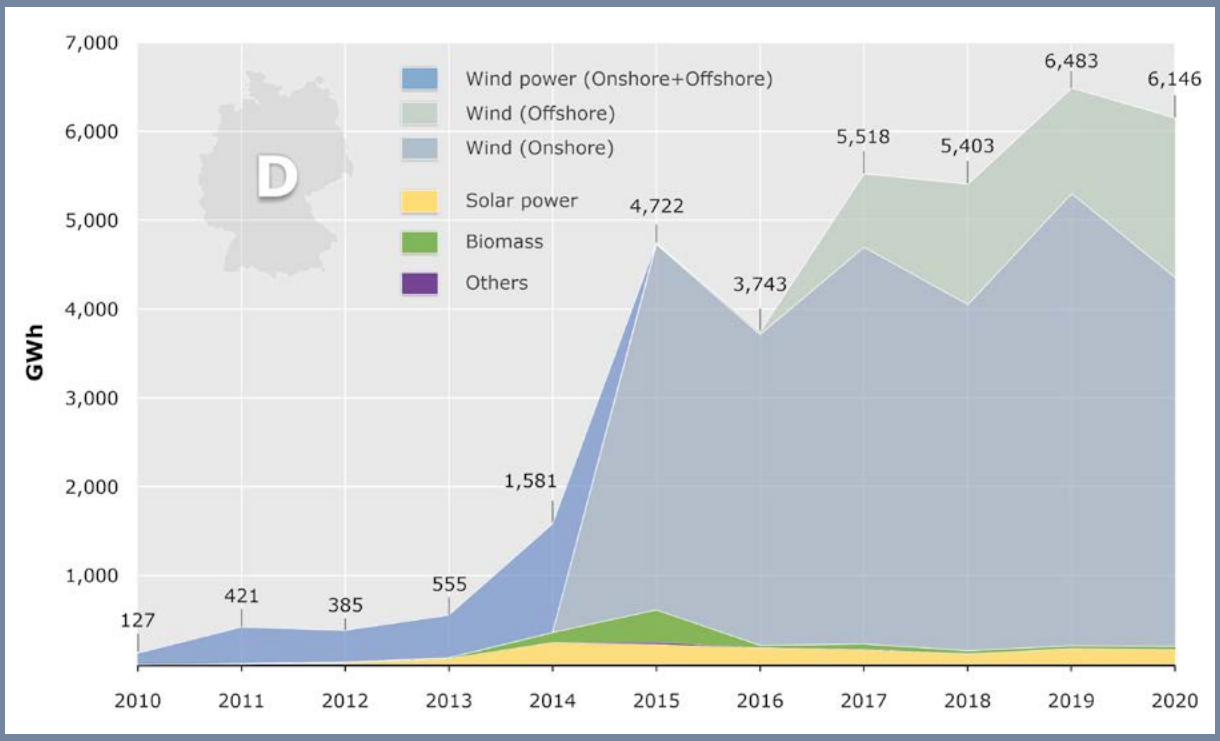


Figure 2-7: Development of discard production caused by feed-in management measures from 2010 to 2020 (after Bundesnetzagentur/ Bundeskartellamt 2021).

Underground hydrogen storage

Large future storage volumes for hydrogen are envisaged in various scenarios in the framework of the National Hydrogen Strategy. Analogous to the proven storage of natural gas, hydrogen can be stored in geological structures. Two types of storage are used for natural gas storage in Germany, which are cyclically filled and partially emptied during operation: 1. porous rocks, mainly depleted natural gas reservoirs, 2. cavities in rock salt specifically created for storage (cavern storage). At the end of 2020, the usable working gas storage volume of natural gas storage facilities was 23.7 billion m^3, of which about one third was in pore storage facilities and two thirds in salt caverns (LBEG 2021). There are many years of positive experience with these underground natural gas storage facilities in Germany and worldwide.

In contrast, the state of knowledge on hydrogen storage in existing or newly developed underground storage facilities is limited. In the USA and the United Kingdom, there are many years of experience in storing small amounts of hydrogen in caverns (Warnecke & Röhling 2021). In Germany, pilot projects for storage in existing salt caverns have recently strated as part of the establishment of real-world laboratories for the energy transition, such as the salt cavern near Bad Lauchstätt. Other caverns will be converted in the next few years, such as the Huntorf cavern and parts of the Gronau cavern storage facility. The use of pore storage facilities for hydrogen storage has been successfully tested in Austria so far and further projects are currently taking place at the same location. However, the state of knowledge on pore storage is less advanced compared to salt caverns.

Therefore, selected aspects of hydrogen storage in underground storage facilities are being studied worldwide (Heinemann et al. 2021). In cooperation with other research institutions, the BGR is currently investigating possible conversions of hydrogen by microorganisms or on mineral surfaces in storage facilities and the transport of hydrogen in pore storage facilities. In addition, storage volumes for hydrogen are also being determined for possible, newly created underground storage facilities with regads to potentially competing uses. In general, the storage of large volumes of hydrogen in the subsurface appears to be possible, although aspects of the suitability of individual structures are still being investigated in detail (Forschungsnetzwerke Energie 2021).

3 Energy resources worldwide

3.1 Natural gas

Global natural gas reserves have hardly changed compared to the previous year and amount to 206 trillion m³ (previous year 208 trillion m³) (Tab. 5; Fig. 3-1). Around 95 % of the world's natural gas reserves are located in conventional deposits. Unconventional natural gas deposits (shale gas and coal bed methane, CBM), on the other hand, account for only a small share of natural gas reserves (Table A-17 in the Appendix). Significant shale gas reserves are currently only reported for the USA, which has a share of about 75 % of total US natural gas reserves. Slightly more than half of the world's natural gas reserves are concentrated in the Russian Federation, Iran and Qatar (Tab. A-17 in the Appendix). These are almost exclusively located in conventional deposits.

In terms of global natural gas resources, conventional deposits also dominate with around 328 trillion m³, followed by shale gas resources with 203 trillion m³, tight gas with 55 trillion m³ and CBM with 44 trillion m³ (Table A-16 in the Appendix).

In 2020, global natural gas production decreased by 3 % and amounted to just under 3.99 trillion m³ (previous year 4.1 trillion m³).

Table 5: Global development in production and reserves of natural gas

	Production	3.99 Bcm	-3.4 % →
	Conventional reserves	195 Bcm	-0.6 % →
	Unconv. reserves	11 Bcm	-3.2 % →
	Resources	630 Bcm	-0.1 % →

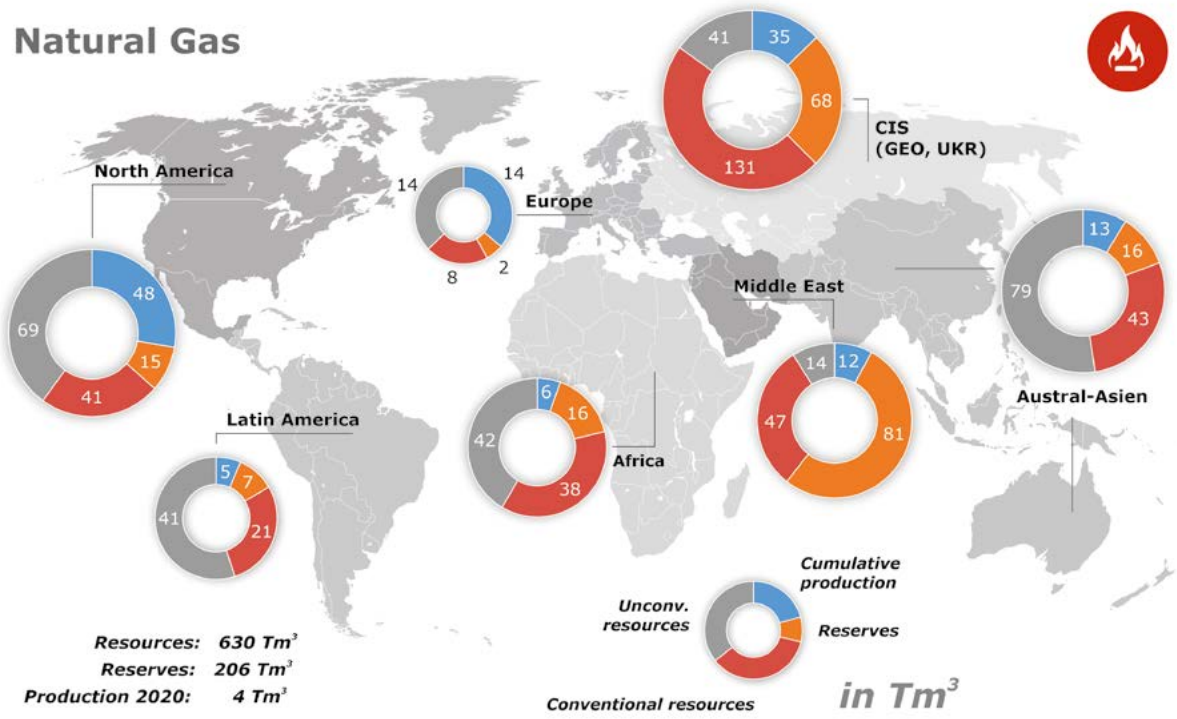


Figure 3-1: Regional distribution of the total natural gas potential 2020 (Tm^3 = Bill. m^3 = 10^{12} m^3; without aquifer gas and gas hydrates).

In the USA, production decreased by less than 1 %, while the Russian Federation produced 6 % less and Uzbekistan 18 % less. In Europe, production was down by around 9 %. Of the top 20 producing countries, only Nigeria showed a notable increase (plus 5 %). In absolute terms, the USA produced the most natural gas worldwide, as in the previous year, followed by the Russian Federation and Iran (Tab. A-18 in the Appendix).

Global natural gas consumption decreased by 1.5 % compared to the previous year. The USA remained the largest consumer of natural gas with 863 bcm, followed by the Russian Federation (488 bcm) and China (321 bcm) (Table A-19 in the Appendix). With a consumption of around 91 bcm, Germany ranks eighth among global natural gas consumers (Table A-19 in the appendix). In the EU-28, natural gas consumption decreased by 4 % compared to the previous year and amounted to 467 bcm.

Natural gas imports stagnated worldwide. Europe imported slightly less natural gas than in the previous year (minus 4 %), while Africa (minus 32 %) and Latin America (minus 11 %) imported significantly less. The EU-28 imported a large share of the globally traded natural gas, around 42 %. The largest importers of natural gas are Germany, China and Japan. Unlike China and Japan, however, Germany re-exports a significant share to neighbouring European countries.

Global liquefied natural gas (LNG) trade remained almost constant in 2020 (up 0.4 %, compared to up to 13 % in 2019; GIIGNL 2021) and represented around 52 % of inter-regional natural gas trade (BP 2021). This was the first time that more natural gas was traded inter-regionally in the form of LNG than through pipeline transport. Globally, 42 LNG-importing nations stood unchanged against 20 LNG-exporting countries. In the USA, five new, large onshore natural gas liquefaction plants were commissioned.

Due to the low spot market prices, Europe purchased a large part of its natural gas imports on the spot market, especially in the first half of the year. In the second half of the year, this trend reversed due to the economic recovery and the increase in spot market prices in Asia. India and especially China imported large quantities of LNG from the spot market. Asia accounted for the largest share of global LNG imports at 71 %, with Japan (103 bcm), China (95 bcm) and South Korea (56 bcm) accounting for the largest volumes (GIIGNL 2021).

In 2020, Australia was the world's largest LNG exporter for the first time (107 bcm, 21.8 % share), just ahead of Qatar with a slightly lower export volume of 106 bcm (21.7 %). The USA ranked third (62 bcm, 12.6 %) with a significant increase of almost 33 % compared to the previous year (GIIGNL 2021).

LNG supplied to the EU-28 in 2020 came mainly from Qatar (27 bcm), the USA (22 bcm) and the Russian Federation (17 bcm). Only the US increased its supply volumes to the EU-28 (plus 36 %), while all other major supplier countries reduced their volumes (GIIGNL 2021; Fig. 3-2).

Gas prices fell to multi-year lows in 2020: the US Henry Hub price averaged USD 1.99/million BTU – the lowest level (in nominal terms) since 1995, while Asian LNG prices (Japan-Korea marker) recorded their lowest level ever at USD 4.39/million BTU. In 2021, especially in the second half of the year, gas prices increased significantly in all markets worldwide. The US Henry Hub price averaged 5.05 USD/million BTU in November 2021.

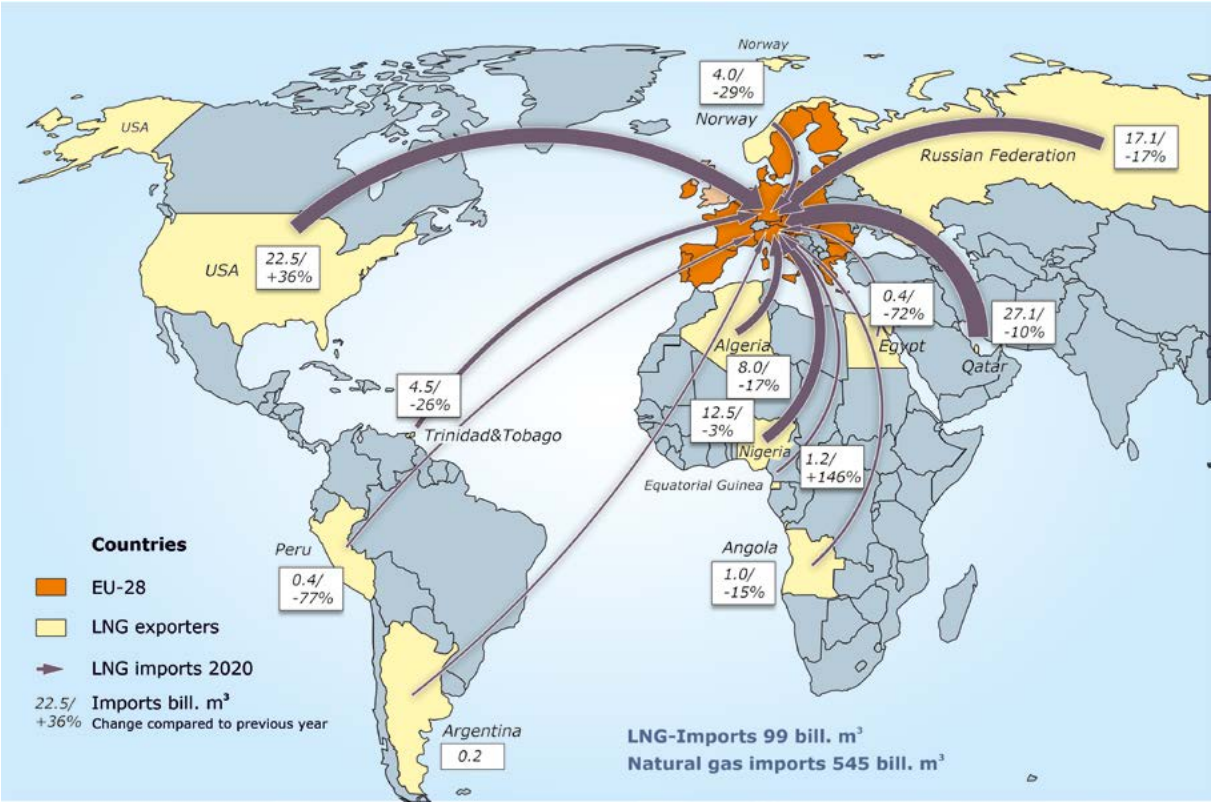


Figure 3-2: LNG import volumes (bcm of natural gas, gaseous) to the EU (including the United Kingdom) and changes compared to previous year; total LNG imports and sum of natural gas imports of EU-28 countries.

3.2 Crude oil

As a result of the pandemic-related measures and the subsequent economic slump, there was the sharpest decline in crude oil consumption (minus 9.1 %) in decades. Crude oil production was also significantly curtailed. However, crude oil remained the world's most important energy source, accounting for 31.2 % of global primary energy consumption. Stocks remained essentially unchanged (Tab. 6; Fig. 3-3).

>> *Biggest drop in demand in decades due to pandemic measures*

About two thirds of the **conventional crude oil** reserves, which are **particularly relevant** for the global supply of liquid hydrocarbons due to the comparatively low extraction costs, are located in the countries of the **Middle East** (Fig. 3-3).

>> *For the first time in history briefly negative WTI oil price*

Crude oil production is unevenly distributed among the individual countries and regions. The 20 largest crude oil-producing countries already cover around 89 % of total crude oil production. The most important producing region remained the Middle East with a share of 30.7 %. By far the strongest producing nations remained the USA, the Russian Federation and Saudi Arabia.

Crude oil prices had already been declining since the beginning of 2020 (Fig. 3-4). Since the end of 2017, the OPEC countries, together with other leading producers, including the Russian Federation (together the „OPEC+ group"), have regularly coordinated the level of crude oil production of the individual group countries in order to counteract overproduction and thus to stabilise crude oil prices. At the beginning of March 2020, Saudi Arabia and the Russian Federation were unable to agree on new production quotas. In addition, the pandemic reduced economic activity and mobility in more and more countries from March onwards. This resulted in a drastic decline in crude oil demand and a significant drop in crude oil prices. Despite a restriction on crude oil production from April 2020 by the OPEC+ group (OPEC 2020), forward contracts for the US reference grade WTI fell from USD 18 to just under minus USD 37/barrel within hours on 20 April. For the first time in economic history, albeit only briefly, negative WTI crude oil prices were thus recorded. Due to the drastic cutbacks in crude oil production by the OPEC+ group as well as a renewed increase in demand for crude oil as a result of the gradual global economic recovery, crude oil prices rose again. The average price for WTI crude for the year was 39.2 USD/bbl.

>> *Low investment in the E&P sector may lead to a supply gap in the medium term*

Table 6: Global development in production and reserves of crude oil

Production	4.16 Gt	-7.2 % ↘
Conventional reserves	174 Gt	+0.5 % →
Unconv. reserves	71 Gt	+0.1 % →
Resources	501 Gt	-0.2 % →

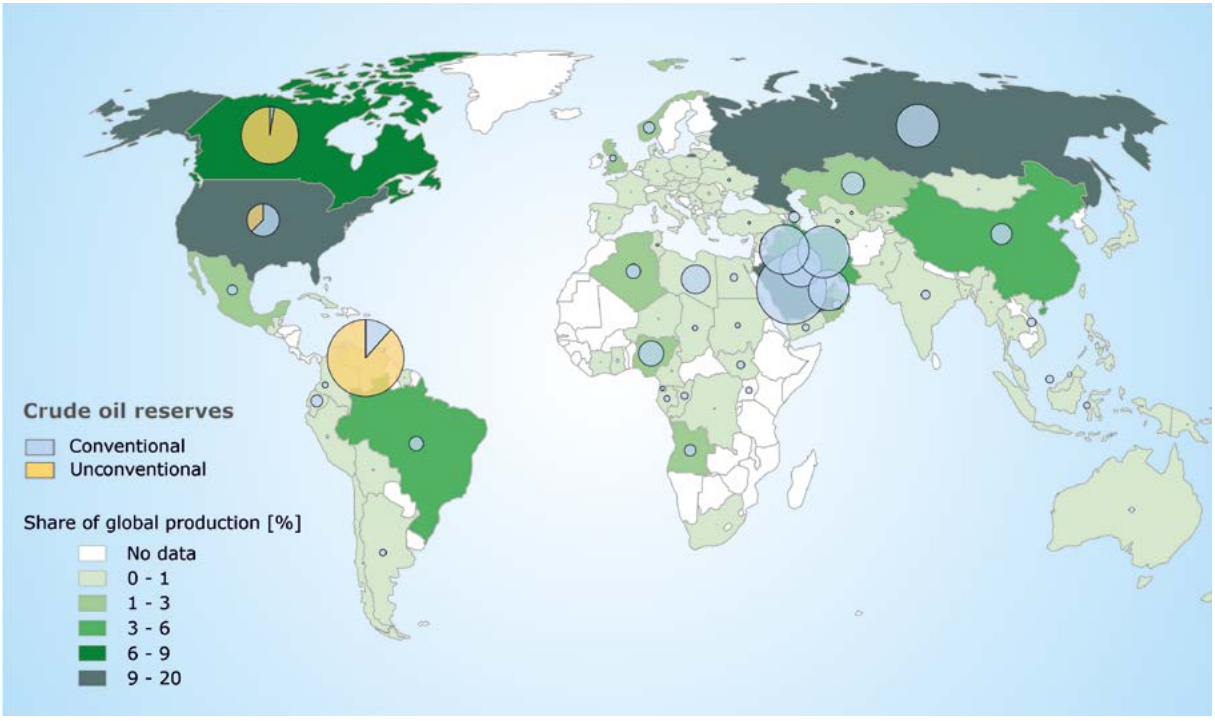


Figure 3-3: Distribution of the world's conventional and unconventional crude oil reserves and crude oil production.

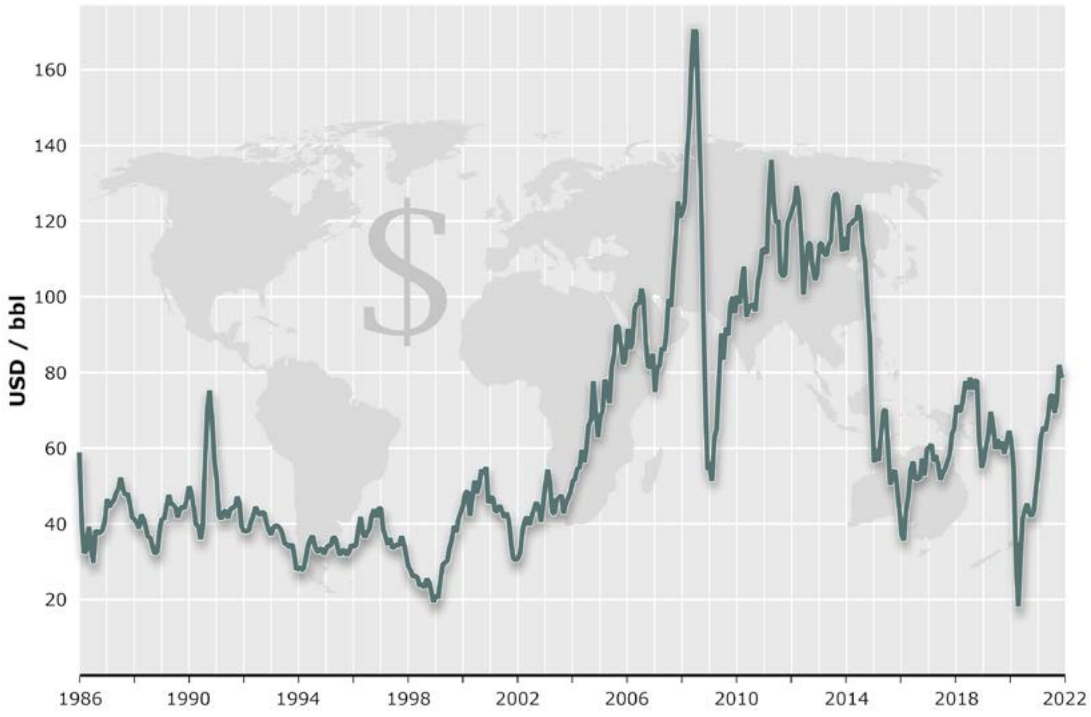


Figure 3-4: Inflation-adjusted crude oil price on a monthly basis from 1986 to November 2021 (EIA 2021a, U.S. Bureau of Labor Statistics 2021; bbl – barrel).

Although unconventional crude oil production has become increasingly important in recent decades, conventional crude oil production remained the mainstay of liquid hydrocarbon supply, accounting for about 73 % of total production in the year under review (Fig. 3-5).

The increases in total production of liquid hydrocarbons since 2005 have been realised mainly through production increases of condensate (NGL natural gas liquids), unconventional crude oil (shale oil, oil sands and heavy oil) and biofuels.

Condensate (NGL) is mainly produced during the processing of natural gas and is added to crude oil production. As a result of the decades-long increase in natural gas production, more NGL is also being produced. The production of unconventional crude oil to a significant extent has so far been limited to North and South America. Shale oil is mainly produced in the USA, where it already accounts for around 65 % of crude oil production, and to a lesser extent in Canada and Argentina. Crude oil from oil sands has so far only been extracted in Canada. There, production has been expanding for decades, with the exception of the year under review, when there was a slight decline in production. Extra-Heavy oil production has so far only taken place in Venezuela. As a result of the ongoing economic crisis there and the comparatively low crude oil prices for years, however, this has been in sharp decline for years.

The two continents also dominate the production of biofuels. The USA and Brazil accounted for about 59 % of global biofuel production in 2020 (BP 2021).

In response to the sharp drop in crude oil prices from March 2020, there was a sharp decline in drilling and production activity, particularly in the US shale oil industry (EIA 2021d, Baker Hughes 2021). Significant production declines occurred in all major oil producers, with the exception of

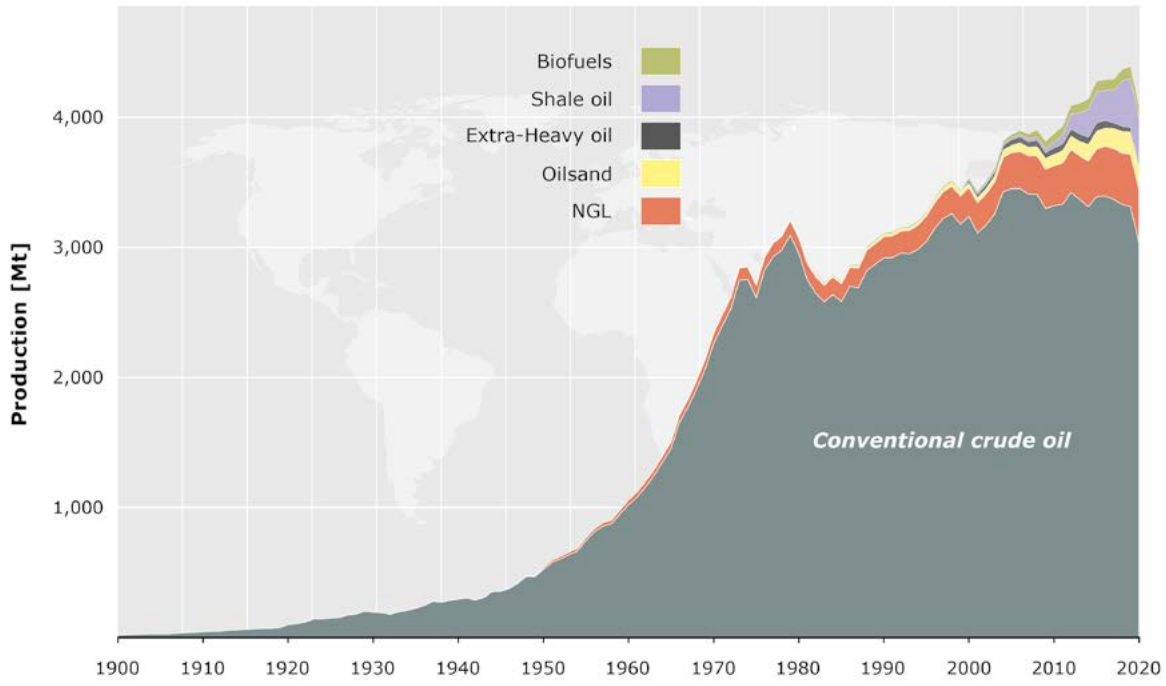


Figure 3-5: Development of the worldwide production of liquid hydrocarbons (NGL: natural gas liquids).

China. The production declines in the countries are primarily due to the curtailment of production volumes as a result of the decline in demand and the associated decline in crude oil prices.

Liquid hydrocarbons can also be produced synthetically by natural gas and coal liquefaction processes, which is done to a very small extent (< 1 % – IEA 2021a). The leading countries in the production of synthetic liquid hydrocarbons from coal are South Africa and China, from natural gas they are Qatar and Malaysia. More than three quarters of the mineral oil was used by the 20 leading consumer countries. The EU 28 covered only just under 14 % of its demand through own production.

About half of the crude oil produced in 2020 was traded across borders, mainly by tanker or pipeline. Worldwide, 2,124 million tonnes of crude oil were exported, a decrease of 7.1 % compared to the previous year. The two leading export nations are Saudi Arabia and the Russian Federation. The five largest exporting countries already cover about half of the exports. Global refining capacity increased by 0.2 % to 5,063 million tonnes (BP 2021).

Austral-Asia remained the most important import region with a share of 56 %. Africa imported the least crude oil with a total share of 0.5 %. China imported 540 million tonnes of crude oil (plus 6.7 %) in the reporting year and remained by far the largest crude oil importer in the world. China was one of the few countries in the world to import more crude oil than in the previous year. Crude oil imports by the USA, whose crude oil imports had been declining almost continuously since the end of the 2000s due to increased domestic production, amounted to 293 million tonnes (minus 13.4 %). India was the third largest crude oil importer with 204 million tonnes (minus 8.9 %).

The storage capacities of OECD countries for crude oil and crude oil products (strategic reserves and industrial stocks) held in caverns or above-ground tank farms amounted to around 3.02 billion barrels in the fourth quarter of 2020 (EIA 2021b). The spare production capacity of OPEC countries, i. e. the additional amount of crude oil by which production can be increased within 30 days and maintained for at least 90 days, amounted to 7.68 million barrels per day in the fourth quarter of 2020 (EIA 2021c). This much higher free production capacity compared to the last decades is due to the production regulations of the OPEC+ group in spring 2020.

Security of supply with liquid hydrocarbons

Although the geological reserves of crude oil can meet increasing demand for decades and the oil market has tended to face an oversupply of crude oil for years, overarching developments, especially exploration and production (E&P) investments and future consumption, are crucial for medium- and long-term security of supply. Investment in the E&P sector was 27 % lower in 2020, at 382 billion USD, as a result of significantly lower oil and gas prices compared to the previous year (Rystad Energy 2021).

Insofar as global crude oil consumption deviates from the IEA‘s „Net-Zero“ scenario (NZE) in the coming years, and this is already foreseeable in 2021 (EIA 2021b), spending in the E&P sector and thus the volumes of future crude oil production would foreseeably no longer be in line with demand. Since investments in the E&P sector, especially in the development of new fields, only take effect with a time lag, supply-demand discrepancies and price spikes occurring in the medium term cannot be ruled out against the background of the phase of low investments in the E&P sector that has already existed since the end of 2014.

3.3 Renewable energy

>> *Net-Zero-2050: EU and nine other countries aim for climate neutrality by 2050*

In 2020, 16 % of global primary energy consumption was covered by renewable energies (Fig. 1-1). More than half of this is accounted for by biogenic energy sources, with the main share of around 40 % being based on solid biomass and, in particular, on firewood. Even today, wood and charcoal are still mainly used for energy generation, especially in developing countries, but the number of privately used systems such as wood-burning stoves or pellet heating systems for heat generation is also increasing in industrialised countries. Biomass, for example, accounts for the largest share of renewable energy consumption in the EU, at around 60 % (European Commission 2019). After biomass, hydropower is the most widely used classic renewable energy source, with a share of around 3.6 % of global primary energy consumption. Modern renewable energies such as solar or wind energy only contribute around 2.4 % to global primary energy consumption. Their expansion has recorded the highest growth rates in recent years.

>> *261 GW record expansion of renewables in 2020 – 117 GW in China alone*

As in the previous year, the newly installed electricity generation capacities were mainly provided by the addition of renewable energies. Their share in 2020 was around 83 % (2019: 64 %). This means that the annual addition of renewable energies for electricity generation exceeds the addition of fossil energies and nuclear energy (REN21 2021). One reason is the changing political framework conditions, which favour the expansion of renewable energies. However, technology costs, especially for solar and wind energy, have also fallen significantly in recent years, leading to an increase in the competitiveness of renewable energies. In 2020, new installations in the electricity sector were mainly driven by photovoltaics. Around 54 % of the newly installed capacity was realised through the addition of photovoltaic systems (127 GW) (IRENA 2021). For wind power and hydropower, additional capacities of 111 GW and 21 GW respectively were newly installed worldwide in 2020. China remains the main driver in the expansion of renewable energies, accounting for 117 GW in 2020, or around 45 % of the global expansion (IRENA 2021).

Worldwide, the capacity for electricity generation from renewable energies will be around 2,800 GW in 2020 (Fig. 3-6). China leads the way with around one-third of global installed renewable energy capacity (908 GW) (Table A-44 in the Appendix). Hydropower alone accounts for 370 GW in China, as well as a further 282 GW of wind power and 254 GW of photovoltaics.

The expansion of wind power and photovoltaics is being intensively promoted; however, their share in electricity generation has been low so far. Although the total share of renewable energies in global electricity generation was 29 %, it was mainly generated by hydropower. Wind power, photovoltaics and biomass together contributed to 9% of electricity generation in 2020 (REN21 2021). While hydropower dominates electricity generation from renewable sources worldwide, in Germany more than half was generated from wind power (131 billion kWh; 23 % of German electricity generation) and photovoltaics (50.6 billion kWh; 9 %) (Chapter 2.3). China, USA, Brazil and Canada use more than half of the energy generated worldwide for electricity generation from renewable energy sources (Fig. 3-7).

>> *In 11 countries, more than 20 % of electricity demand is covered by wind energy and photovoltaics*

The expected further expansion will increase the share of renewable energies in the global energy supply. In addition to the geographical conditions, the strategies and goals of the countries are particularly decisive in determining which development path is taken for the expansion. For example, 11 countries already cover more than 20 % of their electricity demand with wind energy and photovoltaics (REN21 2021; Fig. 3-8). Iceland covers 100 % of its electricity demand from renewables (79 % hydropower; 20 %

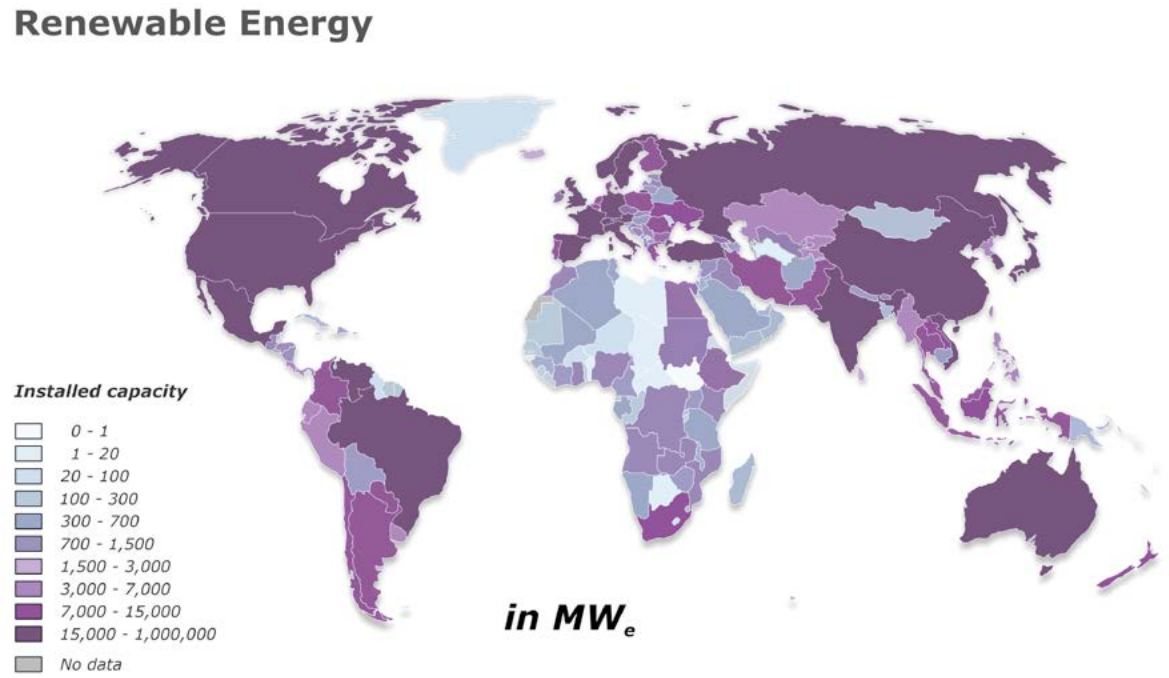


Figure 3-6: Total potential of the installed capacity of renewables for power generation: regional distribution (IRENA 2021).

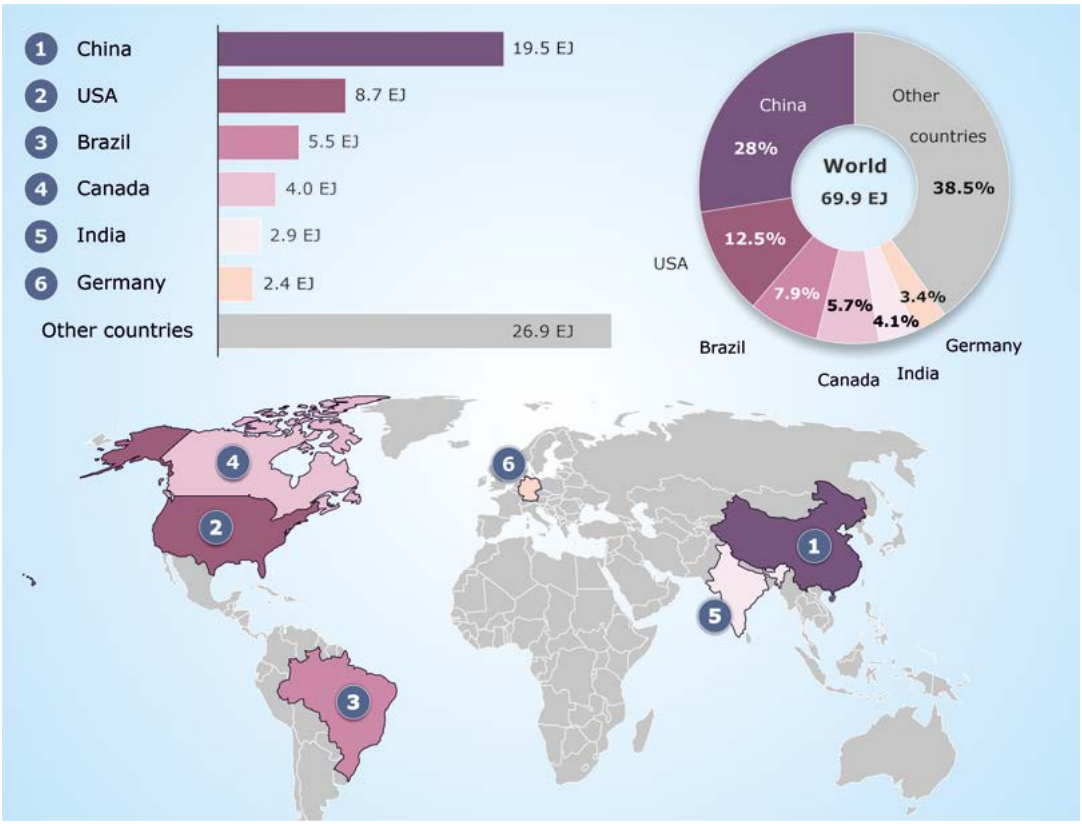


Figure 3-7: The largest users of renewables for power generation 2020 (BP 2021).

geothermal; <1 % wind power) (IEA 2021b). In Germany, around 44 % (2019: 35 %) of electricity demand was covered by renewable energies in 2020 (Chapter 2.3).

>> *10 million electric cars on the road worldwide – number doubled within two years*

Renewable energies are also gaining importance in the traffic and transport sector as biofuels (ethanol, biodiesel) or as electricity in electric vehicles (e-mobility), albeit much slower than for electricity generation. Currently, biofuels contribute to 1 % of global final energy consumption. Production has more than quadrupled in the last 16 years from around 30 billion litres (2004) to around 152 billion litres (2020) (REN21 2021) and a further increase is expected. The USA and Brazil lead the way in production. More than 60 % of ethanol fuels and biodiesel come from these two countries. But Germany is also a major producer of biodiesel. With 3.5 billion litres (world share 3 %), Germany was Europe's largest producer in 2020.

In addition to the already existing use in rail transport, e-mobility in the traffic and transport sector will continue to advance and become increasingly important. Europe and China are currently leading in the use of e-mobility. Around 10 million electric cars (2018: 5.1 million) and over 280 million two-wheeled electric vehicles (2018: 260 million) are in use worldwide (VDA 2021; REN21 2021), and the trend is rising. Heavy-duty road and marine uses are also being developed and expanded. In the long term, the use of alternative fuels such as synthetic fuels, hydrogen or ammonia for shipping and heavy goods transport is also being targeted. The share of renewable energies in the global transport sector is currently around 3.4 %.

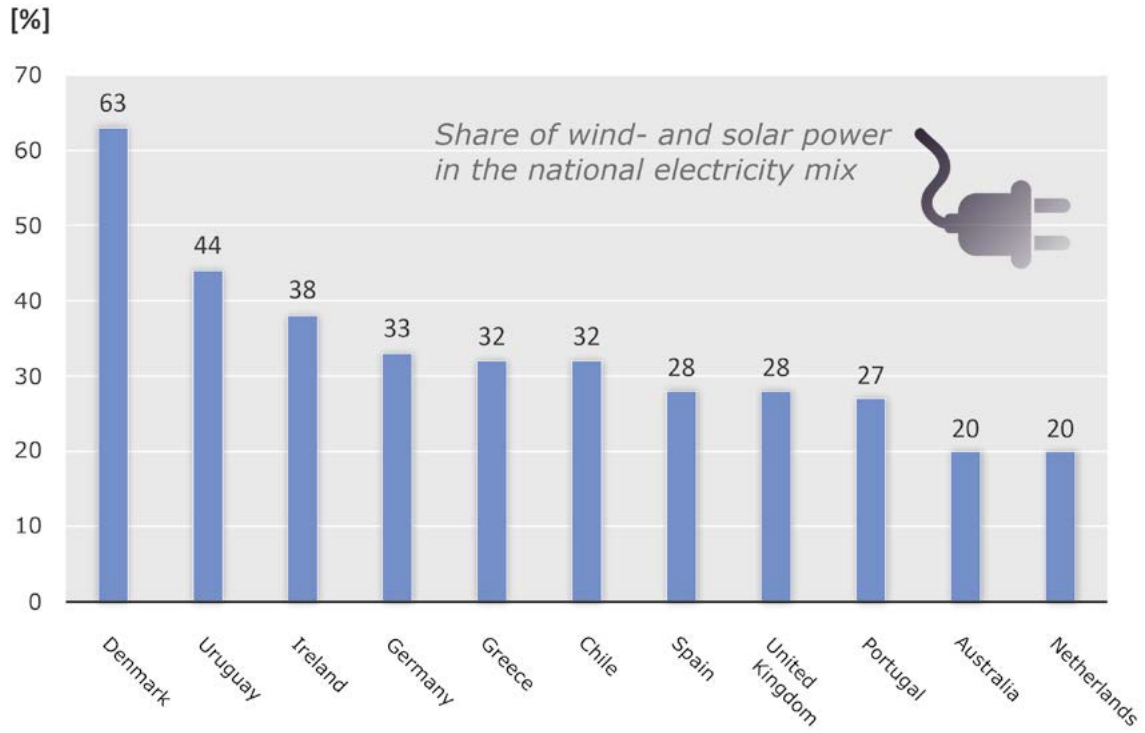


Figure 3-8: In eleven countries, more than 20 % of the electricity demand is covered by renewable energies (wind and photovoltaics (PV)). Share of wind and PV in electricity generation by country (Data: REN21 2021).

3.4 Geothermal energy

Deep geothermal energy is the only energy source in the geological realm that counts as renewable energy, as the decrease in geothermal heat present in the Earth's interior is negligible in relation to human time. It is therefore considered separately from other renewable energies (Section 3.3).

>> *Geothermal electricity generation very low compared to total electricity production (0,3 %)*

Geothermal electricity production recorded a small increase of 0.1 GW_e in 2020, almost all of which was provided by Turkey. The total global installed capacity is 14.1 GW_e (REN21 2021). The share of global geothermally generated electricity (97 TWh) remained very low compared to total electricity production, at around 0.3 %.

>> *Geothermal heat utilisation shows stable growth of eight percent*

The global market for geothermal heat utilisation continues to show stable growth of eight percent. (REN21 2021). In total, the capacity amounts to 32 GW_{th}; the heat produced/used is 128 TWh_{th}. The greater upswing hoped for beyond this failed to materialise, not least due to high project costs and sometimes a lack of political support.

3.5 Nuclear fuels

Uranium

The COVID-19 pandemic had a significant impact on the uranium market. While the operation of nuclear power plants worldwide was not affected, the closure of mines due to the pandemic, especially in North America but also in Kazakhstan and parts of Africa, had a significant impact on uranium mining. US uranium production reached a low of around 6 t U in 2020. The market-regulated reduction in production in recent years resulted in a global decrease in total uranium production (BGR 2019b) and was further exacerbated by the COVID-19 pandemic. As a result, since 2018, production fell by around 6,000 t U to a total of around 45,500 t (minus 12 %). As in the past, the difference between annual demand and primary production was compensated by civilian and military stockpiles, especially from the Russian Federation and the USA (BGR 2019b). Another source of uranium is the reprocessing of fuel elements.

Around 81 % of the world's production came from five countries (Fig. 3-9). The largest producing country was again Kazakhstan. Due to the global market situation, the country again noticeably reduced its production compared to the previous year (2019: 22,808 t U) to 19,477 t U, but remained decisive with a share of over 40 % of global uranium production.

>> *In 2020, 142 reactors were in operation in Asia and 32 more were under construction*

While the demand for uranium in Europe and in North America is expected to decrease in the future, there is still interest worldwide in the energetic use of nuclear fuels. Especially in the emerging and developing countries in Asia and the Middle East, uranium consumption is expected to increase (IAEA 2020, OECD-NEA/IAEA 2020, WNA 2021a).

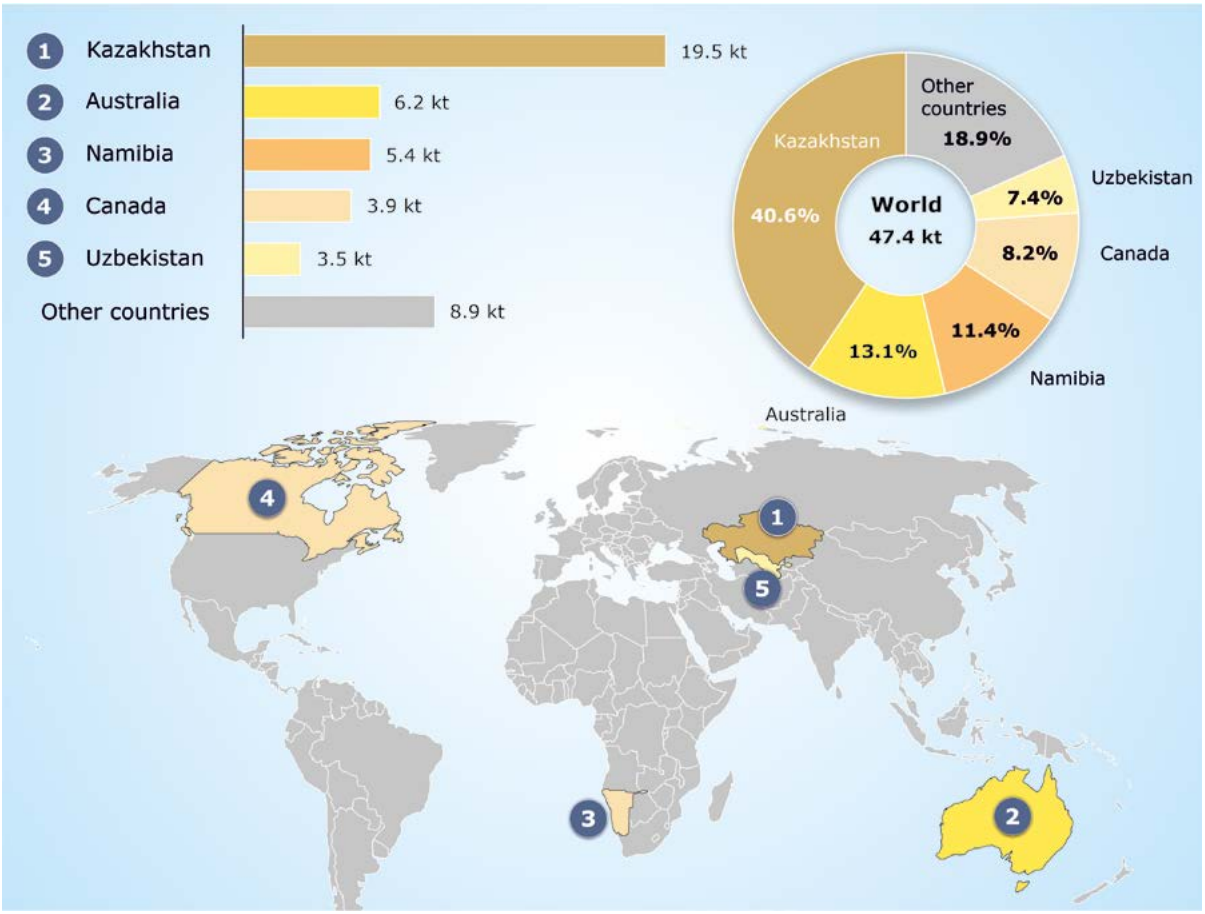


Figure 3-9: The largest uranium producing countries 2020. The largest single production site in 2020 was the Canadian Cigar Lake mine with 3,885 t U and a market share of 8 %. Ranking by quantities in 1,000 tonnes [kt] of uranium (Data source: WNA 2021b).

At the end of 2020, 51 nuclear power plants were under construction in 19 countries, including 13 in China alone (Fig. 3-10). Since the use of nuclear reactors, over 115 commercial reactors (plus 48 prototypes and 250 research reactors) have been decommissioned worldwide (as of August 2021). Of these, 17 reactors (including research reactors and prototypes) have been completely decommissioned (WNA 2021c). In Europe, four decommissioning projects were fully completed, three of them in Germany alone (BfE 2019). Two new nuclear power plants were commissioned in China and one each in the Russian Federation, Belarus and the United Arab Emirates.

The global demand for uranium amounted to 68,269 t U for 2020 (2019: 68,240 t U) and thus remained almost the same as in the previous year. Although Asia and the Middle East in particular are recording higher consumption (especially in China and India; Table A-39 in the Appendix), which is also expected to increase in the following years, this is currently compensated for in particular by the decline in consumption in the USA and Germany.

Worldwide, uranium is mainly traded via long-term supply contracts. Uranium deliveries to EU member states in 2020 were 12,592 t U (minus 2 %) below the previous year‘s level (2019: 12,835 t U). As is usual in Europe, deliveries from spot market contracts accounted for only 3 % (EU 2021).

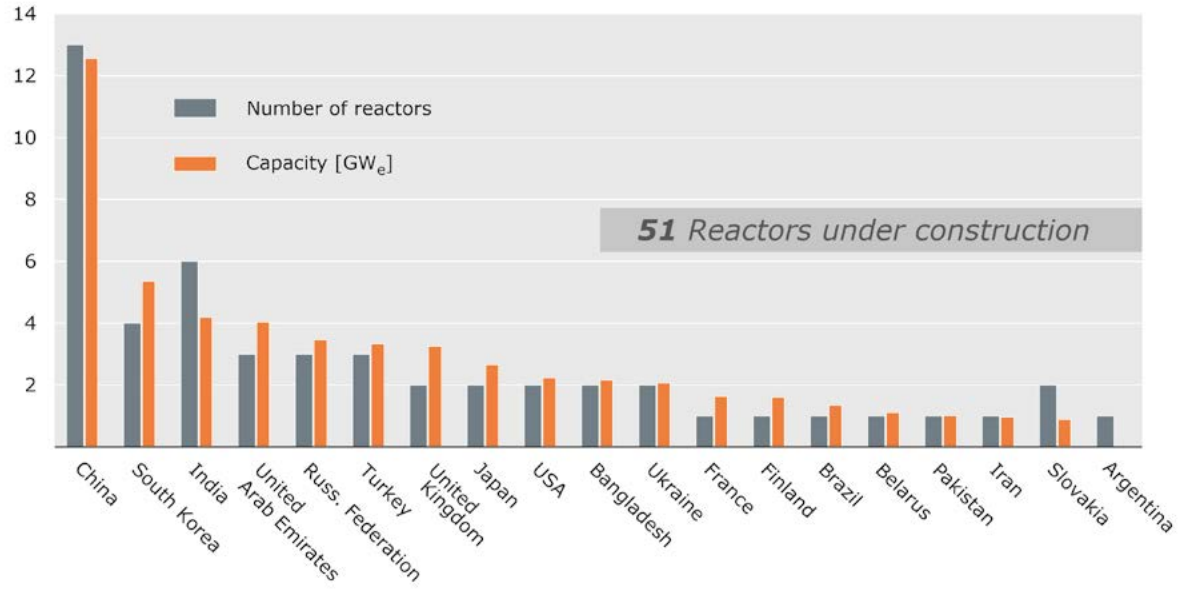


Figure 3-10: Global number and power of nuclear reactors under construction (Status: 2021). The growing energy demand in Asia in particular is expected to result in a higher demand for uranium. Several Asian states are aiming to start using nuclear energy (BGR 2019b). In Europe, too, uranium will endure as an energy resource in the long term, despite the expected decline in demand due to the nuclear phase-out in Germany and Belgium, and the halt to expansion plans in Italy, Spain and Switzerland. Countries such as Finland, France, Romania, Sweden, Slovakia, Slovenia, the Czech Republic, Turkey, Hungary and the United Kingdom rely on nuclear energy as an important part of their national energy supply. Poland plans to build its first nuclear power plant by 2033.

Global uranium resources, although slightly down on the previous year, remain very substantial at 12.3 million tonnes. As in previous years, uranium resource changes are mainly driven by a few countries. As a result of the continuing recession in the uranium market in 2020 (BGR 2019b), uranium resource increases remained low in 2020.

Uranium reserves have also changed only slightly compared to the previous year (minus 1 %; Table A-36 in the Appendix). Global uranium reserves in the cost category < 80 USD/kg U amount to 1.3 million t (2019: 1.3 million t) (Fig. 3-11).

>> *Around 93% of uranium reserves in just ten countries*

Unlike other energy commodities, stocks of uranium (reserves and resources) are subdivided according to extraction costs. According to the definition for uranium reserves, the limit of extraction costs is < 80 USD/kg U (see definitions in the Appendix).

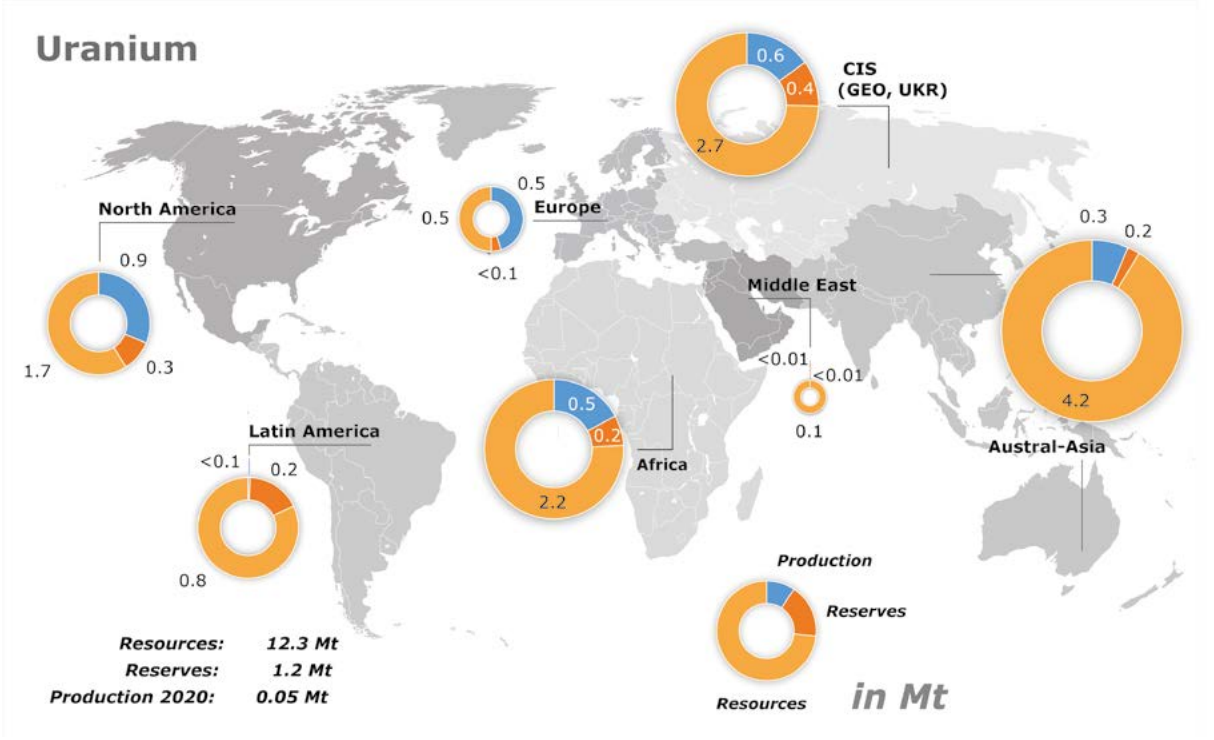


Figure 3-11: Total uranium potential 2020: regional distribution.

Thorium

Thorium is considered a possible alternative to uranium from a scientific point of view. At present, however, thorium is not used for energy production. There are no commercial reactors powered by thorium in operation worldwide. Thorium deposits are nevertheless being recorded and evaluated through the exploration for other resources (uranium, rare earths, phosphate), which has increased in recent years. The content of thorium in the earth‘s crust averages between 6 and 10 g/t, which is about three to four times higher than that of uranium. In 2017, approximately 6.35 Mt of thorium resources were reported.

3.6 Coal

With a share of 27.2 % of global PEC, coal was the second most important energy resource behind crude oil in 2020 (BP 2021). With a share of 35 %, coal accounted for the largest share of power generation around the world (IEA 2021a). Among the fossil fuels, coal has both the highest specific CO_2 emissions and by far the largest global reserves and resources (Table 7).

>> *World coal production declined by around 5 % in 2020*

World coal production decreased in 2020 and amounted to about 7,645 Mt. This corresponds to a reduction of 4.6 % compared to the previous year. Of this, 6,679 Mt (minus 4.2%) was hard coal and the remaining 966 Mt (minus 7.5 %) lignite (Tab. A-20 to A-31 in the Appendix).

Tables A-20 to A-31 in the Appendix provide a summary of country-specific production, consumption, imports and exports as well as reserves and resources of hard coal and lignite.

To improve the comparability of the data,this study only differentiates between lignite and hard coal. Hard coal with an energy content of ≥ 16,500 kJ/kg includes sub-bituminous coal, bituminous coal and anthracite. Hard coals are frequently differentiated in coal trading depending on their use as ither coking coal or steam coal. Because of its relatively high energy content, hard coal is economical to transport and therefore traded worldwide. Lignite on the other hand (energy content < 16,500 kJ/kg) is primarily used in the vicinity of the lignite field and therefore usually used in power plants because of the lower energy and higher water content.

Table 7: Worldwide production and resources of lignite and hard coal in 2020, as well as year-on-year changes

	Lignite		Hard coal	
Production	966 Mt	-7.5 % ↘	6,679 Mt	-4.2 % →
Reserves	320.5 Gt	-1.0 % →	756.2 Gt	+0.3 % →
Resources	3,681 Mt	-0.05 % →	16,189 Gt	-0.03 % →

Hard coal

>> *China produces more than half of global hard coal; EU-28 countries produce 0.9%*

The three largest hard coal producers (Fig. 3-12) in 2020 were China with a share of 53.6 % (3,580 Mt), India (10.7 %) and Indonesia (7.5 %). While China (up 2.1 %) expanded its production in 2020 despite COVID-19, the production of all other TopTen hard coal producing countries declined. Particularly noteworthy are the United States with a decline in production of 25.6 %, and Colombia with 41.5 %. The European Union (EU-28) produced around 58 Mt (around 15 Mt less than in the previous year), 0.9 % of global hard coal.

>> *The export market is dominated by Indonesia and Australia*

At 1,290 Mt, around 19 % of hard coal mined was traded worldwide in 2020, of which 1,191 Mt was seaborne (VdKi 2021). The global trade volume of hard coal thus decreased by 10.7 % compared to the previous year. Indonesia dominated the world hard coal market (Fig. 3-13) with exports amounting to 406.7 Mt (31.5 %), followed by Australia (28.8 %) and the Russian Federation (15.4 %).

>> *Four-fifths of all imports in Asia. EU-28 countries imported about 65 % of their demand*

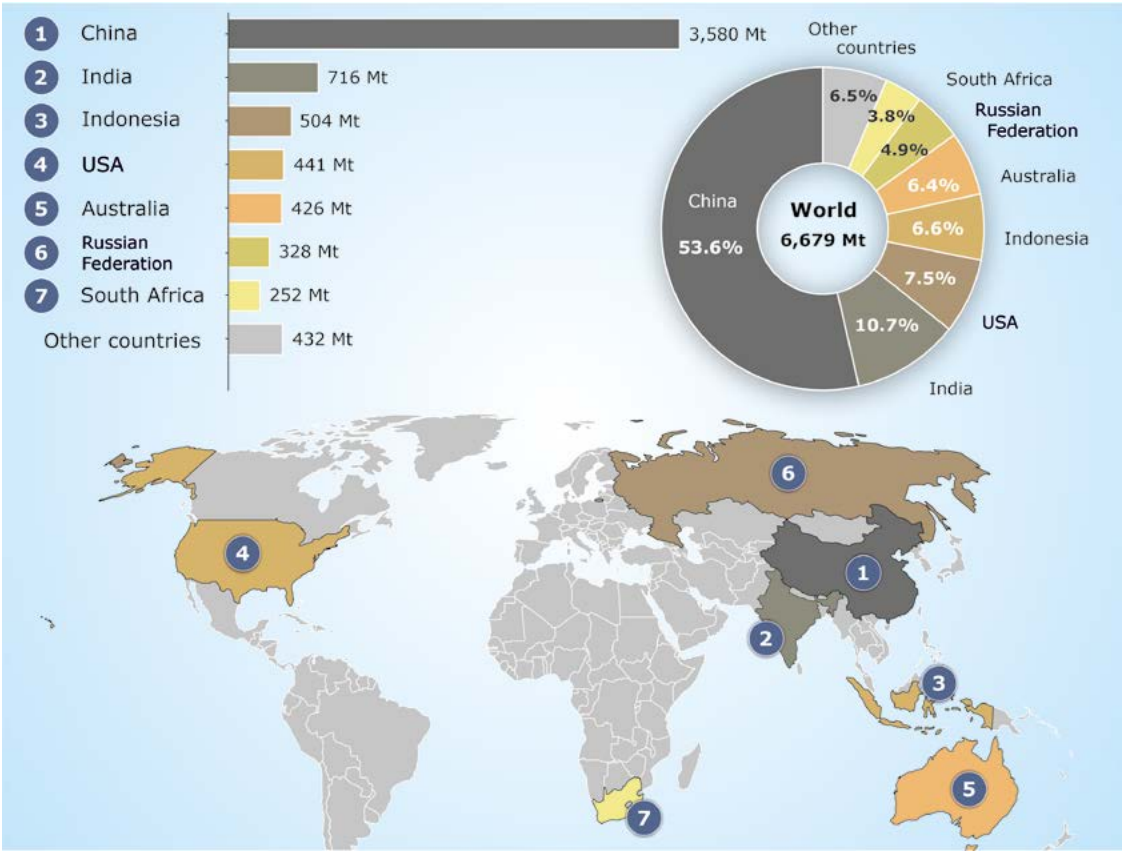


Figure 3-12: The seven largest hard coal producing countries 2020.

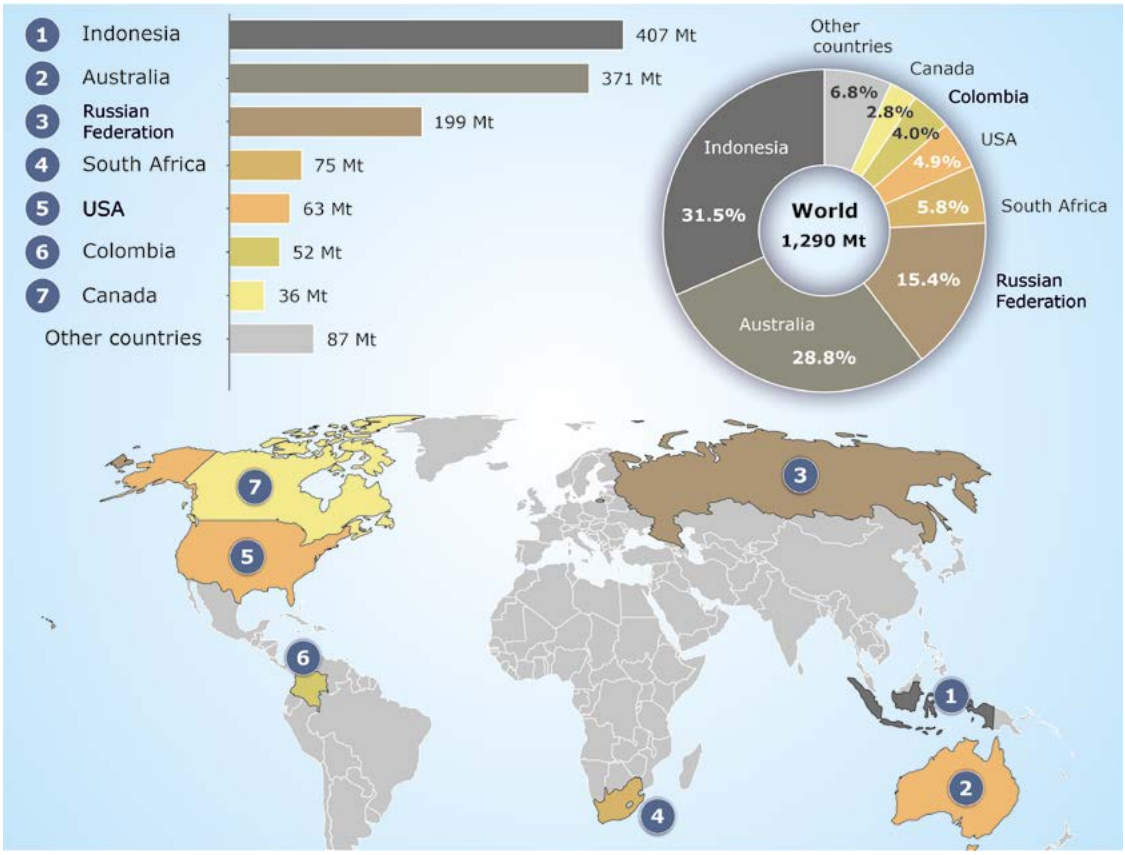


Figure 3-13: The seven largest hard coal exporting countries 2020.

In terms of hard coal imports (Fig. 3-14), Asia dominates the global market with a share of almost 81 % (1,065 Mt). Of the five largest importers, only China slightly increased its imports in 2020 compared to the previous year to 304 Mt (plus 1.4 %). Vietnam in particular recorded strong growth in recent years. While Vietnam was still a net exporter in 2015 with 2.5 Mt of hard coal imports, in 2020 imports already amounted to 54 Mt. With 94.5 Mt – and thus around 39 Mt or 29 % less than in the previous year – in 2020 only slightly more than a fourteenths of global hard coal imports were accounted for by the European Union (EU-28), which thus covered around 65 % of its hard coal demand.

>> *World coal market prices decreased again in 2020*

Northwest European average spot prices for thermal coal (ports of Amsterdam, Rotterdam or Antwerp; cif ARA) decreased by around 13 USD/tce from 71.2 USD/tce in 2019 (down 18 %) to 58.7 USD/tce in 2020. Coking coal prices declined even more than thermal coal prices. Average spot prices for high-quality Australian coking coal fell by 32 % from around USD 186/t in 2019 to around USD 120/t in 2020 (IHS Markit 2021). The background to the coal price development was primarily the COVID-19-related

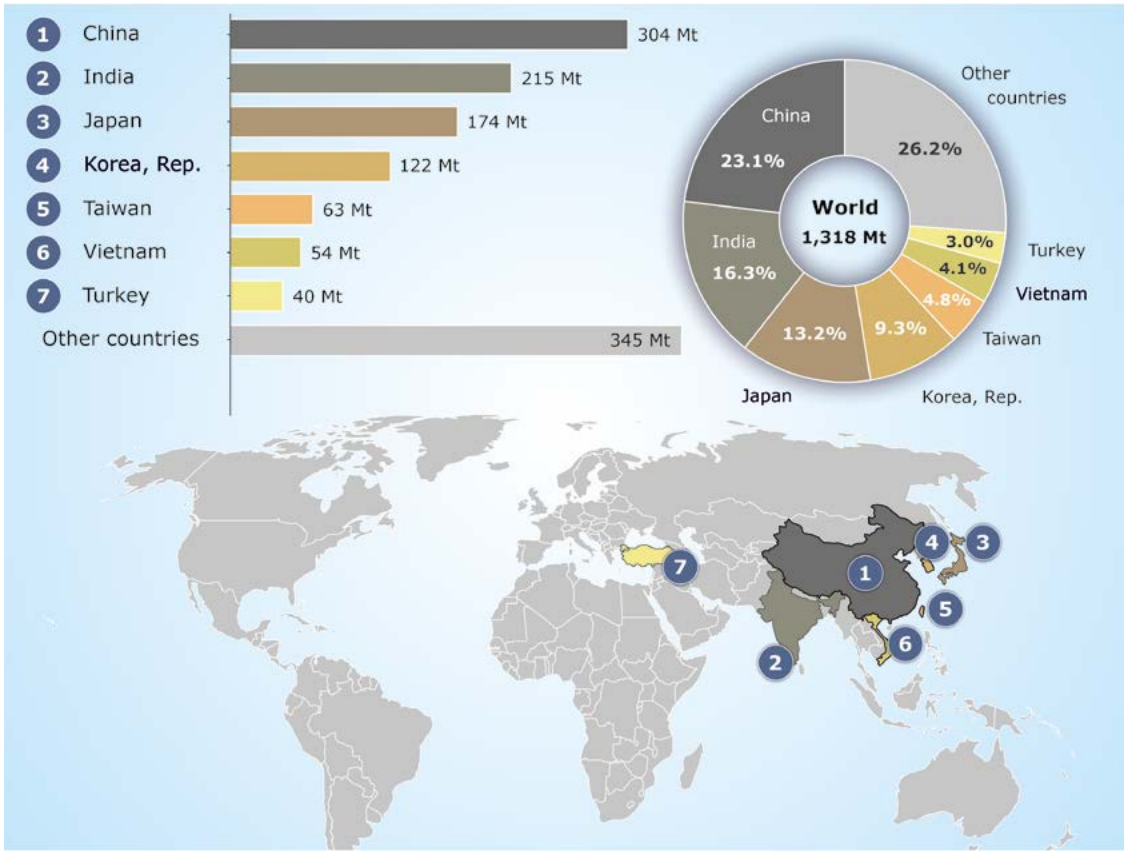


Figure 3-14: The seven largest hard coal importing countries 2020.

reduction in demand. In 2021, especially in the second half of the year, coal and coke prices increased significantly worldwide and reached new all-time highs. In October 2021, Northwest European thermal coal prices rose to more than 200 USD/tce, while high-quality Australian coking coal was priced at more than 400 and coke at more than 600 USD (IHS Markit 2021).

Lignite

Global lignite production in 2020 decreased by 7.5 % year-on-year to 966 Mt. Germany reduced domestic production by 18.2 % year-on-year and, with a share of 11.1% (107 Mt), was the second largest lignite producer after China with 26.9 % (260 Mt).

3.7 Hydrogen

In 2018, around 70 million tonnes (780 billion m^3) of pure hydrogen were consumed worldwide (IEA 2019). In addition, there were about 40 million tonnes (445 billion m^3) of hydrogen in the form of gas mixtures used for the synthesis of chemical base materials (Fig. 3-15).

>> *EU electrolysis capacity to be expanded to 40 GW by 2030*

Currently, pure hydrogen is produced mainly from natural gas and coal without capturing the resulting CO_2. About 6 % of global natural gas production and 2 % of global coal production is used for hydrogen production (IEA 2019). The most important user of coal gasification is China, which in 2018 met an estimated two-thirds of its hydrogen demand via it (TU, K.J. 2020). A research project on lignite gasification with CO_2 capture is currently underway in an Australia-Japan collaboration in the Australian state of Victoria. In Europe, projects for the production of blue hydrogen, whereby CO_2 is separated and stored in the geological subsurface, are located in the United Kingdom and the Netherlands (see „Hydrogen: Fundamentals“ in the Appendix).

>> *Projects planned so far for the production of blue hydrogen in the EU-28 by 2030 in the order of 12 billion m^3/a*

Electrolysis processes play a minor role in the production of hydrogen, with an estimated 1 to 2 % share to date. The current installed electrolysis capacity in the EU-27 is around 0.045 GW as of 2019 (Table A-45 in the Appendix). However, in view of falling production costs of electrolysers and political support for their use, their importance is assumed to increase (European Commission 2020).

>> *Anticipated EU hydrogen demand at around 220 billion m^3 by 2030*

The European Union plans to build 6 GW of electrolysis capacity by 2024 and to expand this to 40 GW by 2030 to produce up to 1 million or 10 million tonnes (11 to 111 billion m^3) of green hydrogen per year, respectively (see „Hydrogen: Fundamentals“ in the Appendix).

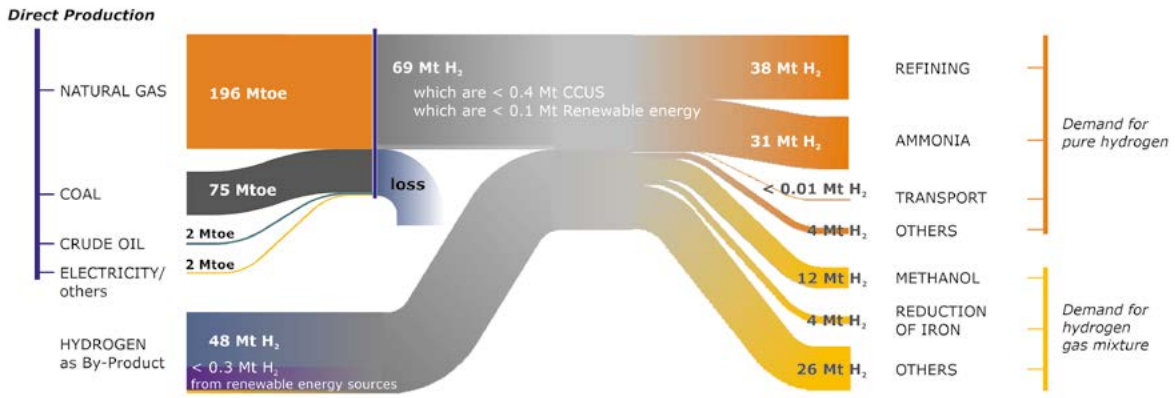


Figure 3-15: Hydrogen value chain (after IEA 2019).

In addition, over 40 GW of electrolysis capacity is to be built in non-EU countries by 2030 to meet the assumed hydrogen demand of up to 20 million tonnes (220 billion m^3) (European Commission 2020). Some European states have already adopted national hydrogen strategies. Other European states are currently working on finalising them. Overall, it is becoming apparent that the 40 GW of electrolysis capacity set as a target by 2030 in the EU hydrogen strategy will also be reflected in the sum of the national hydrogen strategies of the EU states (Fig. 3-16).

The national hydrogen strategies are oriented towards the respective economic conditions and political objectives of the countries. In the United Kingdom and the Netherlands, for example, projects for the production of blue hydrogen are underway in addition to the development of electrolysis capacities for the production of green hydrogen. Both countries are pursuing this path because, in addition to the existing cost advantages of blue hydrogen over electrolysis processes, parts of the existing natural gas import infrastructure or their own natural gas deposits and

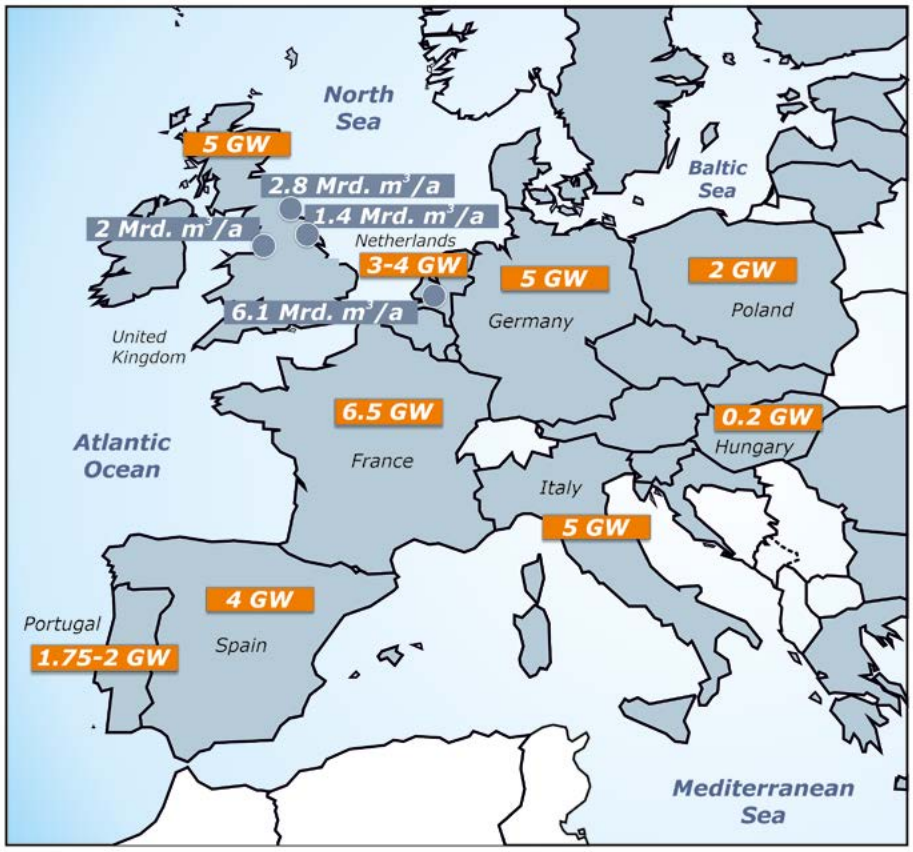


Figure 3-16: Planned electrolysis capacities by 2030 according to national hydrogen strategies of individual EU states and the United Kingdom (orange). In addition, planned hydrogen projects with CO_2 capture (blue hydrogen) and their annual (calculated and preliminary) generation capacities in the EU and the United Kingdom until 2030 (blue).

possibilities for storing the CO_2 in the geological subsurface are available. There are four major projects near the cities of Rotterdam (H-Vision 2019), Liverpool (HyNet 2018), Hull (S&P Global Platts 2020) and Teesside (S&P Global Platts 2021). These projects would have a combined annual production capacity of around 12 billion m³ (1.1 million tonnes) of hydrogen (Figure 3-16).

The future hydrogen demand of the EU member states cannot be realised in the medium term through own production from renewable energies, but requires considerable import. This is estimated at around 10 million tonnes (111 billion m^3) by 2030 (European Commission 2020). The EU is therefore seeking partnerships with countries that have the prerequisites to produce green hydrogen and could export it to the EU. The preconditions include a potential for renewable energies as well as the shortest possible distance to the EU in order to keep costs and emissions low when importing. Countries that fall under these criteria are North African states such as Morocco, but also European states such as Ukraine.

Research projects on turquoise hydrogen (see „Hydrogen: Fundamentals“ in the appendix) are underway in **Germany**, **the Russian Federation**, **the USA** and **Australia**, among others. An expansion of nuclear hydrogen production is expected in the medium term (after 2030) in Europe and other parts of the world (e. g. the USA, the United Kingdom, France and the Russian Federation).

4 References

AGEB – Arbeitsgemeinschaft für Energiebilanzen e.V. (2020): Auswertungstabellen zur Energiebilanz für die Bundesrepublik Deutschland 1990 bis 2019 (Status: September 2020); Berlin.
https://ag-energiebilanzen.de/10-0-Auswertungstabellen.html [accessed on: 06.2021]

– (2021): Energieverbrauch in Deutschland im Jahr 2020. – Jahresbericht. – 46 p.; Berlin, Köln.
https://www.ag-energiebilanzen.de/
[accessed on: 11.2021]

BAFA – Bundesamt für Wirtschaft und Ausfuhrkontrolle (2021a): Entwicklung des deutschen Gasmarktes (monatliche Bilanz 1998-2021, Einfuhr seit 1960); Eschborn.
https://www.bafa.de/SharedDocs/Downloads/DE/Energie/egas_entwicklung_1991.xlsm;jsessionid=8EFE43281024A6A6BD8B8E57335F9366.2_cid371?__blob=publicationFile&v=40
[accessed on: 06.2021]

– (2021b): Entwicklung Grenzübergangspreis ab 1991; Eschborn.
https://www.bafa.de/SharedDocs/Downloads/DE/Energie/egas_aufkommen_export_1991.xlsm;jsessionid=0E5EE0750FEA3639942834573D52B980.2_cid371?__blob=publicationFile&v=85
[accessed on: 08.2021]

– (2021c): Entwicklung der Rohöleinfuhr (1991-2020); Eschborn.
https://www.bafa.de/SharedDocs/Downloads/DE/Energie/roel_entwicklung_rohoeleinfuhr_1991_2020.xls;jsessionid=9F785C306798F3FEC5F866673C7F07BC.2_cid371?__blob=publicationFile&v=19
[accessed on: 06.2021]

– (2021d): Amtliche Mineralöldaten Dezember 2020; Eschborn.
https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2020_12.html [accessed on: 06.2021]

– (2021e): RohölINFO Dezember 2020 (Rohölimporte); Eschborn.
URL: https://www.bafa.de/SharedDocs/Kurzmeldungen/DE/Energie/Rohoel/2020_12_rohloelinfo.html
[accessed on: 06.2021]

Baker Hughes (2021): Worldwide Rig Counts – Current & Historical Data.
https://rigcount.bakerhughes.com/intl-rig-count/ [accessed on: 11.2021]

BfE – Bundesamt für kerntechnische Entsorgungssicherheit (2019): Stilllegung kerntechnischer Anlagen in Europa, Stand: August 2019, Schriften, BfE-KE-05/19; urn:nbn:de:0221-2019111120204. – 57 p.; Salzgitter.
https://doris.bfs.de/jspui/bitstream/urn:nbn:de:0221-2019111120204/3/BfE-KE-05-19_barrierearm.pdf [accessed on: 11.2021]

BGR – Bundesanstalt für Geowissenschaften und Rohstoffe (2016): Schieferöl und Schiefergas in Deutschland – Potenziale und Umweltaspekte. – 197 p.; Hannover.
https://www.bgr.bund.de/DE/Themen/Energie/Downloads/Abschlussbericht_13MB_Schieferoelgaspotenzial_Deutschland_2016.pdf [accessed on: 08.2021]

– (2019a): Deutschland – Rohstoffsituation 2018 – 144 p.; Hannover.
https://www.bgr.bund.de/DE/Themen/Min_rohstoffe/Downloads/rohsit-2018.pdf?__blob=publicationFile&v=5. [accessed on: 11.2021]

– (2019b): BGR Energiestudie 2018 – Daten und Entwicklungen der deutschen und globalen Energieversorgung (22). – 178 p.; Hannover.
https://www.bgr.bund.de/DE/Themen/Energie/Downloads/energiestudie_2018.pdf
[accessed on: 11.2019]

– (2020): BGR Energiedaten 2019 – Daten zu Entwicklungen der deutschen und globalen Energieversorgung; Hannover.
DOI:10.25928/es-2019-tab [accessed on: 11.2021]

–BP (2021): Statistical Review of World Energy – 69 p.; London.
https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf. [accessed on: 11.2021]

BMJV – Bundesministerium der Justiz und für Verbraucherschutz (2019): Gesetz über die Bevorratung mit Erdöl und Erdölerzeugnissen (Erdölbevorratungsgesetz – ErdölBevG); Berlin.
https://www.gesetze-im-internet.de/erd_lbevg_2012/BJNR007410012.html [accessed on: 11.2019]

BMWi – Bundesministerium für Wirtschaft und Energie (2017): Erneuerbare-Energien-Gesetz – EEG 2017
https://www.bmwi.de/Redaktion/DE/Gesetze/Energie/EEG.html [accessed on: 11.2019]

– (2019): Unsere Energiewende: sicher, sauber, bezahlbar; Berlin.
https://www.bmwi.de/Redaktion/DE/Dossier/energiewende.html [accessed on: 11.2019]

– (2020): Die Nationale Wasserstoffstrategie. – 32 p.; Berlin.
https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/die-nationale-wasserstoffstrategie.pdf?__blob=publicationFile&v=20. [accessed on: 11.2021]

– (2021): Pressemitteilung: Wir wollen bei Wasserstofftechnologien Nummer 1 in der Welt werden.
https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/05/20210528-bmwi-und-bmvi-bringen-wasserstoff-grossprojekte-auf-den-weg.html
[accessed on: 11.2021]

Bundesnetzagentur (2021): Quartalsbericht Netz- und Systemsicherheit – Gesamtes Jahr 2020. – 27 p.; Bonn.
https://www.bundesnetzagentur.de/SharedDocs/Mediathek/Berichte/2020/Quartalszahlen_Gesamtjahr_2020.pdf?__blob=publicationFile&v=3
[accessed on: 11.2021]

Bundesnetzagentur/Bundeskartellamt (2021): Monitoringbericht 2020. – 510 p.; Bonn.
https://www.bundesnetzagentur.de/SharedDocs/Mediathek/Monitoringberichte/Monitoringbericht_Energie2020.pdf?__blob=publicationFile&v=8
[accessed on: 11.2021]

BVEG – Bundesverband Erdgas, Erdöl und Geoenergie e. V. (2021): Die E&P-Industrie in Zahlen. Statistischer Bericht 2020. – 32 p.; Hannover.
https://www.bveg.de/content/download/15664/181302/file/BVEG%20Statistischer%20Bericht%202020.pdf. [accessed on: 11.2021]

DEBRIV – Deutscher Braunkohlen-Industrie-Verein e.V. (2021): Braunkohle in Deutschland – Daten und Fakten 2020.
https://braunkohle.de/wp-content/uploads/2019/03/DEBRIV_Statistikflyer-de_105x210mm_Wickelfalz_20210325.pdf. [accessed on: 11.2021]

DESTATIS – Statistisches Bundesamt (2021a): Gewinnung, Netzeinspeisung, Eigenverbrauch, Speicherstand von Gas: Deutschland, Monate (43321-0001); Wiesbaden.
https://www-genesis.destatis.de/genesis//online?operation=table&code=43321-0001&bypass=true&levelindex=0&levelid=1634580435130#abreadcrumb. [accessed on: 11.2021]

– (2021b): Presse KORREKTUR: Über zwei Drittel der im Jahr 2020 gebauten Wohngebäude heizen mit erneuerbaren Energien, Pressemitteilung Nr. 296 vom 24. Juni 2021,
https://www.destatis.de/DE/Presse/Pressemitteilungen/2021/06/PD21_296_31121.html [accessed on: 10.2021]

EBV – Erdölbevorratungsverband (2008): Mineralölpflichtbevorratung in der Bundesrepublik Deutschland. – 6 p.; Hamburg.
https://www.ebv-oil.org/cms/pdf/pflicht2008.pdf [accessed on 11.2021]

– (2020): Geschäftsbericht einschl. Jahresabschluss 2019/2020. – 75 p.; Hamburg.
https://www.ebv-oil.org/cms/pdf/EBV-GB_2019_2020.pdf. [accessed on: 11.2021]

EIA – U.S. Energy Information Administration (2021a): Cushing, OK WTI Spot Price FOB, Washington D.C.
https://www.eia.gov/dnav/pet/hist/rwtcD.htm [accessed on: 11.2021]

– (2021b): Short-Term Energy Outlook, Oktober 2021; Washington D.C, USA.
https://www.eia.gov/outlooks/steo/report/global_oil.php. [accessed on: 11.2021]

– (2021c): What drives crude oil prices?: Supply OPEC, Oktober 2021, Washington D.C.
https://www.eia.gov/finance/markets/crudeoil/supply-opec.php. [accessed on: 11.2021]

– (2021d): Drilling Productivity Report, Oktober 2021, Washington D.C.
https://www.eia.gov/petroleum/drilling/pdf/dpr-full.pdf. [accessed on: 11.2021]

Europäische Kommission (2019): Brief on biomass for energy in the European Union, Publications Office, Join Research Centre. – 8 p. ISBN 978-92-79-77234-4, JRC 109354. DOI:10.2760/49052
https://op.europa.eu/en/publication-detail/-/publication/7931acc2-1ec5-11e9-8d04-01aa75ed71a1/language-en [accessed on: 11.2021]

– (2020): Eine Wasserstoffstrategie für ein klimaneutrales Europa. – 29 p.; Brüssel, Belgium.
https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:52020DC0301&from=EN. [accessed on: 11.2021]

EU – European Union (2021): 60 Years of ESA (Euratom Supply Agency) – Annual Report 2020. – 85 p.; Luxemburg.
https://ec.europa.eu/euratom/ar/last.pdf [accessed on: 08.2021]

Forschungsnetzwerke Energie (2021): Forschungsnetzwerk Wasserstoff
https://www.forschungsnetzwerke-energie.de/wasserstoff. [accessed on: 11.2021]

GIIGNL (2021): The LNG industry – GIIGNL ANNUAL REPORT 2021.– 35 p.; Neuilly-sur-Seine; France.
https://giignl.org/wp-content/uploads/2021/11/GIIGNL_Annual_Report_November2021.pdf. [accessed on: 11.2021]

Heinemann, N., Alcalde, J., Miocic, J., Hangx, S., Kallmeyer, J., Ostertag-Henning, C., Hassanpouryouzband, A., Thaysen, E., Strobel, G., Schmidt-Hattenberger, C., Edlmann, K., Wilkinson, Bentham, M., Haszeldine, R. Carbonell, R. & Rudloff, A. (2021): Enabling large-scale hydrogen storage in porous media – the scientific challenges. – In: Energy & Environmental Science, 14: 853-864
DOI: 10.1039/d0ee03536j. [accessed on: 11.2021]

H-Vision (2019): Feasibility study report – Blue hydrogen as accelerator and pioneer for energy transition in the industry. – 90 p.; Rotterdam, Netherlands.
https://publications.tno.nl/publication/34634138/pnAaJD/TNO-2019-hydrogen.pdf [accessed on: 11.2021]

HyNet (2018): HyNet North West: From Vision to Reality- – 40 p.
https://hynet.co.uk/wp-content/uploads/2018/05/14368_CADENT_PROJECT_REPORT_AMENDED_v22105.pdf
[accessed on: 11.2021]

IAEA – International Atomic Energy Agency (2020): Energy, Electricity and Nuclear Power Estimates for the period up to 2050, 2020 edition. – 137 p.; Wien, Austria..
https://www.iaea.org/publications/14786/energy-electricity-and-nuclear-power-estimates-for-the-period-up-to-2050 [accessed on: 09.2021]

IEA – International Energy Agency (2019): The Future of Hydrogen. – 203 p.; Paris, France.
https://www.iea.org/reports/the-future-of-hydrogen
[accessed on: 11.2021]

– (2020): IEA Hydrogen Projects Database; Paris, France.
https://www.iea.org/data-and-statistics/data-product/hydrogen-projects-database [accessed on: 11.2021]

– (2021a): World Energy Outlook 2021. – 383 p.; Paris, France
https://iea.blob.core.windows.net/assets/4ed140c1-c3f3-4fd9-acae-789a4e14a23c/WorldEnergyOutlook2021.pdf. [accessed on: 11.2021]

– (2021): Net Zero by 2050: A Roadmap for the Global Energy Sector; Paris, France.
https://www.iea.org/events/net-zero-by-2050-a-roadmap-for-the-global-energy-system
[accessed on: 11.2021]

– (2021b): Renewables Information 2021.
https://www.iea.org/data-and-statistics/data-product/renewables-information [accessed on: 09.2021]

– (2021): IHS Markit (2021): McCloskey Coal Report. – 14-tägiger Newsletter.
https://ihsmarkit.com/btp/mccloskey.html.
[accessed on: 11.2021]

IRENA –International Renewable Energy Agency (2021): Renewable Capacity Statistics 2021. – 64 p.; Abu Dhabi; United Arab Emirates
https://www.irena.org/publications/2021/March/Renewable-Capacity-Statistics-2021
[accessed on: 09.2021]

– (2021): Renewable Energy Statistics 2021. – 460 p.; Abu Dhabi; United Arab Emirates
https://irena.org/publications/2021/Aug/Renewable-energy-statistics-2021 [accessed on: 11.2021]

Koalitionsvertrag zwischen SPD, Bündnis 90/die Grünen und FDP (2021): Mehr Fortschritt wagen – Bündnis für Freiheit, Gerechtigkeit und Nachhaltigkeit. Koalitionsvertrag 2021 – 2025 zwischen der Sozialdemokratischen Partei Deutschlands (SPD), BÜNDNIS 90 / DIE GRÜNEN und den Freien Demokraten (FDP). – 177 p.
https://www.spd.de/fileadmin/Dokumente/Koalitionsvertrag/Koalitionsvertrag_2021-2025.pdf
[accessed on: 11.2021]

KBA – Kraftfahrt-Bundesamt (2021): Jahresbilanz des Fahrzeugbestandes am 1. Januar 2021; Flensburg.
https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/Jahrebilanz_Bestand/fz_b_jahresbilanz_node.html
[accessed on: 11.2021]

LBEG – Landesamt für Bergbau, Energie und Geologie (2021): Erdöl und Erdgas in der Bundesrepublik Deutschland 2020. – 49 p.; Hannover.
https://www.lbeg.niedersachsen.de/download/169420
[accessed on: 06.2021]

LIAG – Leibnitz Institut für Angewandte Geophysik (2021): GeotIS Geothermal Information System; Hannover,
https://www.geotis.de [accessed on: 10.2021]

Maaßen, U. & Schiffer, H.-W. (2021): The German lignite industry in 2020 / Die deutsche Braunkohlenindustrie im Jahr 2020. – In: World of Mining – surface & underground, 73(3): 141-153; Clausthal-Zellerfeld.
https://braunkohle.de/wp-content/uploads/2020/06/WoM-Maassen-Schiffer-2020.pdf.
[accessed on: 11.2021}

Nationaler Wasserstoffrat (2021): Wasserstoff Aktionsplan Deutschland 2021-2025. – 56 p.; Berlin.
https://www.wasserstoffrat.de/fileadmin/wasserstoffrat/media/Dokumente/NWR_Aktionsplan_Wasserstoff_2021-2025_WEB-Bf.pdf
[accessed on: 11.2021]

OECD-NEA/IAEA (2020): Uranium 2020: Resources, Production and Demand, NEA No. 7551. – 484 p.; OECD Publishing; Paris, France.
http://www.oecd.org/publications/uranium-20725310.htm [accessed on: 09.2021]

OPEC – Organization of the Petroleum Exporting Countries (2020): The 10th (Extraordinary) OPEC and non-OPEC Ministerial Meeting concludes. Videoconference 12 Apr 2020; Wien, Austria.
https://www.opec.org/opec_web/en/press_room/5891.htm [accessed on: 11.2021]

REN21 (2021): Renewables 2021 – Global Status Report. – 371 p.; Paris, France.
https://www.ren21.net/wp-content/uploads/2019/05/GSR2021_Full_Report.pdf [accessed on: 09.2021]

Rystad Energy (2021): Press Release: Upstream spending, cut by $285 billion in two years, will struggle to recover to pre-pandemic levels (12 May 2021).
https://www.rystadenergy.com/newsevents/news/press-releases/upstream-spending-cut-by-$285-billion-in-two-years-will-struggle-to-recover-to-pre-pandemic-levels/. [accessed on: 11.2021]

ShaleProfile (2021): US – update through June 2021, Well Quality / Year of first flow,
https://shaleprofile.com/blog/us/us-update-through-june-2021/. [accessed on: 11.2021]

S&P Global Platts (2020): Norway‘s Equinor favors blue hydrogen developments over green: CFO.
https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/072420-norways-equinor-favors-blue-hydrogen-developments-over-green-cfo.
(accessed on: 11.2021]

– (2021): BP studies building UK‘s biggest blue hydrogen plant on Teesside.
https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/031821-bp-studies-building-uks-biggest-blue-hydrogen-plant-on-teesside
[accessed on: 11.2021]

SdK – Statistik der Kohlenwirtschaft e.V. (2021): Datenangebot Statistik der Kohlenwirtschaft.
https://kohlenstatistik.de/downloads/.
[accessed on: 11.2021]

Tu, Kevin Jianjun (2020): Prospects of a hydrogen economy with chinese characteristics, IFRI – Institut français des relations internationals. – 64 p.; Paris, France.
https://www.ifri.org/sites/default/files/atoms/files/tu_china_hydrogen_economy_2020_1.pdf
[accessed on: 11.2021]

UBA – Umweltbundesamt (2021): Erneuerbare Energien in Deutschland – Daten zur Entwicklung im Jahr 2020. – 28 p.
https://www.umweltbundesamt.de/publikationen/erneuerbare-energien-in-deutschland-2020
[accessed on: 11.2021]

VDKI – Verein der Kohlenimporteure e.V. (2021): Jahresbericht 2021. Fakten und Trends 2020/21. – 135 p.; Berlin.
https://www.kohlenimporteure.de/publikationen/jahresbericht-2021.html?file=files/user_upload/jahresberichte/Jahresbericht_2021.pdf.
[accessed on: 11.2021]

UNFCCC (2015): Paris Agreement. – 27 p.
https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf
[accessed on: 09.2021]

– (2019): Status of ratification of the convention.
https://unfccc.int/process/the-paris-agreement/status-of-ratification [accessed on: 09.2021]

– (2021): Climate Ambition Alliance: Net Zero 2050.
https://climateaction.unfccc.int/views/cooperative-initiative-details.html?id=94 [accessed on: 09.2021]

U.S. Bureau of Labor Statistics (2021): Consumer Price Index for All Urban Consumers: All Items in U.S. City Average (CPIAUCSL), retrieved from FRED, Federal Reserve Bank of St. Louis.
https://fred.stlouisfed.org/series/CPIAUCSL.
[accessed on: 11.2021]

VDA – Verband der Automobilindustrie (2021): Erstes globales E-Mobility-Ranking.
https://www.vda.de/de/presse/Pressemeldungen/210423-Erstes-globales-E-Mobility-Ranking [accessed on: 09.2021]

VDKI – Verein der Kohlenimporteure e.V. (2021): Jahresbericht 2021. Fakten und Trends 2020/21. – 135 p., Berlin.
https://www.kohlenimporteure.de/publikationen/jahresbericht-2021.html?file=files/user_upload/jahresberichte/Jahresbericht_2021.pdf.
[accessed on: 11.2021]

Warnecke, M. & Röhling, S. (2021): Untertägige Speicherung von Wasserstoff – Status quo. – In: Zeitschrift der Deutschen Gesellschaft für Geowissenschaften 172(4), p. 641-659
DOI: 10.1127/zdgg/2021/0295

WNA – World Nuclear Association (2021a): World Uranium Mining Production
https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx [accessed on: 09.2021]

– (2021b): Nuclear Power in the World Today
http://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx [accessed on: 09.2021]

– (2021c): Decommissioning Nuclear Facilities.
http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Nuclear-Wastes/Decommissioning-Nuclear-Facilities/
[accessed on: 08.2021]

Wietschel, M., Zheng, L., Arens, M., Hebling, C., Ranzmeyer, O., Schaadt, A., Hank, C., Sternberg, A., Herkel, S., Kost, C., Ragwitz, M., Herrmann, U., Pfluger, B. (2021): Metastudie Wasserstoff – Auswertung von Energiesystemstudien. Studie im Auftrag des Nationalen Wasserstoffrats. – 87 p.; Karlsruhe, Freiburg, Cottbus.
https://www.wasserstoffrat.de/fileadmin/wasserstoffrat/media/Dokumente/Metastudie_Wasserstoff-Abschlussbericht.pdf [accessed on: 11.2021]

5 Appendix

- Tables / Figures
- Sources
- Hydrogen: Fundamentals
- Glossary / List of abbreviations
- Definitions
- Country groups of the BGR energy study
- Ecconomic country groupings
- Units
- Conversion factors

Table A-1: Reserves of non-renewable fuels 2020: Regional distribution [EJ]

Region	Crude oil		Natural gas		Coal		Uranium	Total	Share [%]
	conven-tional	unconventi-onal	conven-tional [1]	unconventi-onal	Hard coal	Lignite			
Europe	75	7	85	< 0.5	710	675	19	1,571	3.8
CIS (+ GEO, UKR)	838	–	2,585	2	3,333	1,350	222	8,331	20.3
Africa	712	–	617	–	347	1	107	1,784	4.3
Middle East	4,726	–	3,065	–	30	–	–	7,821	19.0
Austral-Asia	261	–	560	54	8,537	1,172	50	10,634	25.8
North America	285	1,214	210	369	5,634	381	136	8,230	20.0
Latin America	379	1,751	284	–	223	43	88	2,768	6.7
World	7,276	2,973	7,406	426	18,814	3,622	622	41,139	100.0
OECD	378	1,222	359	402	8,505	1,714	156	12,734	31.0
EU-28	28	7	24	< 0.5	682	475	19	1,235	3.0
OPEC	5,382	1,751	2,693	–	59	1	–	9,885	24.0

[1] including tight gas

Table A-2: Resources of non-renewable energy resources 2020: regional distribution [EJ]

Region	Crude oil		Natural gas		Coal		Uranium	Thorium	Total	Share [%]
	conven-tional	unconventi-onal	conven-tional	unconventi-onal[1]	Hard coal	Lignite				
Europe	198	209	302	538	12,569	2,969	257	286	17,326	3.5
CIS (+ GEO, UKR)	3,025	1,245	4,962	1,572	32,719	8,003	1,340	103	52,968	10.7
Africa	1,171	443	1,443	1,611	7,687	4	1,112	264	13,734	2.8
Middle East	1,276	254	1,773	521	1,008	–	60	–	4,892	1.0
Austral-Asia	1,025	1,254	1,633	3,020	176,141	12,447	2,078	771	198,368	39.9
North America	1,082	6,576	1,547	2,635	166,914	17,549	862	427	197,592	39.8
Latin America	1,034	2,159	814	1,570	686	173	422	466	7,323	1.5
World	8,810	12,139	12,473	11,467	401,549[2]	41,145	6,130	3,178[3]	496,892	100.0
OECD	1,359	7,398	2,108	4,097	220,940	24,032	2,244	1,010	263,188	53.0
EU-28	91	162	191	494	12,530	2,684	250	55	16,457	3.3
OPEC	1,848	2,160	1,991	1,717	1,220	3	21	150	9,110	1.8

[1] without natural gas in gas hydrates and aquifer gas (7,904 EJ)

[2] includin hard coal in the Antarktic für Hartkohle (3,825 EJ)

[3] including Thorium resources without country allocation (863 EJ)

Table A-3: Production of non-renewable energy resources 2020: regional distribution [EJ]

Region	Crude oil	Natural gas	Hard coal	Lignite	Uranium	Total	Share [%]
Europe	7.3	7.7	1.6	3.5	< 0.05	20.1	3.9
CIS (+ GEO, UKR)	27.2	33.8	11.4	1.2	13.1	86.7	16.6
Africa	13.7	9.3	6.3	< 0.05	4.3	33.6	6.5
Middle East	53.5	26.0	< 0.05	–	< 0.05	79.5	15.3
Austral-Asia	14.5	25.8	129.5	4.2	4.3	178.2	34.2
North America	45.7	43.2	12.0	0.6	1.9	103.4	19.8
Latin America	12.1	6.0	1.4	< 0.05	< 0.05	19.6	3.8
World	174.0	151.8	162.3	9.5	23.7	521.2	100.0
OECD	55.5	57.3	26.3	3.5	5.1	147.7	28.3
EU-28	3.0	3.5	1.6	2.3	< 0.05	10.3	2.0
OPEC	59.8	23.5	0.1	–	< 0.05	83.3	16.0

Table A-4: Consumption of non-renewable energy resources 2020: regional distribution [EJ]

Region	Crude oil	Natural gas	Hard coal	Lignite	Uranium	Total	Share [%]
Europe	24.8	20.0	5.0	3.5	8.8	62.1	11.6
CIS (+ GEO, UKR)	8.2	24.8	7.0	1.2	4.2	45.3	8.5
Africa	8.0	6.0	4.7	< 0.05	0.1	18.9	3.5
Middle East	15.7	20.9	0.3	–	0.5	37.5	7.0
Austral-Asia	64.3	32.1	134.8	4.2	10.2	245.5	46.0
North America	45.1	40.3	11.2	0.6	10.0	107.2	20.1
Latin America	10.7	5.4	0.9	< 0.05	0.3	17.3	3.2
World	176.9	149.6	163.8	9.5	34.1	533.9	100.0
OECD	82.7	68.4	25.4	3.5	22.3	202.3	37.9
EU-28	21.7	17.7	3.9	2.3	8.6	54.2	10.1
OPEC	16.2	20.5	0.1	–	0.5	37.3	7.0

– no reserves, resources, production or consumption

Table A-5: Germany: Supply of crude oil 2020 [kt]

Rank	Country / Region	[kt/a]	Share [%] country	Share [%] cumulative
1	Russian Federation	28,159	33.9	33.9
2	United Kingdom	9,629	11.6	45.5
3	USA	9,371	11.3	56.8
4	Norway	8,164	9.8	66.6
5	Kazakhstan	7,427	8.9	75.6
6	Nigeria	5,182	6.2	81.8
	other countries [1]	15,117	18.2	100.0
	World	83,049	100.0	

Source: BAFA (2021)
Dates for 2020 are partly preliminary

Table A-6: Germany: Origin of consumed natural gas 2019 / 2020 [TWh]

Origin	2019	2020	Changes 2019/ 2020 TWh	Changes 2019/ 2020 [%]
Gas production (incl. associated gas)	55.8	47.6	-8.2	-14.7
Associated gas production	0.3	0.4	0.1	29.3
Natural gas feed-in	56.6	48.5	-8.1	-14.4
Bio gas feed-in	1.9	1.8	-0.1	-7.4
Import	1,712.1	1,684.9	-27.2	-1.6
Export	736.6	826.0	89.4	12.1
Energy industrie's own use	9.8	6.1	-3.7	-38.0
Storage change	-52.6	56.0	108.6	-206.5
Consumption	970.9	958.3	-12.6	-1.3

Source:: DESTATIS 2021

Table A-7: Germany: Imports of hard coal and hard coal products by supplying countries 2016 to 2020 [kt]

Country / Group	2016	2017	2018	2019	2020	Changes 2019 / 2020	[%]
Australia	6,608	5,635	5,195	4,771	3,906	-865	-18.1
Canada	1,487	1,523	1,586	1,252	1,266	14	1.1
Colombia	10,787	6,511	3,886	1,828	1,921	93	5.1
Poland	3,706	2,678	1,639	1,401	1,197	-204	-14.6
CIS (+ GEO, UKR)	17,948	19,810	19,254	19,360	14,457	-4,903	-25.3
United States	9,547	9,142	9,958	8,111	5,838	-2,273	-28.0
total	57,181	51,414	46,965	42,237	31,815	-10,422	-24.7
hard coal	55,086	49,039	44,733	40,278	30,179	-10,099	-25.1
coke	1,958	2,261	2,124	1,886	1,569	-317	-16.8
briquets	137	114	108	73	67	-6	-8.2

Source: VDKI Annual Report 2021

Table A-8: Crude oil 2020 [Mt]

	Country / Region	Production	Cum. production	Reserves	Resources	EUR	Remaining potential
EUROPE	Albania	0.7	63	20	56	140	76
	Austria	0.5	128	5	10	143	15
	Bosnia & Herzegovina	–	–	–	10	10	10
	Bulgaria	0.2	11	2	34	47	36
	Croatia	0.7	108	10	16	134	26
	Cyprus	–	–	–	35	35	35
	Czechia	0.1	15	1	27	44	29
	Denmark	3.5	383	57	187	627	244
	Estonia	1.2	13	172	455	640	627
	Finland	–	7	–	–	7	–
	France	0.6	131	8	801	941	809
	Germany	1.9	315	18	240	573	258
	Greece	0.2	18	1	35	54	36
	Hungary	1.6	109	2	16	127	18
	Ireland	–	–	–	245	245	245
	Italy	5.4	219	80	1,540	1,839	1,620
	Lithuania	0.2	6	2	60	67	62
	Malta	–	–	–	5	5	5
	Netherlands	1.8	159	19	455	632	474
	Norway	99.7	4,202	1,057	2,415	7,674	3,472
	Poland	0.9	69	12	255	336	267
	Romania	3.5	794	82	200	1,076	282
	Serbia	0.9	52	11	220	282	231
	Slovakia	0.2	5	1	5	11	6
	Spain	< 0.05	39	20	43	102	63
	Sweden	–	–	–	112	112	112
	Turkey	3.3	163	50	980	1,193	1,030
	United Kingdom	48.5	3,913	340	1,263	5,516	1,603
CIS (+ GEO, UKR)	Armenia	–	–	–	6	6	6
	Azerbaijan	35.1	2,079	952	1,245	4,276	2,197
	Belarus	1.7	149	27	158	333	185
	Georgia	< 0.05	24	5	51	79	55
	Kazakhstan	86.1	2,216	4,082	12,933	19,231	17,015
	Kyrgyzstan	0.1	12	5	10	27	15

continuation of table A-8
[Mt]

	Country / Region	Production	Cum. production	Reserves	Resources	EUR	Remaining potential
CIS (+ GEO, UKR)	Moldova, Republic	–	–	–	10	10	10
	Russian Federation	512.8	26,002	14,767	84,799	125,567	99,566
	Tajikistan	< 0.05	8	2	60	69	62
	Turkmenistan	10.3	620	82	1,700	2,402	1,782
	Ukraine	2.6	380	54	377	811	431
	Uzbekistan	2.6	215	81	800	1,096	881
AFRICA	Algeria	57.6	3,417	1,660	1,483	6,561	3,143
	Angola	64.5	2,024	1,050	5,095	8,170	6,145
	Benin	–	4	1	70	75	71
	Cameroon	3.3	210	27	350	587	377
	Chad	6.6	106	216	2,365	2,687	2,581
	Congo, DR	1.1	52	27	1,980	2,059	2,007
	Congo, Rep.	15.8	460	395	519	1,373	913
	Côte d'Ivoire	1.5	39	14	300	353	314
	Egypt	30.0	1,819	428	2,280	4,527	2,708
	Equatorial Guinea	7.5	282	149	250	681	399
	Eritrea	–	–	–	15	15	15
	Ethiopia	–	–	–	60	60	60
	Gabon	10.4	613	272	1,400	2,285	1,672
	Gambia	–	–	–	20	20	20
	Ghana	9.1	66	90	210	365	300
	Guinea	–	–	–	150	150	150
	Guinea-Bissau	–	–	–	40	40	40
	Kenya	–	–	< 0.5	300	300	300
	Liberia	–	–	–	160	160	160
	Libya	18.3	4,014	6,580	4,750	15,344	11,330
	Madagascar	–	n. s.	n. s.	2,131	2,131	2,131
	Mali	–	–	–	128	128	128
	Mauritania	–	8	3	184	195	187
	Morocco	–	2	< 0.5	2,607	2,609	2,607
	Mozambique	n. s.	n. s.	–	2,300	2,300	2,300
	Namibia	–	–	–	300	300	300
	Niger	0.8	n. s.	20	30	50	50

continuation of table A-8
[Mt]

	Country / Region	Production	Cum. production	Reserves	Resources	EUR	Remaining potential
AFRICA	Nigeria	86.9	5,057	5,019	5,378	15,454	10,397
	São Tomé and Príncipe	–	–	–	180	180	180
	Senegal	–	–	–	136	136	136
	Seychelles	–	–	–	470	470	470
	Sierra Leone	–	–	–	260	260	260
	Somalia	–	–	–	300	300	300
	South Africa	0.1	17	2	502	521	504
	South Sudan	8.4	–	472	365	837	837
	Sudan	4.2	–	202	365	567	567
	Sudan & South Sudan	12.6	210	674	730	1,614	1,404
	Tanzania	–	–	–	500	500	500
	Togo	–	–	–	70	70	70
	Tunisia	1.7	221	55	300	576	355
	Uganda	–	–	340	300	640	640
	Zimbabwe	–	–	–	10	10	10
MIDDLE EAST	Bahrain	9.7	310	25	200	536	225
	Iran	142.7	10,877	21,675	7,200	39,752	28,875
	Iraq	202.0	6,446	19,730	6,320	32,496	26,050
	Israel	0.4	3	2	970	975	972
	Jordan	–	–	< 0.5	1,912	1,912	1,912
	Kuwait	130.1	7,076	13,810	700	21,585	14,510
	Lebanon	–	–	–	150	150	150
	Oman	46.1	1,727	731	1,540	3,998	2,271
	Palestinian territories	–	–	–	60	60	60
	Qatar	75.9	2,142	3,435	700	6,277	4,135
	Saudi Arabia	500.7	23,117	39,617	11,800	74,534	51,417
	Syrian	2.2	753	340	400	1,493	740
	U. Arab Emirates	165.6	5,720	13,306	4,160	23,186	17,466
	Yemen	3.3	410	393	500	1,303	893
AUSTRAL-ASIA	Afghanistan	–	–	12	80	92	92
	Australia	21.2	1,132	245	13,785	15,162	14,030
	Bangladesh	0.5	5	4	30	39	34
	Brunei	5.4	555	150	160	864	310

continuation of table A-8
[Mt]

	Country / Region	Production	Cum. production	Reserves	Resources	EUR	Remaining potential
AUSTRAL-ASIA	Cambodia	–	–	–	25	25	25
	China	195.0	7,475	3,542	29,001	40,018	32,543
	India	30.5	1,505	618	1,840	3,963	2,458
	Indonesia	35.3	3,631	332	3,572	7,535	3,904
	Japan	0.4	55	6	24	85	30
	Korea, DPR	–	–	–	50	50	50
	Korea, Rep.	< 0.05	n. s.	n. s.	n. s.	n. s.	n. s.
	Laos	–	–	–	< 0.5	< 0.5	< 0.5
	Malaysia	27.2	1,281	490	850	2,620	1,340
	Mongolia	0.6	10	43	1,015	1,068	1,058
	Myanmar	0.4	60	19	595	674	614
	New Zealand	1.0	69	6	250	325	256
	Pakistan	4.7	131	73	1,342	1,547	1,415
	Papua New Guinea	1.9	82	22	290	394	312
	Philippines	1.0	23	19	270	312	289
	Sri Lanka	–	–	–	90	90	90
	Taiwan	< 0.05	5	< 0.5	5	10	5
	Thailand	8.8	261	14	452	726	466
	Timor-Leste	0.7	58	49	175	282	224
	Viet Nam	11.7	421	595	600	1,615	1,195
NORTH AMERICA	Canada	253.3	7,082	26,554	57,170	90,806	83,724
	Greenland	–	–	–	3,500	3,500	3,500
	Mexico	95.0	7,073	815	4,760	12,648	5,575
	USA	744.7	35,805	8,493	117,768	162,066	126,261
LATIN AMERCA	Argentina	23.9	1,728	342	4,183	6,253	4,525
	Barbados	0.1	3	< 0.5	30	33	30
	Belize	0.1	2	1	15	18	16
	Bolivia	2.3	104	33	280	417	313
	Brazil	159.2	2,963	1,622	15,206	19,791	16,828
	Chile	0.1	63	20	330	414	351
	Colombia	41.3	1,517	277	1,790	3,584	2,067
	Cuba	2.2	83	17	1,145	1,245	1,162
	Dominican Rep.	–	–	–	150	150	150

continuation of table A-8
[Mt]

	Country / Region	Production	Cum. production	Reserves	Resources	EUR	Remaining potential
LATIN AMERICA	Ecuador	23.8	929	1,126	107	2,161	1,232
	Falkland Islands	–	–	–	800	800	800
	(French) Guiana	–	–	–	800	800	800
	Guatemala	0.3	24	12	40	76	52
	Guyana	–	–	–	450	450	450
	Haiti	–	–	–	100	100	100
	Panama	–	–	–	122	122	122
	Paraguay	–	–	–	575	575	575
	Peru	5.4	424	88	2,321	2,833	2,409
	Puerto Rico	–	–	–	75	75	75
	Suriname	0.8	19	12	700	731	712
	Trinidad and Tobago	3.1	546	33	67	647	101
	Uruguay	–	–	–	275	275	275
	Venezuela	27.4	10,430	47,385	46,820	104,635	94,205
	World	4,162.9	205,378	245,180	501,176	951,734	746,356
	Europe	175.6	10,920	1,969	9,722	22,611	11,691
	CIS (+ GEO, UKR)	651.3	31,704	20,056	102,148	153,909	122,205
	Africa	327.8	18,622	17,022	38,613	74,257	55,635
	Middle East	1,278.7	58,582	113,064	36,612	208,258	149,676
	Austral-Asia	346.5	16,757	6,238	54,502	77,497	60,739
	North America	1,093.0	49,959	35,862	183,198	269,019	219,060
	Latin America	290.1	18,834	50,968	76,381	146,183	127,349
	OPEC	1,429.5	79,533	170,648	95,875	346,057	266,524
	OPEC-Gulf	1,141.1	53,236	108,138	30,180	191,554	138,318
	OECD	1,326.9	62,690	38,262	209,494	310,446	247,756
	EU-28	71.0	6,440	832	6,041	13,313	6,873

n. s. not specified
– no production, reserves or resources

Table A-9: Crude oil resources 2020 [Mt]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Total	conventional	unconventional			
				shale oil	oil sand	extra heavy oil	oil shale
1	USA	117,768	15,900	10,600	1,237	50	89,981
2	Russian Federation	84,799	64,721	10,300	5,225	3	4,550
3	Canada	57,170	3,500	3,390	50,000	–	280
4	Venezuela	46,820	3,000	1,820	–	42,000	–
5	China	29,001	16,200	4,380	2,300	121	6,000
6	Brazil	15,206	13,000	720	–	–	1,486
7	Australia	13,785	300	10,264	–	–	3,221
8	Kazakhstan	12,933	4,000	1,440	7,441	–	52
9	Saudi Arabia	11,800	11,800	–	–	–	–
10	Iran	7,200	7,200	–	–	–	–
11	Iraq	6,320	6,100	220	–	–	–
12	Nigeria	5,378	5,300	–	78	–	–
13	Angola	5,095	5,000	–	95	–	–
14	Mexico	4,760	2,980	1,780	–	< 0.5	–
15	Libya	4,750	1,200	3,550	–	–	–
16	Argentina	4,183	500	3,675	–	–	8
17	U. Arab Emirates	4,160	1,100	3,060	–	–	–
18	Indonesia	3,572	2,400	1,075	97	–	–
19	Greenland	3,500	3,500	–	–	–	–
20	Morocco	2,607	1,600	27	–	–	980
84	Germany	240	20	70	–	–	150
	other countries [123]	60,129	41,444	11,196	162	86	7,241
	World	501,176	210,765	67,567	66,635	42,261	113,949
	Europe	9,722	4,731	2,181	46	33	2,731
	CIS (+ GEO, UKR)	102,148	72,356	11,890	12,667	23	5,213
	Africa	38,613	28,012	7,391	276	8	2,926
	Middle East	36,612	30,532	4,134	–	< 0.5	1,946
	Austral-Asia	54,502	24,514	18,091	2,397	121	9,379
	North America	183,198	25,880	15,770	51,237	50	90,261
	Latin America	76,381	24,739	8,110	13	42,025	1,494
	OPEC	95,875	44,208	9,425	242	42,000	–
	OPEC-Gulf	30,180	26,900	3,280	–	–	–
	OECD	209,494	32,517	29,527	51,283	82	96,084
	EU-28	6,041	2,166	1,541	46	27	2,261

– no resources

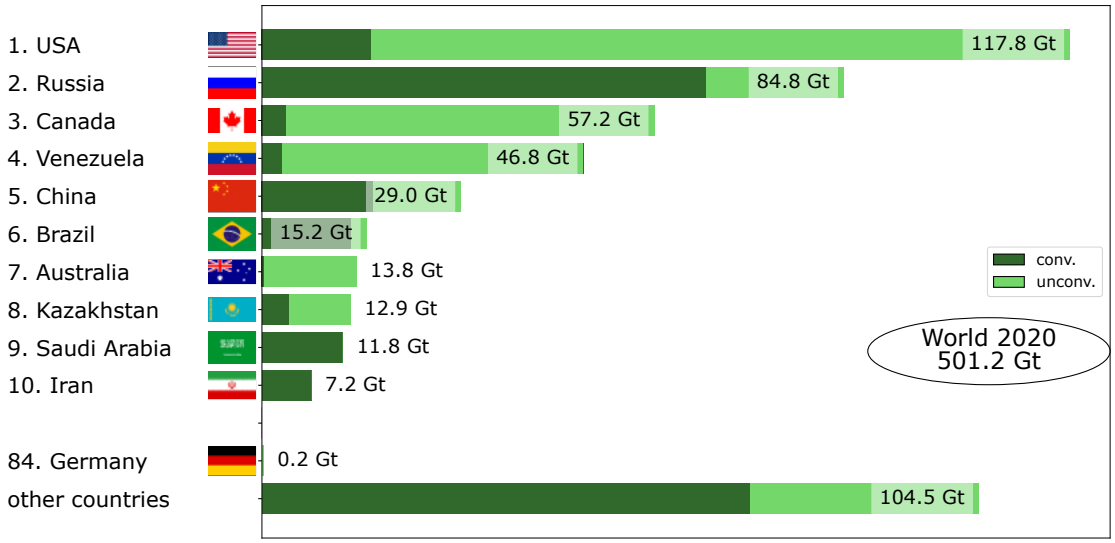


Figure A-1: Crude oil resources − top 10 countries 2020.

Table A-10: Crude oil reserves 2020 [Mt]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Total	Conventional	Unconventional			
				shale oil[1]	oil sand	extra heavy oil	oil shale
1	Venezuela	47,385	5,485	–	–	41,900	–
2	Saudi Arabia	39,617	39,617	–	–	–	–
3	Canada	26,554	667	68	25,819	–	–
4	Iran	21,675	21,675	–	–	–	–
5	Iraq	19,730	19,730	–	–	–	–
6	Russian Federation	14,767	14,767	–	–	–	–
7	Kuwait	13,810	13,810	–	–	–	–
8	U. Arab Emirates	13,306	13,306	–	–	–	–
9	USA	8,493	5,328	3,162	–	3	–
10	Libya	6,580	6,580	–	–	–	–
11	Nigeria	5,019	5,019	–	–	–	–
12	Kazakhstan	4,082	4,082	–	–	–	–
13	China	3,542	3,542	–	–	n. s.	–
14	Qatar	3,435	3,435	–	–	–	–
15	Algeria	1,660	1,660	–	–	–	–
16	Brazil	1,622	1,622	–	–	–	n. s.
17	Ecuador	1,126	1,126	–	–	n. s.	–
18	Norway	1,057	1,057	–	–	–	–
19	Angola	1,050	1,050	–	–	–	–
20	Azerbaijan	952	952	–	–	n. s.	–
70	Germany	18	18	–	–	–	–
	other countries [82]	9,700	9,529	–	–	–	172
	World[2]	245,180	174,056	3,230	25,819	41,903	172
	Europe	1,969	1,798	–	–	–	172
	CIS (+ GEO, UKR)	20,056	20,056	–	–	–	–
	Africa	17,022	17,022	–	–	–	–
	Middle East	113,064	113,064	–	–	–	–
	Austral-Asia	6,238	6,238	–	–	–	–
	North America	35,862	6,810	3,230	25,819	3	–
	Latin America	50,968	9,068	–	–	41,900	–
	OPEC	170,648	128,748	–	–	41,900	–
	OPEC-Gulf	108,138	108,138	–	–	–	–
	OECD	38,262	9,039	3,230	25,819	3	172
	EU-28	832	660	–	–	–	172

[1] crude oil from tight reservoirs
[2] including the oil shale reserves of Estonia

n. s. no specified
– no reserves

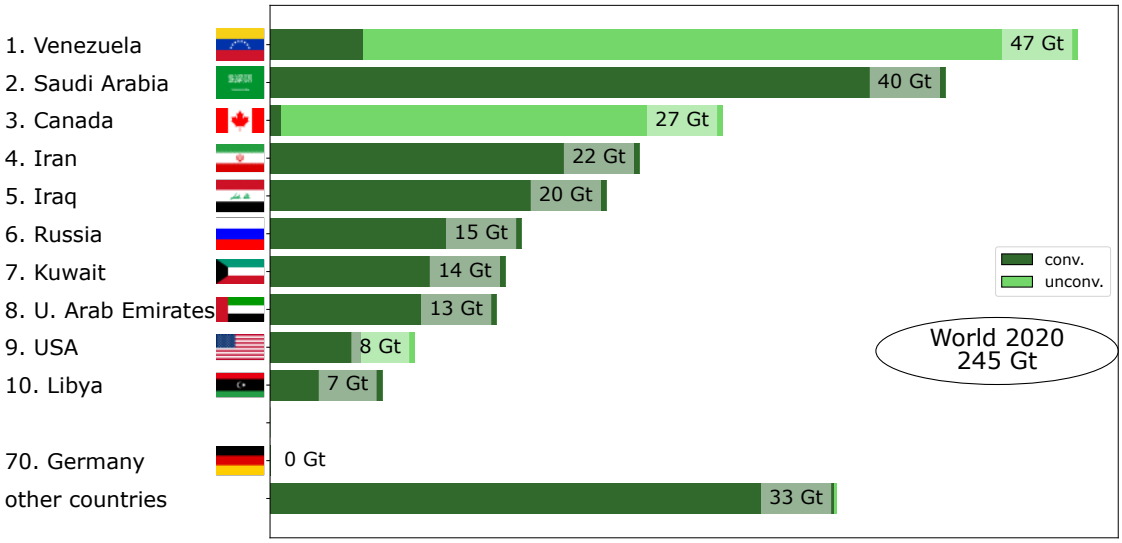


Figure A-2: Crude oil reserves – top 10 countries 2020.

Table A-11: Crude oil production 2015 to 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Counrty / Region	2015	2016	2017	2018	2019	2020	Share [%]		Changes	
		[Mt]						country	cum.	2019/2020	[%]
1	USA	567.2	543.0	595.0	698.4	776.2	744.7	17.9	17.9	-31.5	-4.1
2	Russian Federation	533.6	547.5	546.7	555.8	560.3	512.8	12.3	30.2	-47.5	-8.5
3	Saudi Arabia	565.3	589.1	555.1	578.3	557.2	500.7	12.0	42.2	-56.5	-10.1
4	Canada	215.1	218.2	224.0	232.5	266.0	253.3	6.1	48.3	-12.7	-4.8
5	Iraq	197.0	218.9	222.2	226.1	234.2	202.0	4.9	53.2	-32.2	-13.7
6	China	214.6	199.7	191.5	190.0	191.0	195.0	4.7	57.9	4.0	2.1
7	U. Arab Emirates	175.5	182.4	176.3	177.7	180.2	165.6	4.0	61.8	-14.6	-8.1
8	Brazil	125.6	125.0	130.2	130.2	142.0	159.2	3.8	65.7	17.2	12.1
9	Iran	182.6	216.4	234.6	220.4	160.8	142.7	3.4	69.1	-18.1	-11.2
10	Kuwait	149.1	152.7	146.0	146.8	144.0	130.1	3.1	72.2	-13.9	-9.7
11	Norway	94.8	98.5	97.7	92.0	86.1	99.7	2.4	74.6	13.6	15.8
12	Mexico	128.8	121.0	110.6	102.8	95.3	95.0	2.3	76.9	-0.3	-0.4
13	Nigeria	113.0	98.8	95.3	98.4	101.4	86.9	2.1	79.0	-14.5	-14.3
14	Kazakhstan	80.2	79.3	86.2	90.3	90.6	86.1	2.1	81.0	-4.5	-5.0
15	Qatar	79.3	79.4	79.9	78.8	78.5	75.9	1.8	82.9	-2.6	-3.3
16	Angola	88.7	87.9	81.8	74.6	69.1	64.5	1.5	84.4	-4.6	-6.7
17	Algeria	68.1	67.8	66.6	65.3	64.3	57.6	1.4	85.8	-6.7	-10.4
18	United Kingdom	45.7	47.9	47.0	51.2	52.2	48.5	1.2	87.0	-3.7	-7.1
19	Oman	48.0	49.3	47.6	47.8	47.3	46.1	1.1	88.1	-1.2	-2.5
20	Colombia	51.3	44.0	44.7	45.8	46.7	41.3	1.0	89.1	-5.4	-11.6
58	Germany	2.4	2.4	2.2	2.1	1.9	1.9	< 0.05	99.4	0.0	-1.5
	other countries [76]	636.7	603.9	597.3	557.0	540.9	453.4	10.9	100.0	-87.5	-16.2
	World	4,362.5	4,373.0	4,378.5	4,462.5	4,486.1	4,162.9	100.0		-323.2	-7.2
	Europe	174.3	176.8	176.2	174.9	167.3	175.6	4.2		8.3	4.9
	CIS (+ GEO, UKR)	674.4	687.2	690.4	701.9	707.6	651.3	15.6		-56.3	-8.0
	Africa	397.9	374.7	384.6	388.8	399.5	327.8	7.9		-71.8	-18.0
	Middle East	1,410.4	1,501.2	1,473.6	1,489.1	1,416.2	1,278.7	30.7		-137.5	-9.7
	Austral-Asia	391.4	375.1	360.6	353.5	348.9	346.5	8.3		-2.4	-0.7
	North America	911.1	882.2	929.6	1,033.8	1,137.5	1,093.0	26.3		-44.6	-3.9
	Latin America	402.8	375.7	363.5	320.6	309.1	290.1	7.0		-19.0	-6.2
	OPEC	1,747.1	1,804.0	1,769.5	1,745.6	1,655.1	1,429.5	34.3		-225.6	-13.6
	OPEC-Gulf	1,269.5	1,359.5	1,334.2	1,349.3	1,276.4	1,141.1	27.4		-135.3	-10.6
	OECD	1,147.7	1,112.4	1,159.4	1,265.5	1,365.2	1,326.9	31.9		-38.3	-2.8
	EU-28	74.3	73.1	73.4	77.6	76.6	71.0	1.7		-5.5	-7.2

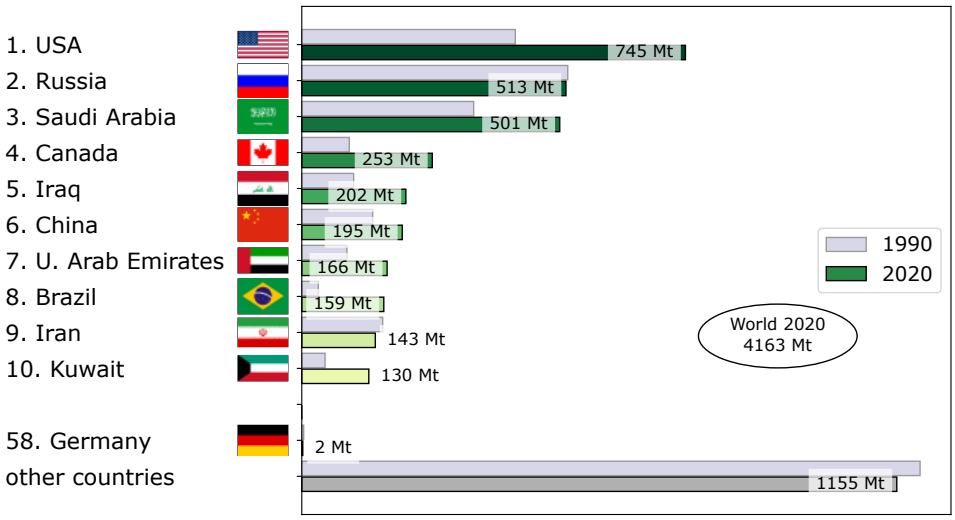


Figure A-3: Crude oil production − top 10 countries 1990 and 2020.

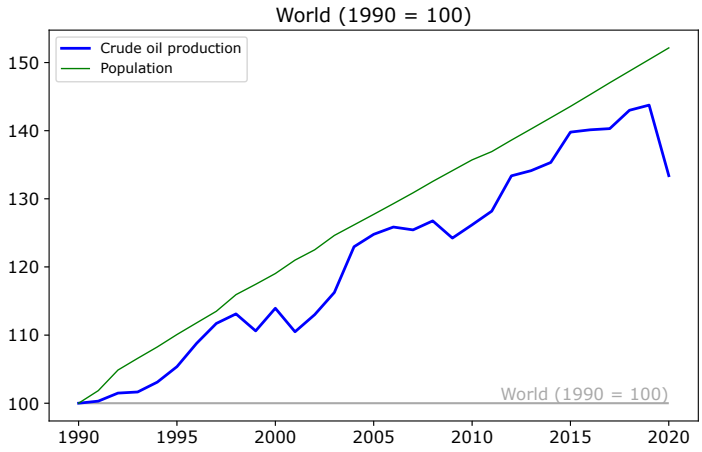


Figure A-4: Development of global crude oil production and global population from 1990 to 2020..

Table A-12: Petroleum consumption 2020[1]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	USA	902.3	21.3	21.3
2	China	669.2	15.8	37.1
3	India	213.1	5.0	42.2
4	Saudi Arabia	150.0	3.5	45.7
5	Russian Federation	146.3	3.5	49.2
6	Japan	132.0	3.1	52.3
7	Korea, Rep.	119.5	2.8	55.1
8	Brazil	106.8	2.5	57.6
9	Canada	98.1	2.3	60.0
10	Germany	93.7	2.2	62.2
11	Iran	84.1	2.0	64.2
12	Mexico	78.6	1.9	66.0
13	France	70.6	1.7	67.7
14	Singapore	69.5	1.6	69.3
15	Indonesia	64.3	1.5	70.9
16	United Kingdom	51.8	1.2	72.1
17	Italy	50.7	1.2	73.3
18	Spain	48.7	1.2	74.4
19	Australia	44.7	1.1	75.5
20	Turkey	43.4	1.0	76.5
	other countries [179]	994.2	23.5	100.0
	World	4,231.5	100.0	
	Europe	592.4	14.0	
	CIS (+ GEO, UKR)	196.7	4.6	
	Africa	191.7	4.5	
	Middle East	375.7	8.9	
	Austral-Asia	1,537.2	36.3	
	North America	1,079.2	25.5	
	Latin America	256.9	6.1	
	OPEC	386.9	9.1	
	OPEC-Gulf	313.8	7.4	
	OECD	1,978.7	46.8	
	EU-28	519.3	12.3	

[1] also includes consumption of biofuels and synthetic fuels based on coal and natural gas, as well as withdrawals fromstocks and strategic stocks.

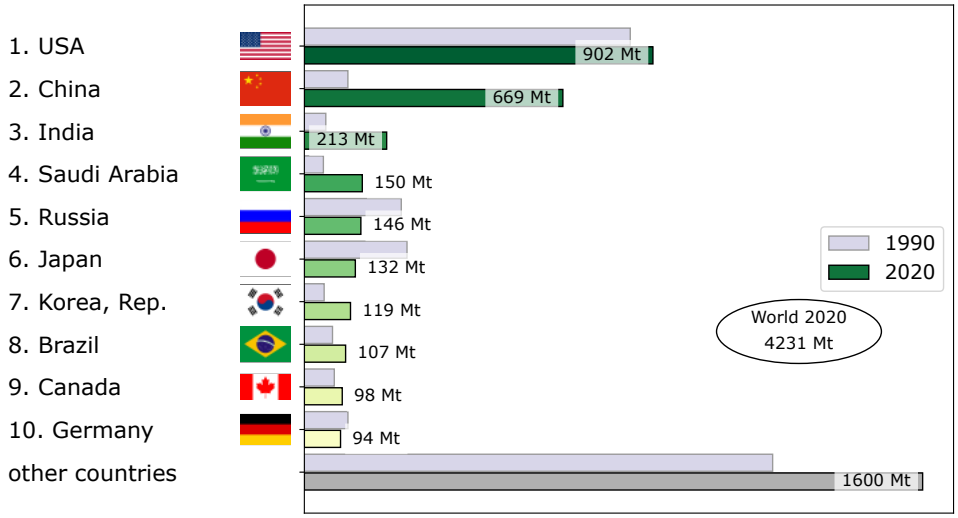


Figure A-5: Petroleum consumption − top 10 countries 1990 and 2020.

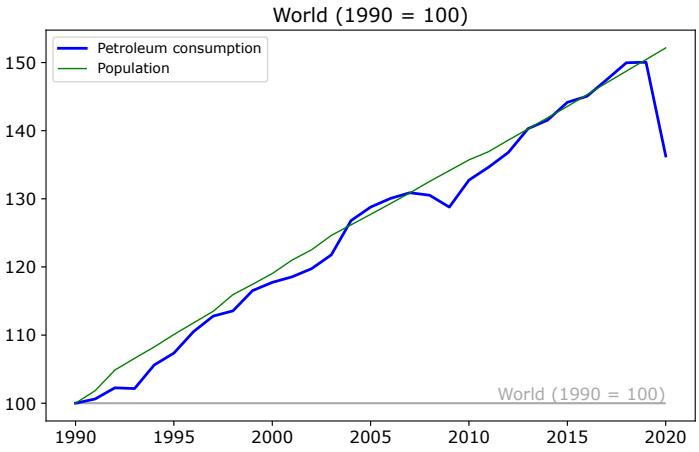


Figure A-6: Growth of global petroleum consumption and global population from 1990 to 2020.

Table A-13: Crude oil export 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	Saudi Arabia	334.5	15.7	15.7
2	Russian Federation	232.4	10.9	26.7
3	Canada	189.3	8.9	35.6
4	Iraq	170.3	8.0	43.6
5	USA	158.1	7.4	51.1
6	U. Arab Emirates	120.1	5.7	56.7
7	Nigeria	93.3	4.4	61.1
8	Kuwait	90.7	4.3	65.4
9	Norway	83.8	3.9	69.3
10	Kazakhstan	70.4	3.3	72.6
11	Brazil	68.1	3.2	75.8
12	Angola	60.6	2.9	78.7
13	Mexico	56.8	2.7	81.4
14	Oman	42.7	2.0	83.4
15	United Kingdom	38.0	1.8	85.2
16	Azerbaijan	28.4	1.3	86.5
17	Colombia	26.9	1.3	87.8
18	Qatar	25.0	1.2	88.9
19	Venezuela	24.2	1.1	90.1
20	Algeria	21.8	1.0	91.1
73	Germany	< 0.05	< 0.05	100.0
	other countries [52]	189.1	8.9	100.0
	World	2,124.3	100.0	
	Europe	134.9	6.4	
	CIS (+ GEO, UKR)	333.1	15.7	
	Africa	255.5	12.0	
	Middle East	805.6	37.9	
	Austral-Asia	48.2	2.3	
	North America	404.2	19.0	
	Latin America	142.8	6.7	
	OPEC	982.1	46.2	
	OPEC-Golf	735.6	34.6	
	OECD	580.5	27.3	
	EU-28	50.5	2.4	

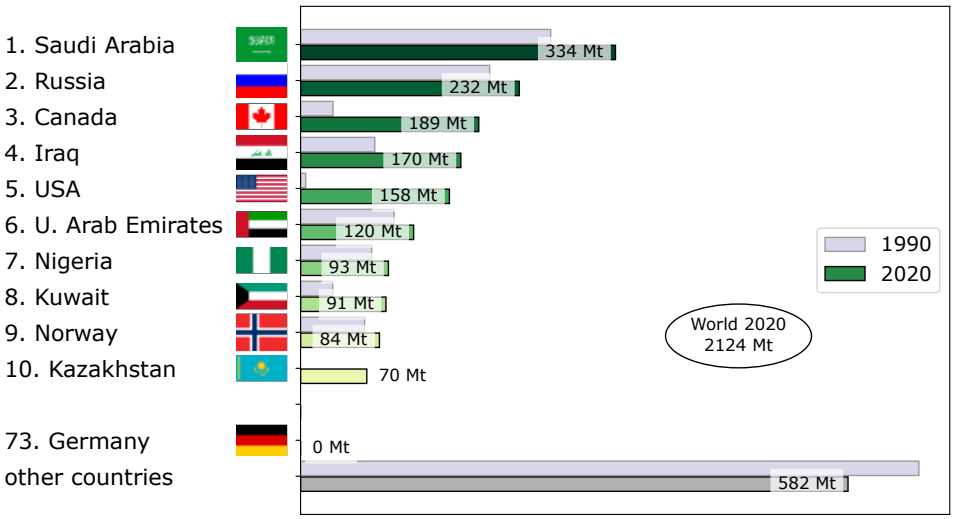


Figure A-7: Crude oil exports − top 10 countries 1990 and 2020.

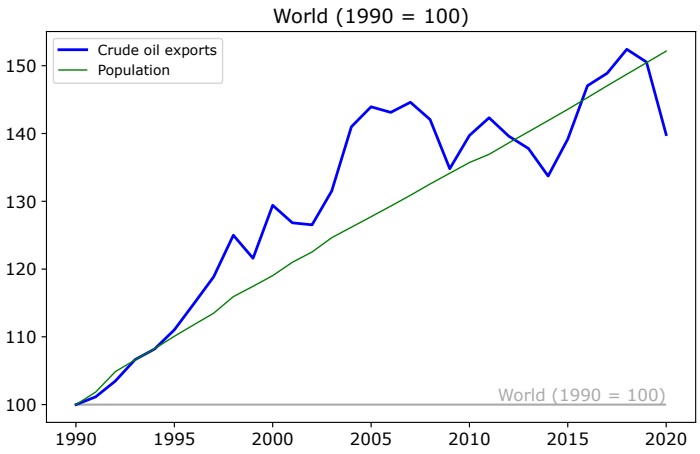


Figure A-8: Development of global crude oil exports and global population from 1990 to 2020.

Table A-14: Crude oil imports 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	China	540.0	25.4	25.4
2	USA	292.5	13.8	39.2
3	India	203.9	9.6	48.8
4	Korea, Rep.	133.4	6.3	55.1
5	Japan	123.1	5.8	60.9
6	Germany	82.7	3.9	64.8
7	Spain	54.9	2.6	67.4
8	Italy	50.4	2.4	69.8
9	Netherlands	49.6	2.3	72.1
10	Singapore	46.1	2.2	74.3
11	Thailand	40.4	1.9	76.2
12	United Kingdom	37.4	1.8	77.9
13	Taiwan	36.7	1.7	79.7
14	France	33.2	1.6	81.2
15	Turkey	29.5	1.4	82.6
16	Canada	27.9	1.3	83.9
17	Belgium	27.4	1.3	85.2
18	Greece	27.2	1.3	86.5
19	Poland	25.2	1.2	87.7
20	Sweden	19.6	0.9	88.6
	other countries [49]	242.0	11.4	100.0
	World	2,123.1	100.0	
	Europe	524.9	24.7	
	CIS (+ GEO, UKR)	17.9	0.8	
	Africa	10.0	0.5	
	Middle East	28.3	1.3	
	Austral-Asia	1,193.1	56.2	
	North America	320.9	15.1	
	Latin America	27.9	1.3	
	OECD	1,121.1	52.8	
	EU-28	486.9	22.9	

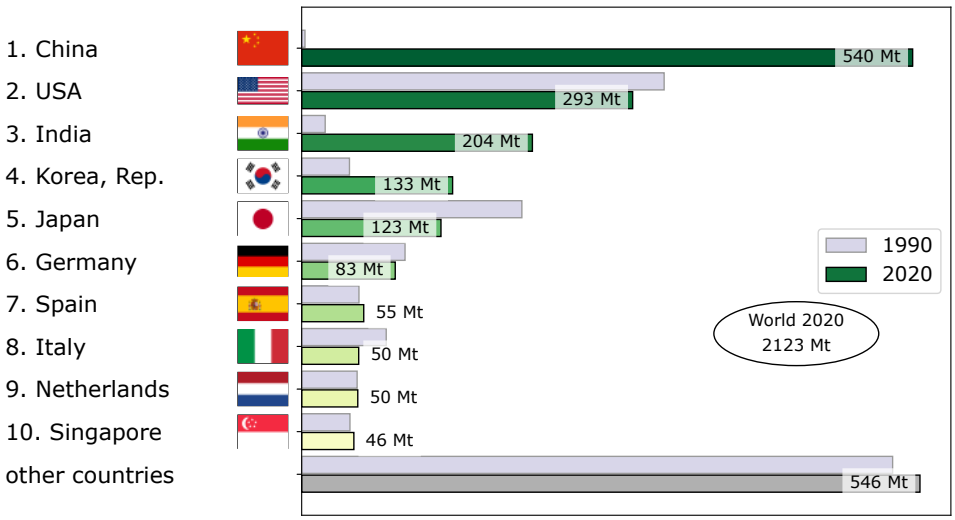


Figure A-9: Crude oil imports – top 10 countries 1990 and 2020.

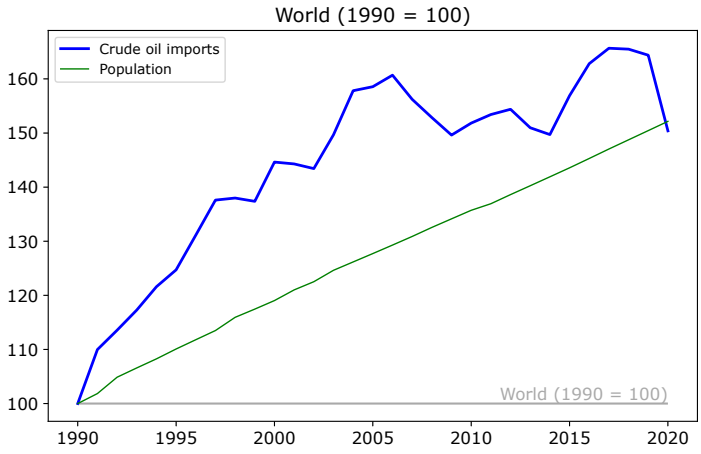


Figure A-10: Development of global crude oil imports and global population from 1990 to 2020.

Table A-15: Natural gas 2020 [bcm]

	Country / Region	Production	Cum. production	Reserves	Resources	EUR	Remaining potential
EUROPE	Albania	0.1	8	6	50	64	56
	Austria	0.8	105	5	244	354	249
	Belgium	–	–	–	85	85	85
	Bulgaria	0.1	8	6	575	589	581
	Croatia	0.9	80	25	50	155	75
	Cyprus	–	–	–	500	500	500
	Czechia	0.2	17	4	181	202	185
	Denmark	1.4	204	30	236	470	266
	France	0.1	229	8	3,984	4,221	3,992
	Germany	5.7	1,065	22	1,360	2,447	1,382
	Greece	< 0.05	2	1	10	12	11
	Hungary	1.7	239	4	173	416	177
	Ireland	2.0	71	10	50	131	60
	Italy	4.4	781	46	405	1,232	450
	Lithuania	–	–	–	14	14	14
	Malta	–	–	–	10	10	10
	Netherlands	20.0	3,753	133	512	4,397	645
	Norway	110.0	2,692	1,545	2,445	6,682	3,989
	Poland	5.1	288	92	1,252	1,631	1,343
	Portugal	–	–	–	148	148	148
	Romania	8.7	1,356	105	1,142	2,604	1,248
	Serbia	0.4	36	48	10	94	58
	Slovakia	0.1	26	14	10	51	24
	Slovenia	< 0.05	n. s.	1	30	31	31
	Spain	0.1	12	3	653	667	655
	Sweden	–	–	–	48	48	48
	Turkey	0.5	17	4	1,553	1,573	1,557
	United Kingdom	39.8	2,744	133	6,359	9,236	6,492
CIS (+ GEO, UKR)	Armenia	–	–	–	18	18	18
	Azerbaijan	25.8	682	2,200	1,500	4,382	3,700
	Belarus	0.2	14	3	10	27	13
	Georgia	< 0.05	3	8	102	113	110
	Kazakhstan	24.2	673	1,830	4,179	6,682	6,009
	Kyrgyzstan	< 0.05	8	6	20	34	26

continuation of table A-15
[bcm]

	Country / Region	Production	Cum. production	Reserves	Resources	EUR	Remaining potential
CIS (+ GEO, UKR)	Moldova, Republic	–	–	–	20	20	20
	Russian Federation	693.4	25,812	47,805	145,200	218,817	193,005
	Tajikistan	–	9	6	20	34	26
	Turkmenistan	81.7	3,042	13,601	15,000	31,643	28,601
	Ukraine	19.1	2,118	1,104	4,495	7,718	5,599
	Uzbekistan	44.5	2,579	1,522	1,400	5,501	2,922
AFRICA	Algeria	85.1	2,848	2,279	27,320	32,447	29,599
	Angola	11.3	60	301	800	1,161	1,101
	Benin	–	–	1	100	101	101
	Botswana	–	–	–	1,840	1,840	1,840
	Cameroon	2.4	n. s.	135	250	385	385
	Chad	–	–	–	1,455	1,455	1,455
	Comoros	–	–	–	13	13	13
	Congo, DR	n. s.	n. s.	1	70	71	71
	Congo, Rep.	0.4	n. s.	284	350	634	634
	Côte d'Ivoire	2.7	42	28	380	450	408
	Egypt	62.1	1,157	2,138	12,380	15,674	14,518
	Equatorial Guinea	6.0	90	39	180	309	219
	Eritrea	–	–	–	29	29	29
	Ethiopia	–	–	25	151	176	176
	Gabon	0.5	8	26	650	684	676
	Gambia	–	–	–	25	25	25
	Ghana	2.7	n. s.	23	275	298	298
	Guinea	–	–	–	160	160	160
	Guinea-Bissau	–	–	–	90	90	90
	Kenya	–	–	–	330	330	330
	Liberia	–	–	–	225	225	225
	Libya	13.3	382	1,505	6,620	8,507	8,125
	Madagascar	–	–	–	4,500	4,500	4,500
	Mali	–	–	–	30	30	30
	Mauritania	n. s.	n. s.	280	1,100	1,380	1,380
	Morocco	0.1	3	5	2,120	2,128	2,125
	Mozambique	4.3	60	2,832	3,160	6,052	5,992
	Namibia	–	–	62	300	362	362

continuation of table A-15
[bcm]

	Country / Region	Production	Cum. production	Reserves	Resources	EUR	Remaining potential
AFRICA	Niger	–	–	–	250	250	250
	Nigeria	50.0	762	5,848	3,300	9,910	9,148
	Rwanda	n. s.	n. s.	28	130	158	158
	São Tomé and Príncipe	–	–	–	100	100	100
	Senegal	< 0.05	–	212	350	562	562
	Seychelles	–	–	–	400	400	400
	Sierra Leone	–	–	–	197	197	197
	Somalia	–	–	6	450	456	456
	South Africa	1.2	50	10	7,277	7,337	7,287
	Sudan & South Sudan	n. s.	n. s.	85	300	385	385
	Tanzania	1.0	n. s.	7	1,600	1,607	1,607
	Togo	–	–	–	80	80	80
	Tunisia	2.0	66	65	925	1,056	990
	Uganda	–	–	14	90	104	104
	Zimbabwe	–	–	–	10	10	10
MIDDLE EAST	Bahrain	16.4	374	81	350	806	431
	Iran	253.8	3,760	34,077	10,000	47,836	44,077
	Iraq	10.5	184	3,729	6,000	9,913	9,729
	Israel	9.3	87	589	1,650	2,326	2,239
	Jordan	< 0.05	6	4	270	280	274
	Kuwait	12.9	431	1,784	500	2,715	2,284
	Lebanon	–	–	–	600	600	600
	Oman	36.9	615	666	3,085	4,367	3,751
	Palestinian territories	–	–	–	380	380	380
	Qatar	184.9	2,485	23,860	2,000	28,346	25,860
	Saudi Arabia	103.2	2,446	9,234	25,664	37,344	34,898
	Syrian	3.0	160	269	300	729	569
	U. Arab Emirates	52.2	1,531	6,092	9,065	16,687	15,156
	Yemen	0.1	54	266	500	819	766
AUSTRAL-ASIA	Afghanistan	0.1	58	50	400	508	450
	Australia	153.6	1,785	1,888	27,379	31,052	29,267
	Bangladesh	25.1	509	126	800	1,435	926
	Brunei	12.6	484	240	200	924	440
	Cambodia	–	–	–	50	50	50

continuation of table A-15
[bcm]

	Country / Region	Production	Cum. production	Reserves	Resources	EUR	Remaining potential
AUSTRAL-ASIA	China	204.8	2,451	6,654	63,400	72,505	70,054
	India	27.4	944	1,320	7,023	9,287	8,343
	Indonesia	59.2	2,489	1,234	9,980	13,703	11,214
	Japan	2.4	152	21	10	183	31
	Korea, Rep.	0.2	n. s.	7	50	57	57
	Laos	–	–	–	10	10	10
	Malaysia	73.2	1,707	2,252	1,900	5,859	4,152
	Mongolia	–	–	–	133	133	133
	Myanmar	18.0	289	637	2,000	2,926	2,637
	New Zealand	4.4	189	31	353	573	384
	Pakistan	35.0	1,071	592	4,560	6,223	5,152
	Papua New Guinea	11.5	36	163	1,000	1,199	1,163
	Philippines	4.0	64	99	502	664	600
	Sri Lanka	–	–	–	300	300	300
	Taiwan	0.1	53	6	5	64	11
	Thailand	33.8	798	112	740	1,650	852
	Timor-Leste	5.0	n. s.	88	300	388	388
	Viet Nam	9.1	161	646	1,355	2,162	2,001
NORTH AMERICA	Canada	158.3	6,979	2,067	26,801	35,847	28,868
	Mexico	30.1	1,853	180	17,720	19,753	17,900
	USA	947.7	39,327	12,996	65,531	117,855	78,527
LATIN AMERICA	Argentina	45.1	1,386	397	23,710	25,493	24,107
	Barbados	n. s.	n. s.	< 0.5	100	100	100
	Belize	–	–	–	10	10	10
	Bolivia	16.3	368	213	1,620	2,201	1,833
	Brazil	23.9	441	338	18,446	19,225	18,784
	Chile	1.3	116	98	1,745	1,959	1,843
	Colombia	9.6	320	84	2,307	2,710	2,391
	Cuba	0.9	21	71	400	492	471
	Ecuador	0.6	9	11	20	40	31
	Falkland Islands	–	–	–	1,500	1,500	1,500
	(French) Guiana	–	–	–	400	400	400
	Grenada	–	–	–	25	25	25
	Guatemala	–	–	–	10	10	10

continuation of table A-15
[bcm]

	Country / Region	Production	Cum. production	Reserves	Resources	EUR	Remaining potential
LATIN AMERICA	Guyana	–	–	–	300	300	300
	Haiti	–	–	–	40	40	40
	Paraguay	–	–	–	2,420	2,420	2,420
	Peru	12.1	194	300	1,340	1,834	1,640
	Puerto Rico	–	–	–	30	30	30
	Suriname	–	–	–	350	350	350
	Trinidad and Tobago	31.5	840	290	–	1,130	290
	Uruguay	–	–	–	828	828	828
	Venezuela	18.0	1,256	5,674	7,130	14,060	12,804
	World	3,993.7	132,685	206,102	630,009	968,796	836,111
	Europe	201.9	13,732	2,242	22,089	38,063	24,331
	CIS (+ GEO, UKR)	888.9	34,939	68,086	171,964	274,988	240,049
	Africa	245.0	5,528	16,239	80,361	102,128	96,600
	Middle East	683.1	12,134	80,651	60,364	153,148	141,014
	Austral-Asia	679.5	13,240	16,166	122,449	151,855	138,615
	North America	1,136.1	48,159	15,244	110,052	173,455	125,296
	Latin America	159.2	4,953	7,475	62,731	75,158	70,206
	OPEC	617.1	13,758	70,872	97,579	182,209	168,451
	OPEC-Gulf	432.5	8,352	54,916	51,229	114,496	106,144
	OECD	1,508.8	63,052	20,013	163,297	246,362	183,310
	EU-28	91.0	10,979	640	18,031	29,650	18,671

n. s. not specified
– no production or reserves

Table A-16: Natural gas resources 2020 [bcm]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Total	Conventional	Unconventional		
				tight gas	shale gas	CBM
1	Russian Federation	145,200	110,000	20,000	9,500	5,700
2	USA	65,531	31,970	11,815	17,276	4,470
3	China	63,400	20,000	10,500	22,000	10,900
4	Australia	27,379	4,938	5,100	11,500	5,841
5	Algeria	27,320	1,800	5,500	20,020	–
6	Canada	26,801	6,500	–	16,230	4,071
7	Saudi Arabia	25,664	20,000	–	5,664	–
8	Argentina	23,710	1,000	–	22,710	–
9	Brazil	18,446	11,500	–	6,940	6
10	Mexico	17,720	2,250	–	15,440	30
11	Turkmenistan	15,000	15,000	–	–	–
12	Egypt	12,380	9,550	–	2,830	–
13	Iran	10,000	10,000	–	–	–
14	Indonesia	9,980	5,500	–	1,300	3,180
15	U. Arab Emirates	9,065	3,250	–	5,815	–
16	South Africa	7,277	1,000	–	5,707	570
17	Venezuela	7,130	2,400	–	4,730	–
18	India	7,023	2,000	–	2,720	2,303
19	Libya	6,620	3,170	–	3,450	–
20	United Kingdom	6,359	2,786	–	3,543	30
47	Germany	1,360	20	90	800	450
	other countries [123]	96,645	63,618	1,567	24,545	6,916
	World	630,009	328,252	54,572	202,720	44,466
	Europe	22,089	7,937	527	12,416	1,209
	CIS (+ GEO, UKR)	171,964	130,588	20,000	11,274	10,102
	Africa	80,361	37,970	5,500	35,482	1,410
	Middle East	60,364	46,650	670	13,044	–
	Austral-Asia	122,449	42,963	15,790	40,740	22,956
	North America	110,052	40,720	11,815	48,946	8,571
	Latin America	62,731	21,425	270	40,818	218
	OPEC	97,579	52,400	5,500	39,679	–
	OPEC-Gulf	51,229	39,750	–	11,479	–
	OECD	163,297	55,475	17,712	74,331	15,780
	EU-28	18,031	5,032	327	11,746	926

– no resources or no information

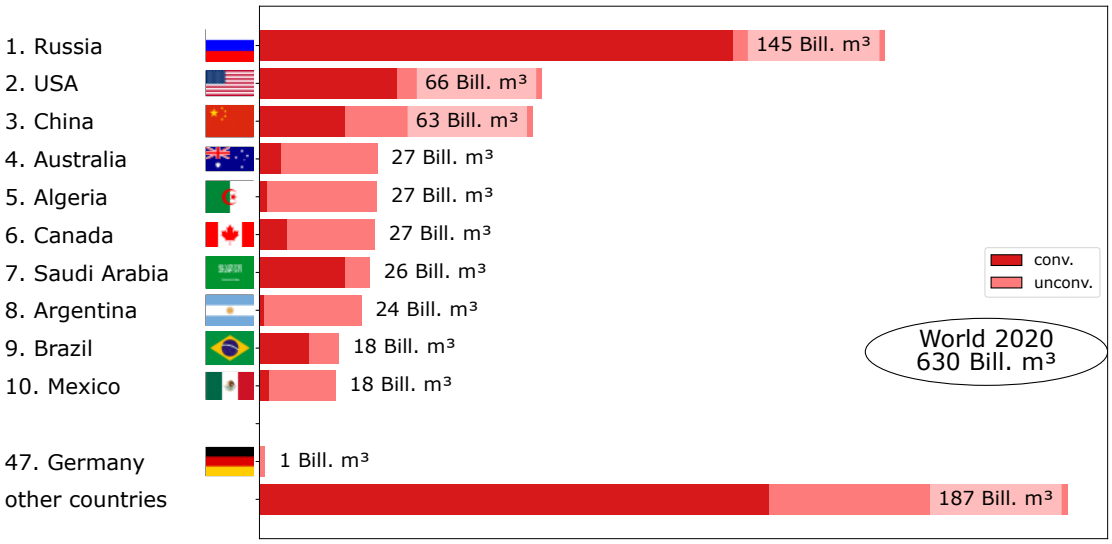


Figure A-11: Natural gas resources – top 10 countries 2020.

Table A-17: Natural gas reserves 2020 [bcm]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Total	Conventional	Unconventional	
				shale gas	CBM
1	Russian Federation	47,805	47,754	–	51
2	Iran	34,077	34,077	–	–
3	Qatar	23,860	23,860	–	–
4	Turkmenistan	13,601	13,601	–	–
5	USA	12,996	3,307	9,689	n. s.
6	Saudi Arabia	9,234	9,234	–	–
7	China	6,654	6,152	198	304
8	U. Arab Emirates	6,092	6,092	–	–
9	Nigeria	5,848	5,848	–	–
10	Venezuela	5,674	5,674	–	–
11	Iraq	3,729	3,729	–	–
12	Mozambique	2,832	2,832	–	–
13	Algeria	2,279	2,279	–	–
14	Malaysia	2,252	2,252	–	–
15	Azerbaijan	2,200	2,200	–	–
16	Egypt	2,138	2,138	–	–
17	Canada	2,067	2,038	n. s.	29
18	Australia	1,888	1,044	n. s.	844
19	Kazakhstan	1,830	1,830	–	–
20	Kuwait	1,784	1,784	–	–
74	Germany	22	22	–	–
	other countries [82]	17,239	17,152	–	87
	World	206,102	194,901	9,887	1,314
	Europe	2,242	2,231	–	11
	CIS (+ GEO, UKR)	68,086	68,035	–	51
	Africa	16,239	16,239	–	–
	Middle East	80,651	80,651	–	–
	Austral-Asia	16,166	14,745	198	1,223
	North America	15,244	5,526	9,689	29
	Latin America	7,475	7,475	–	–
	OPEC	70,872	70,872	–	–
	OPEC-Gulf	54,916	54,916	–	–
	OECD	20,013	9,440	9,689	884
	EU-28	640	629	–	11

[1] including tight gas

n. s. not specified
– no reserves

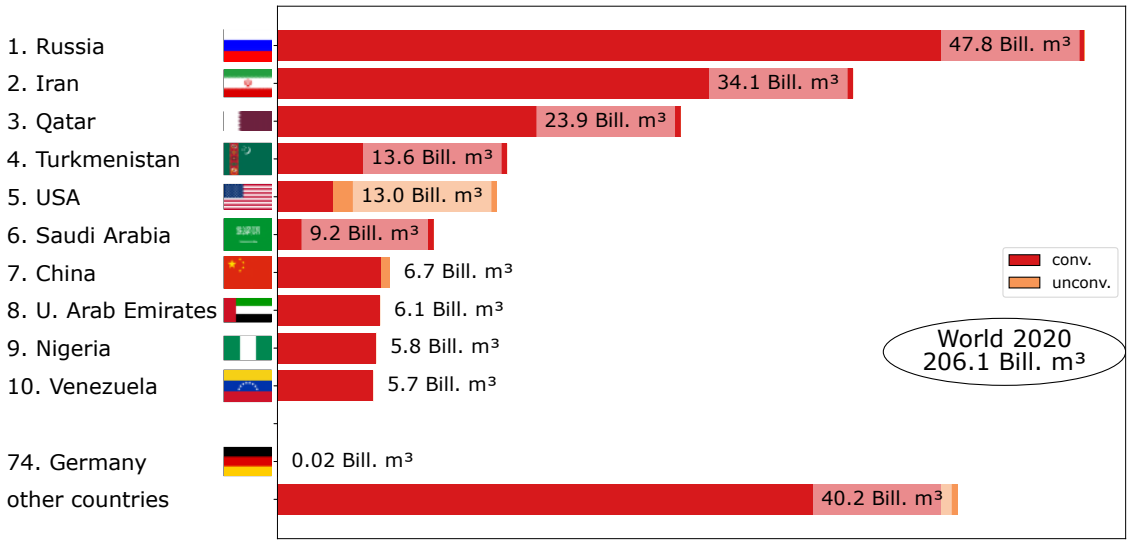


Figure A-12: Natural gas reserves − top 10 countries conventional and unconventional 2020.

Table A-18: Natural gas production 2015 to 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2015	2016	2017	2018	2019	2020	Share [%]		Changes	
		[bcm]						country	cum.	2019/2020	[%]
1	USA	768.1	755.8	761.1	863.0	954.1	947.7	23.7	23.7	-6.4	-0.7
2	Russian Federation	636.0	640.7	691.6	725.5	737.5	693.4	17.4	41.1	-44.1	-6.0
3	Iran	183.9	202.4	238.0	248.5	253.7	253.8	6.4	47.4	0.1	0.0
4	China	138.2	141.9	154.0	176.0	192.2	204.8	5.1	52.6	12.6	6.6
5	Qatar	171.3	165.4	163.6	181.6	183.6	184.9	4.6	57.2	1.3	0.7
6	Canada	154.8	157.1	176.3	172.7	164.9	158.3	4.0	61.2	-6.6	-4.0
7	Australia	88.2	105.2	120.6	145.5	154.9	153.6	3.8	65.0	-1.3	-0.8
8	Norway	121.3	121.2	124.2	119.2	115.2	110.0	2.8	67.8	-5.2	-4.5
9	Saudi Arabia	106.4	109.4	111.4	112.1	113.6	103.2	2.6	70.4	-10.4	-9.2
10	Algeria	82.3	93.2	94.8	95.9	89.6	85.1	2.1	72.5	-4.5	-5.0
11	Turkmenistan	80.2	77.0	80.5	80.7	86.6	81.7	2.0	74.5	-4.9	-5.7
12	Malaysia	68.2	73.8	78.4	72.5	78.8	73.2	1.8	76.4	-5.6	-7.1
13	Egypt	44.3	41.8	51.9	62.3	68.9	62.1	1.6	77.9	-6.7	-9.8
14	Indonesia	72.7	74.0	70.4	69.9	65.8	59.2	1.5	79.4	-6.6	-10.1
15	U. Arab Emirates	55.8	61.9	54.1	47.6	55.1	52.2	1.3	80.7	-2.9	-5.3
16	Nigeria	43.7	41.2	43.0	44.3	47.8	50.0	1.3	82.0	2.2	4.5
17	Argentina	42.9	45.0	44.6	47.2	41.6	45.1	1.1	83.1	3.5	8.4
18	Uzbekistan	58.8	51.6	52.1	53.0	54.4	44.5	1.1	84.2	-10.0	-18.3
19	United Kingdom	41.3	42.0	42.3	40.9	39.9	39.8	1.0	85.2	-0.1	-0.3
20	Oman	34.3	34.7	32.2	36.0	36.3	36.9	0.9	86.1	0.6	1.7
48	Germany	9.7	9.0	8.3	7.2	7.0	5.7	0.1	98.6	-1.3	-18.5
	other countries [71]	604.5	596.3	608.0	612.4	593.1	548.7	13.7	100.0	-44.4	-7.5
	World	3,606.8	3,640.8	3,801.5	4,014.0	4,134.7	3,993.7	100.0		-140.9	-3.4
	Europe	258.6	255.1	253.2	243.5	221.2	201.9	5.1		-19.3	-8.7
	CIS (+ GEO, UKR)	832.5	826.9	884.6	921.8	946.2	888.9	22.3		-57.3	-6.1
	Africa	202.7	208.1	230.5	248.8	252.8	245.0	6.1		-7.8	-3.1
	Middle East	605.4	628.6	656.1	686.4	698.4	683.1	17.1		-15.3	-2.2
	Austral-Asia	559.4	587.8	620.1	662.7	697.1	679.5	17.0		-17.6	-2.5
	North America	968.9	960.1	978.1	1,075.9	1,153.0	1,136.1	28.4		-16.9	-1.5
	Latin America	179.2	174.3	179.0	175.0	165.9	159.2	4.0		-6.7	-4.1
	OPEC	539.6	574.1	625.2	634.7	637.8	617.1	15.5		-20.7	-3.2
	OPEC-Gulf	369.3	398.0	431.5	437.1	447.9	432.5	10.8		-15.4	-3.4
	OECD	1,331.9	1,338.1	1,369.0	1,482.1	1,545.6	1,508.8	37.8		-36.8	-2.4
	EU-28	136.3	132.8	128.1	123.3	105.0	91.0	2.3		-14.0	-13.3

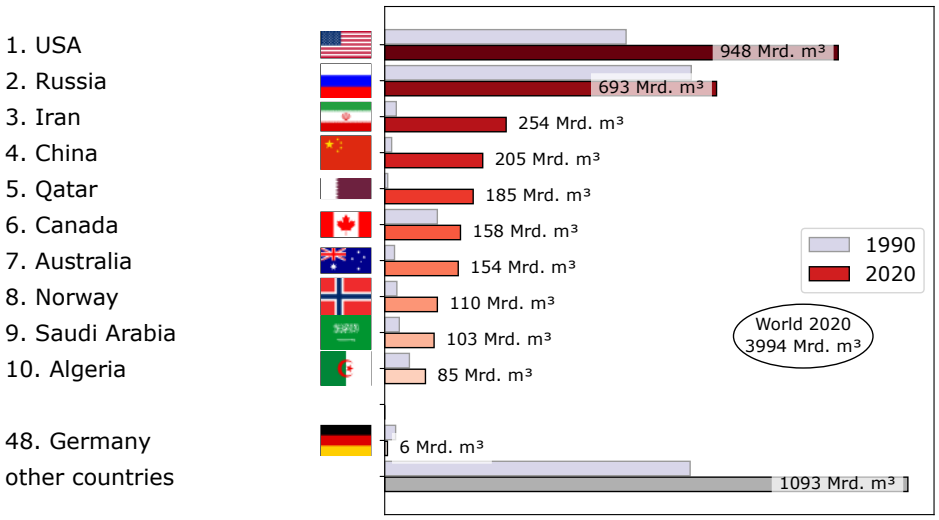


Figure A-13: Natural gas production − top 10 countries 1990 and 2020.

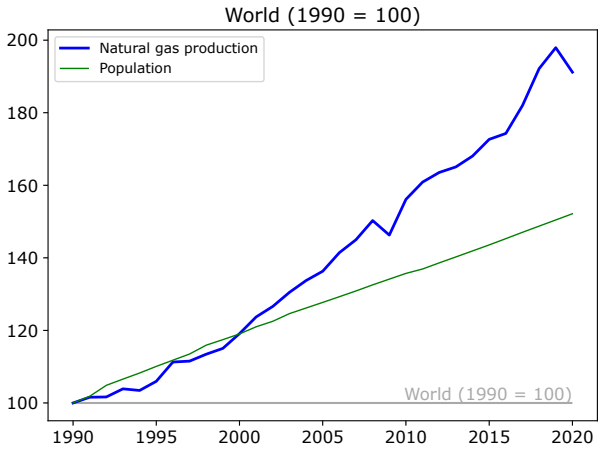


Figure A-14: Development of global natural gas production and global population from 1990 to 2020.

Table A-19: Natural gas consumption 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[bcm]	Share [%]	
			country	cumulative
1	USA	863.1	21.9	21.9
2	Russian Federation	488.2	12.4	34.3
3	China	320.8	8.1	42.5
4	Iran	233.1	5.9	48.4
5	Saudi Arabia	112.1	2.8	51.2
6	Canada	111.6	2.8	54.1
7	Japan	104.4	2.7	56.7
8	Germany	90.8	2.3	59.0
9	Mexico	86.3	2.2	61.2
10	United Kingdom	73.7	1.9	63.1
11	Italy	67.7	1.7	64.8
12	U. Arab Emirates	65.2	1.7	66.5
13	Egypt	61.2	1.6	68.0
14	India	59.6	1.5	69.5
15	Korea, Rep.	56.6	1.4	71.0
16	Algeria	51.0	1.3	72.3
17	Turkey	48.0	1.2	73.5
18	Argentina	47.8	1.2	74.7
19	Thailand	46.9	1.2	75.9
20	Netherlands	43.9	1.1	77.0
	other countries [90]	905.0	23.0	100.0
	World	3,937.0	100.0	
	Europe	527.2	13.4	
	CIS (+ GEO, UKR)	652.8	16.6	
	Africa	158.8	4.0	
	Middle East	550.9	14.0	
	Austral-Asia	843.6	21.4	
	North America	1,061.0	26.9	
	Latin America	142.8	3.6	
	OPEC	538.3	13.7	
	OPEC-Gulf	447.4	11.4	
	OECD	1,800.7	45.7	
	EU-28	466.9	11.9	

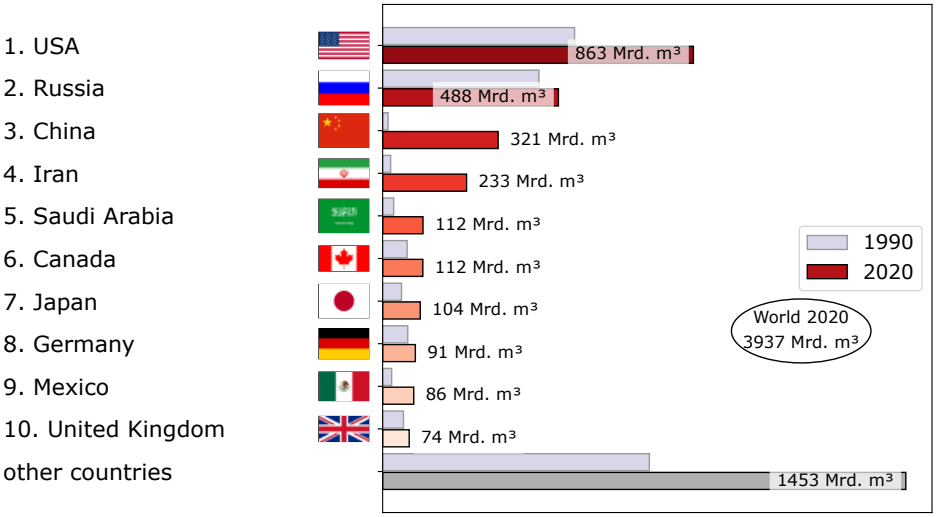


Figure A-15: Natural gas consumption − top 10 countries 1990 and 2020.

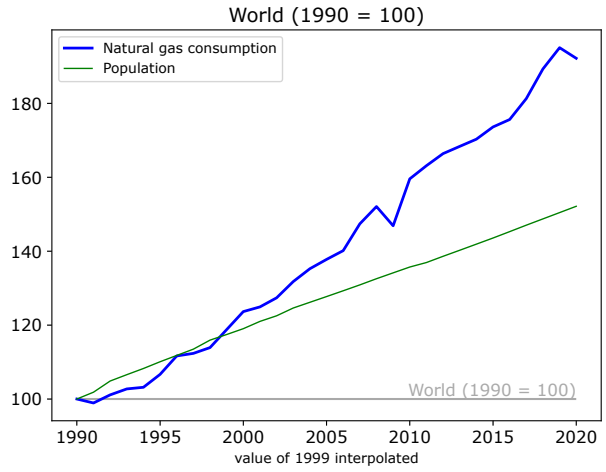


Figure A-16: Growth of global natural gas consumption and the global population from 1990 to 2020.

Table A-20: Natural gas export 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[bcm]	Share [%]	
			country	cumulative
1	Russian Federation	232.5	17.3	17.3
2	USA	149.5	11.1	28.4
3	Qatar	143.7	10.7	39.0
4	Norway	112.0	8.3	47.4
5	Australia	102.1	7.6	55.0
6	Germany	78.3	5.8	60.8
7	Canada	70.9	5.3	66.0
8	Turkmenistan	55.7	4.1	70.2
9	Algeria	39.5	2.9	73.1
10	Netherlands	39.4	2.9	76.0
11	Nigeria	35.6	2.6	78.7
12	Malaysia	31.3	2.3	81.0
13	Belgium	28.9	2.1	83.1
14	Indonesia	22.5	1.7	84.8
15	Azerbaijan	13.4	1.0	85.8
16	Kazakhstan	13.2	1.0	86.8
17	Iran	12.6	0.9	87.7
18	Bolivia	12.4	0.9	88.6
19	Trinidad and Tobago	12.0	0.9	89.5
20	Uzbekistan	11.7	0.9	90.4
	other countries [25]	129.1	9.6	100.0
	World	1,346.3	100.0	
	Europe	297.2	22.1	
	CIS (+ GEO, UKR)	326.5	24.3	
	Africa	100.7	7.5	
	Middle East	175.7	13.0	
	Austral-Asia	195.9	14.6	
	North America	220.5	16.4	
	Latin America	29.8	2.2	
	OPEC	111.2	8.3	
	OPEC-Gulf	21.3	1.6	
	OECD	619.7	46.0	
	EU-28	184.5	13.7	

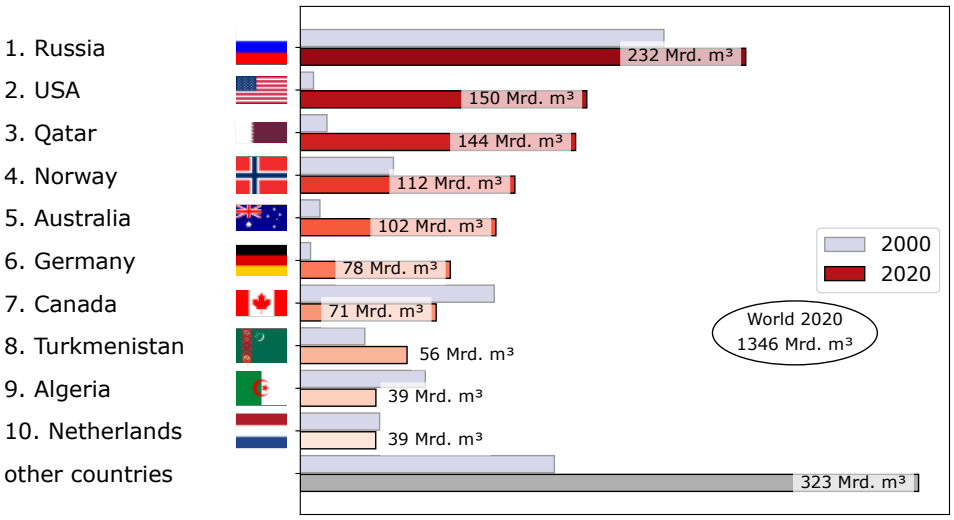


Figure A-17: Natural gas exports − top 10 countries 2020.

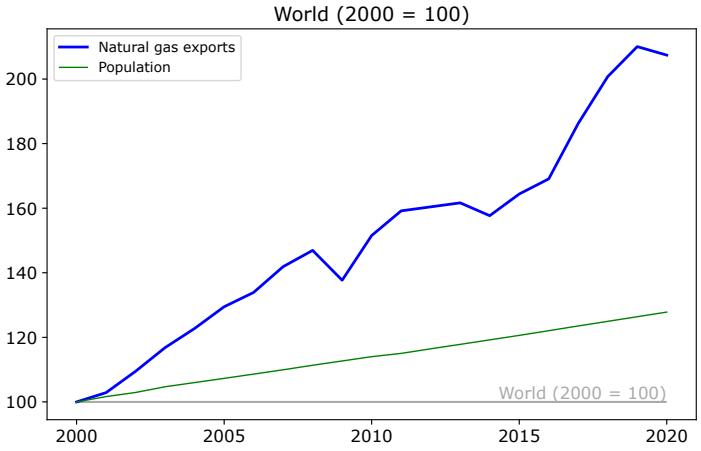


Figure A-18: Development of global natural gas exports and global population from 2000 to 2020.

Table A-21: Natural gas imports 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[bcm]	Share [%]	
			country	cumulative
1	Germany	159.7	12.2	12.2
2	China	138.4	10.6	22.8
3	Japan	104.8	8.0	30.8
4	USA	72.3	5.5	36.4
5	Italy	66.4	5.1	41.5
6	Mexico	63.5	4.9	46.3
7	Netherlands	59.8	4.6	50.9
8	Korea, Rep.	53.6	4.1	55.0
9	Turkey	48.0	3.7	58.7
10	France	46.4	3.6	62.2
11	United Kingdom	43.9	3.4	65.6
12	Belgium	42.7	3.3	68.9
13	India	34.0	2.6	71.5
14	Spain	32.5	2.5	74.0
15	Canada	23.6	1.8	75.8
16	Taiwan	22.7	1.7	77.5
17	U. Arab Emirates	20.4	1.6	79.1
18	Belarus	18.8	1.4	80.5
19	Poland	17.4	1.3	81.8
20	Ukraine	16.8	1.3	83.1
	other countries [55]	220.5	16.9	100.0
	World	1,305.9	100.0	
	Europe	598.6	45.8	
	CIS (+ GEO, UKR)	60.5	4.6	
	Africa	9.3	0.7	
	Middle East	40.8	3.1	
	Austral-Asia	414.0	31.7	
	North America	159.4	12.2	
	Latin America	23.5	1.8	
	OPEC	34.0	2.6	
	OPEC-Gulf	34.0	2.6	
	OECD	918.7	70.3	
	EU-28	544.9	41.7	

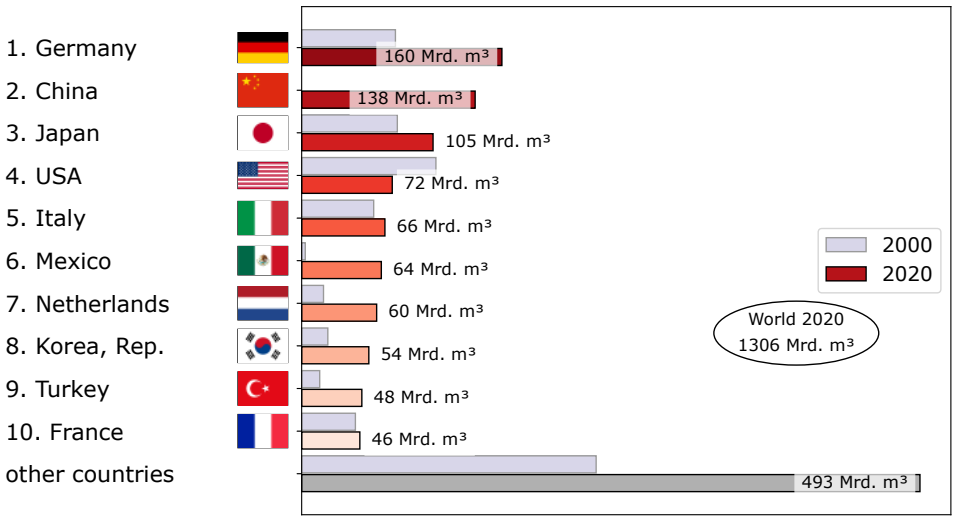


Figure A-19: Natural gas imports − top 10 countries 2020.

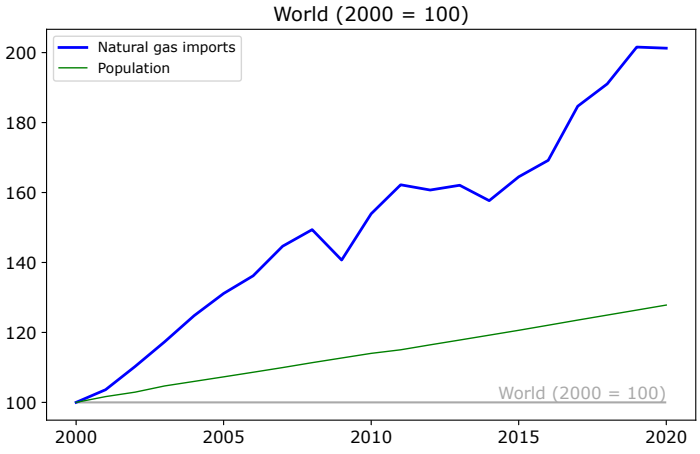


Figure A-20: Development of global natural gas imports and global population from 2000 to 2020.

Table A-22: Hard coal 2020 [Mt]

	Country / Region	Production	Reserves	Resources	Remaining potential
EUROPE	Belgium	–	–	4,100	4,100
	Bulgaria	–	192	3,920	4,112
	Croatia	–	–	4	4
	Czechia	2.1	1,080	15,423	16,503
	France	–	–	160	160
	Germany	–	–	82,965	82,965
	Hungary	–	276	5,075	5,351
	Ireland	–	14	26	40
	Italy	–	10	600	610
	Montenegro	–	142	195	337
	Netherlands	–	497	2,750	3,247
	Norway	0.1	2	84	86
	Poland	54.4	22,464	161,119	183,583
	Portugal	–	3	n. s.	3
	Romania	–	11	2,435	2,446
	Serbia	0.1	402	453	855
	Slovakia	–	–	19	19
	Slovenia	–	56	39	95
	Spain	–	868	3,363	4,231
	Sweden	–	1	4	5
	Turkey	1.1	550	786	1,337
	United Kingdom	1.7	28	186,700	186,728
CIS (+ GEO, UKR)	Armenia	–	163	154	317
	Georgia	–	201	700	901
	Kazakhstan	107.9	25,605	123,090	148,695
	Kyrgyzstan	0.3	971	27,528	28,499
	Russian Federation	327.7	71,719	1,117,389	1,189,108
	Tajikistan	2.0	375	3,700	4,075
	Turkmenistan	–	–	800	800
	Ukraine	22.3	32,039	49,006	81,045
	Uzbekistan	0.2	1,375	9,477	10,852
AFRICA	Algeria	–	59	164	223
	Botswana	1.9	1,660	56,300	57,960
	Congo, DR	–	88	900	988

continuation of table A-22
[Mt]

	Country / Region	Production	Reserves	Resources	Remaining potential
AFRICA	Egypt	–	16	166	182
	Eswatini	0.1	144	4,500	4,644
	Madagascar	–	–	150	150
	Malawi	0.1	2	800	802
	Morocco	–	14	82	96
	Mozambique	8.0	1,792	30,528	32,321
	Namibia	–	–	350	350
	Niger	0.2	–	90	90
	Nigeria	0.2	287	1,857	2,144
	South Africa	252.2	9,893	203,667	213,560
	Tanzania	0.7	269	1,141	1,410
	Uganda	–	–	800	800
	Zambia	1.0	45	900	945
	Zimbabwe	3.3	502	25,000	25,502
	Iran	1.5	1,203	40,000	41,203
AUSTRAL-ASIA	Afghanistan	0.1	66	n. s.	66
	Australia	425.9	75,428	1,548,610	1,624,038
	Bangladesh	0.8	293	2,967	3,260
	Bhutan	0.2	n. s.	n. s.	n. s.
	China	3,580.0	135,475	5,318,118	5,453,593
	India	716.1	106,015	180,560	286,575
	Indonesia	503.7	24,059	67,928	91,988
	Japan	0.8	340	13,543	13,883
	Korea, DPR	20.2	600	10,000	10,600
	Korea, Rep.	1.0	326	1,360	1,686
	Laos	0.1	4	58	62
	Malaysia	3.0	148	840	988
	Mongolia	33.3	1,170	39,854	41,024
	Myanmar	1.9	3	248	252
	Nepal	< 0.05	1	7	8
	New Caledonia	–	2	n. s.	2
	New Zealand	2.5	825	2,350	3,175
	Pakistan	3.5	207	5,789	5,996
	Papua New Guinea	–	–	11	11

continuation of table A-22
[Mt]

	Country / Region	Production	Reserves	Resources	Remaining potential
AUSTRAL-ASIA	Philippines	13.3	303	795	1,098
	Taiwan	–	1	101	102
	Viet Nam	48.4	3,116	3,519	6,635
NORTH AMERICA	Canada	31.8	4,346	183,260	187,606
	Greenland	–	183	200	383
	Mexico	8.8	1,160	3,000	4,160
	USA	441.0	218,497	6,459,507	6,678,004
LATIN AMERICA	Argentina	< 0.05	500	300	800
	Bolivia	–	1	n. s.	1
	Brazil	3.2	1,547	4,665	6,212
	Chile	0.2	1,181	4,135	5,316
	Colombia	49.3	4,554	9,928	14,482
	Costa Rica	–	–	17	17
	Peru	0.1	102	1,465	1,567
	Venezuela	0.4	731	5,981	6,712
	World	6,678.7	756,200	16,188,578	16,944,778
	Europe	59.5	26,596	470,220	496,817
	CIS (+ GEO, UKR)	460.4	132,446	1,331,845	1,464,291
	Africa	267.8	14,770	327,395	342,165
	Middle East	1.5	1,203	40,000	41,203
	Austral-Asia	5,354.8	348,383	7,196,659	7,545,042
	North America	481.6	224,186	6,645,967	6,870,153
	Latin America	53.2	8,616	26,491	35,107
	Antarctica[1]	–	–	150,000	150,000
	OPEC	2.1	2,279	48,002	50,281
	OPEC-Gulf	1.5	1,203	40,000	41,203
	OECD	1,020.7	332,689	8,689,107	9,021,796
	EU-28	58.2	25,500	468,702	494,202

[1] The exploration and production of resources in the Antarctic is prohibited by international law

n. s. not specified
– no production, reserves or resources

Table A-23: Hard coal resources 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	USA	6,459,507	39.9	39.9
2	China	5,318,118	32.9	72.8
3	Australia	1,548,610	9.6	82.3
4	Russian Federation[1]	1,117,389	6.9	89.2
5	South Africa	203,667	1.3	90.5
6	United Kingdom	186,700	1.2	91.6
7	Canada	183,260	1.1	92.8
8	India	180,560	1.1	93.9
9	Poland	161,119	1.0	94.9
10	Kazakhstan	123,090	0.8	95.6
11	Germany	82,965	0.5	96.1
12	Indonesia	67,928	0.4	96.6
13	Botswana	56,300	0.3	96.9
14	Ukraine[1]	49,006	0.3	97.2
15	Iran	40,000	0.2	97.5
16	Mongolia[1]	39,854	0.2	97.7
17	Mozambique	30,528	0.2	97.9
18	Kyrgyzstan	27,528	0.2	98.1
19	Zimbabwe	25,000	0.2	98.2
20	Czechia[1]	15,423	0.1	98.3
	other countries [59]	272,024	1.7	100.0
	World	16,188,578	100.0	
	Europe	470,220	2.9	
	CIS (+ GEO, UKR)	1,331,845	8.2	
	Africa	327,395	2.0	
	Middle East	40,000	0.2	
	Austral-Asia	7,196,659	44.5	
	North America	6,645,967	41.1	
	Latin America	26,491	0.2	
	Antarctica[2]	150,000	0.9	
	OPEC	48,002	0.3	
	OPEC-Gulf	40,000	0.2	
	OECD	8,689,107	53.7	
	EU-28	468,702	2.9	

[1] Hard coal resources contains only bituminous coal and anthracite according to national classification

[2] The exploration and production of resources in the Antarctic is prohibited by international law

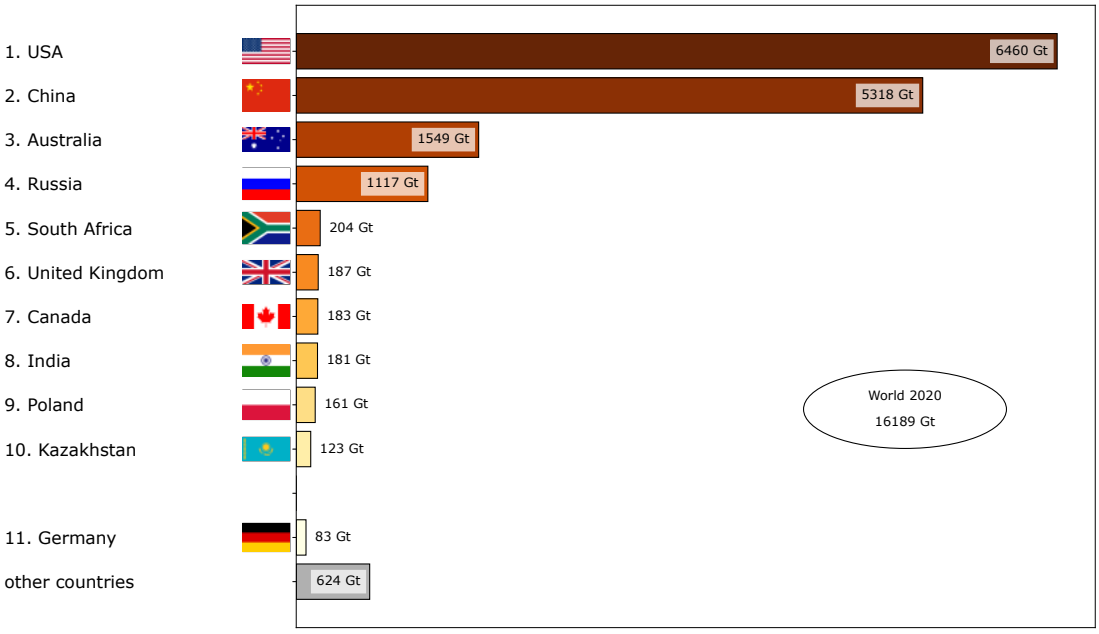


Figure A-21: Hard coal resources 2020.

Table A-24: Hard coal reserves 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	USA	218,497	28.9	28.9
2	China	135,475	17.9	46.8
3	India	106,015	14.0	60.8
4	Australia	75,428	10.0	70.8
5	Russian Federation[1]	71,719	9.5	80.3
6	Ukraine[1]	32,039	4.2	84.5
7	Kazakhstan	25,605	3.4	87.9
8	Indonesia	24,059	3.2	91.1
9	Poland	22,464	3.0	94.1
10	South Africa	9,893	1.3	95.4
11	Colombia	4,554	0.6	96.0
12	Canada	4,346	0.6	96.5
13	Viet Nam	3,116	0.4	97.0
14	Mozambique	1,792	0.2	97.2
15	Botswana	1,660	0.2	97.4
16	Brazil	1,547	0.2	97.6
17	Uzbekistan	1,375	0.2	97.8
18	Iran	1,203	0.2	98.0
19	Chile	1,181	0.2	98.1
20	Mongolia[1]	1,170	0.2	98.3
	other countries [50]	13,063	1.7	100.0
	World	756,200	100.0	
	Europe	26,596	3.5	
	CIS (+ GEO, UKR)	132,446	17.5	
	Africa	14,770	2.0	
	Middle East	1,203	0.2	
	Austral-Asia	348,383	46.1	
	North America	224,186	29.6	
	Latin America	8,616	1.1	
	OPEC	2,279	0.3	
	OPEC-Gulf	1,203	0.2	
	OECD	332,689	44.0	
	EU-28	25,500	3.4	

[1] Hard coal reserves contains only bituminous coal and anthracite according to national classification

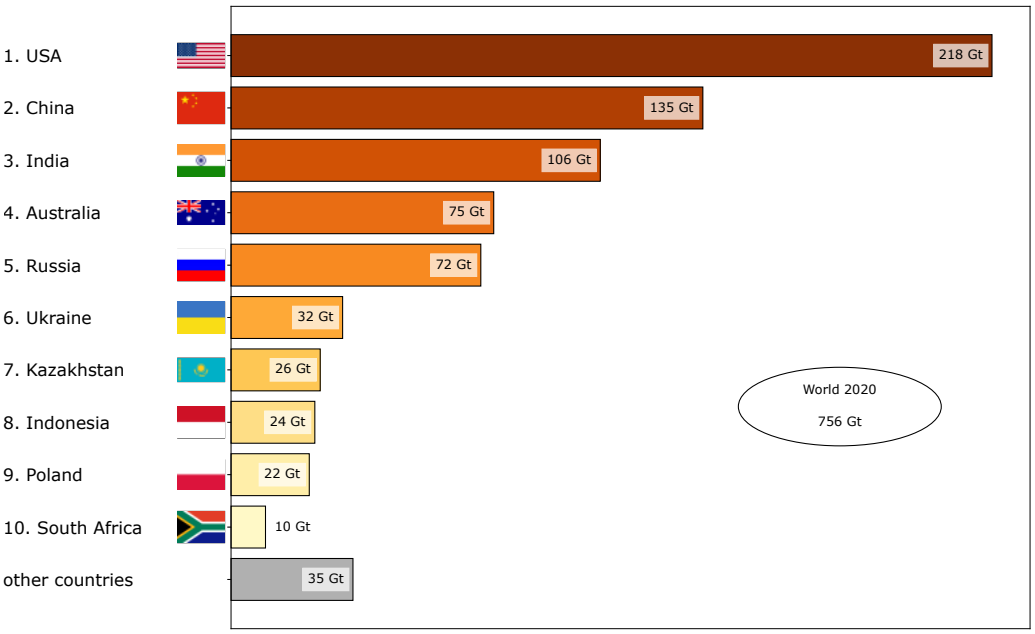


Figure A-22: Hard coal reserves 2020.

Table A-25: Hard coal production 2015 to 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2015	2016	2017	2018	2019	2020	Share [%]		Changes	
		[Mt]						country	cum.	2019/2020	[%]
1	China	3,540.5	3,225.6	3,333.6	3,345.9	3,505.5	3,580.0	53.6	53.6	74.5	2.1
2	India	639.2	657.9	675.4	728.7	730.9	716.1	10.7	64.3	-14.8	-2.0
3	Indonesia	401.6	396.2	401.2	497.8	556.0	503.7	7.5	71.9	-52.3	-9.4
4	USA	749.4	596.1	641.3	634.2	592.5	441.0	6.6	78.5	-151.5	-25.6
5	Australia	440.0	443.4	435.9	457.3	463.0	425.9	6.4	84.8	-37.1	-8.0
6	Russian Federation[1]	300.1	312.0	333.9	352.6	355.0	327.7	4.9	89.8	-27.3	-7.7
7	South Africa	252.2	250.6	252.3	253.3	258.9	252.2	3.8	93.5	-6.7	-2.6
8	Kazakhstan	101.8	97.3	106.2	111.9	109.1	107.9	1.6	95.1	-1.2	-1.1
9	Poland	72.7	70.8	66.0	63.9	62.1	54.4	0.8	96.0	-7.7	-12.4
10	Colombia	86.5	91.1	91.3	86.3	84.3	49.3	0.7	96.7	-35.0	-41.5
11	Viet Nam	41.7	38.7	38.4	42.4	47.2	48.4	0.7	97.4	1.2	2.6
12	Mongolia[1]	18.2	28.4	42.7	45.5	46.9	33.3	0.5	97.9	-13.6	-29.0
13	Canada	44.0	40.9	42.4	37.7	37.2	31.8	0.5	98.4	-5.4	-14.6
14	Ukraine[1]	34.5	31.6	24.2	26.3	25.5	22.3	0.3	98.7	-3.2	-12.7
15	Korea, DPR[2]	27.5	31.1	21.7	18.1	20.2	20.2	0.3	99.0	0.0	0.0
16	Philippines	8.2	12.1	13.3	13.1	15.3	13.3	0.2	99.2	-2.0	-12.9
17	Mexico	10.2	12.1	11.4	10.5	8.6	8.8	0.1	99.4	0.2	2.7
18	Mozambique	6.6	6.2	11.8	15.2	10.3	8.0	0.1	99.5	-2.3	-22.2
19	Pakistan	3.4	3.1	3.0	4.3	4.4	3.5	0.1	99.5	-0.9	-20.5
20	Zimbabwe	4.3	1.6	2.9	3.3	2.7	3.3	< 0.05	99.6	0.6	20.9
	other countries [31]	56.3	45.1	44.8	41.6	34.7	27.6	0.4	100.0	-7.1	-20.5
	World	6,838.8	6,391.9	6,593.5	6,789.9	6,970.3	6,678.7	100.0		-291.6	-4.2
	Europe	102.0	89.9	82.7	77.5	69.5	59.5	0.9		-10.1	-14.5
	CIS (+ GEO, UKR)	438.4	443.0	466.8	493.1	492.2	460.4	6.9		-31.8	-6.5
	Africa	266.5	262.8	271.6	276.7	276.5	267.8	4.0		-8.7	-3.2
	Middle East	1.5	1.3	1.6	1.7	1.5	1.5	< 0.05		0.0	-0.2
	Austral-Asia	5,131.6	4,847.8	4,977.9	5,165.7	5,401.9	5,354.8	80.2		-47.2	-0.9
	North America	803.7	649.1	695.1	682.4	638.3	481.6	7.2		-156.7	-24.6
	Latin America	95.2	98.0	97.8	92.6	90.3	53.2	0.8		-37.1	-41.1
	OPEC	2.4	2.8	2.4	2.3	2.1	2.1	< 0.05		0.0	-0.2
	OPEC-Gulf	1.5	1.3	1.6	1.7	1.5	1.5	< 0.05		0.0	-0.2
	OECD	1,441.2	1,281.6	1,312.7	1,310.8	1,261.3	1,020.7	15.3		-240.6	-19.1
	EU-28	99.3	87.6	81.2	76.2	68.1	58.2	0.9		-9.9	-14.5

[1] Hard coal production contains only bituminous coal and anthracite according to national classification

[2] Data preliminary

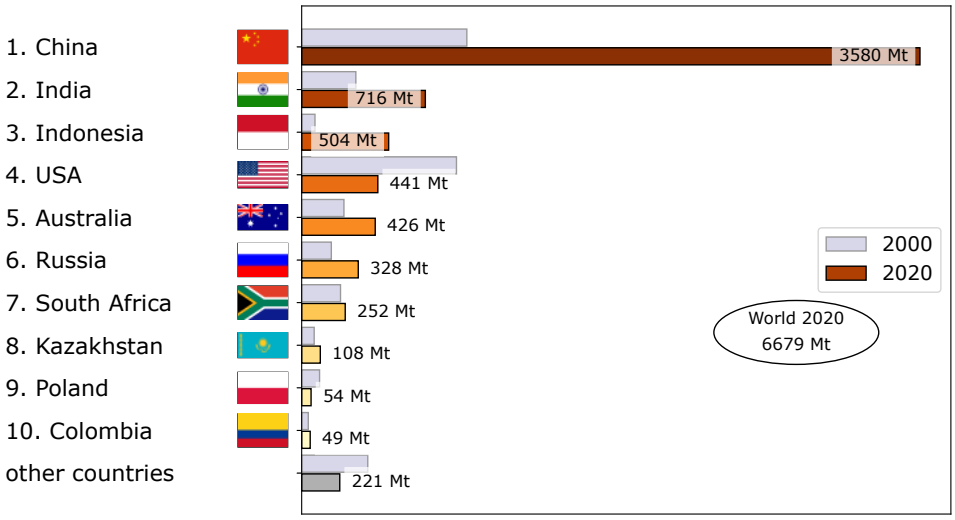


Figure A-23: Hard coal production − top 10 countries 2000 and 2020.

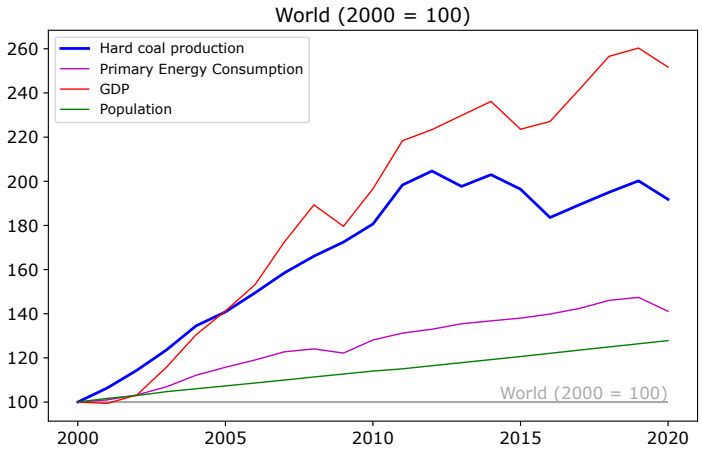


Figure A-24: Development of global hard coal production, primary energy consumption, gross domestic product (GDP) and global population from 2000 to 2020.

Table A-26: Hard coal consumption 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	China	3,880.8	57.5	57.5
2	India	930.3	13.8	71.2
3	USA	432.4	6.4	77.7
4	South Africa	179.4	2.7	80.3
5	Japan	174.5	2.6	82.9
6	Russian Federation	151.0	2.2	85.1
7	Korea, Rep.	116.6	1.7	86.9
8	Indonesia	105.7	1.6	88.4
9	Viet Nam	101.5	1.5	89.9
10	Kazakhstan	83.0	1.2	91.2
11	Taiwan	63.5	0.9	92.1
12	Poland	62.6	0.9	93.0
13	Australia	54.9	0.8	93.8
14	Turkey	41.0	0.6	94.4
15	Ukraine	38.8	0.6	95.0
16	Malaysia	36.0	0.5	95.5
17	Philippines	34.7	0.5	96.1
18	Germany	30.2	0.4	96.5
19	Thailand	23.8	0.4	96.9
20	Korea, DPR	20.7	0.3	97.2
	other countries [87]	191.1	2.8	100.0
	World	6,752.5	100.0	
	Europe	190.3	2.8	
	CIS (+ GEO, UKR)	277.6	4.1	
	Africa	201.3	3.0	
	Middle East	13.1	0.2	
	Austral-Asia	5,589.9	82.8	
	North America	444.0	6.6	
	Latin America	36.3	0.5	
	OPEC	5.1	0.1	
	OPEC-Gulf	4.6	0.1	
	OECD	997.6	14.8	
	EU-28	146.3	2.2	

[1] Hard coal consumption contains only bituminous coal and anthracite according to national classification

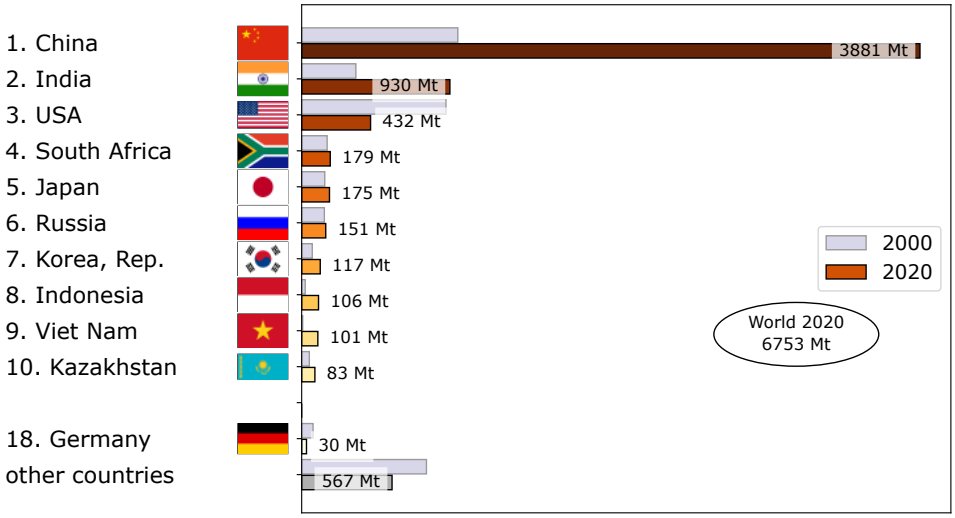


Figure A-25: Hard coal consumption − top 10 countries 2000 and 2020.

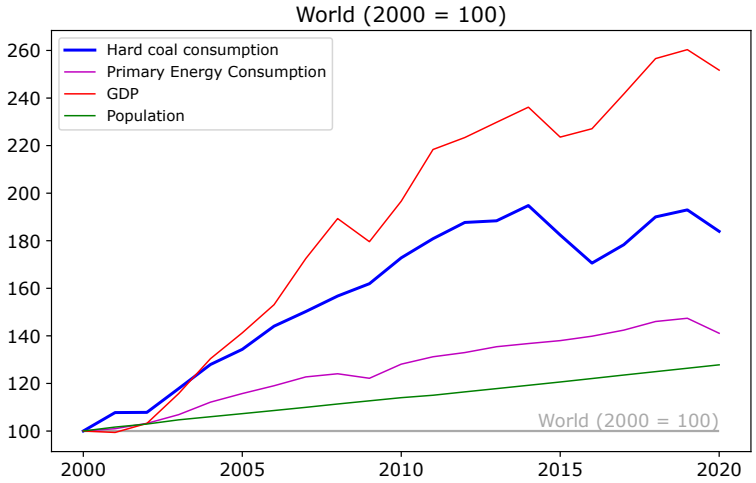


Figure A-26: Development of global hard coal consumption, primary energy consumption, gross domestic product (GDP) and global population from 2000 to 2020.

Table A-27: Hard coal exports 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	Indonesia	406.7	31.5	31.5
2	Australia	371.3	28.8	60.3
3	Russian Federation	199.1	15.4	75.8
4	South Africa	74.8	5.8	81.6
5	USA	62.7	4.9	86.4
6	Colombia	52.1	4.0	90.4
7	Canada	36.0	2.8	93.2
8	Mongolia	31.2	2.4	95.7
9	Kazakhstan	25.0	1.9	97.6
10	Mozambique	8.0	0.6	98.2
11	Philippines	7.6	0.6	98.8
12	Poland	4.6	0.4	99.2
13	China	3.2	0.2	99.4
14	United Kingdom	1.3	0.1	99.5
15	New Zealand	1.1	0.1	99.6
16	Viet Nam	0.9	0.1	99.7
17	Czechia	0.8	0.1	99.7
18	India	0.8	0.1	99.8
19	Kyrgyzstan	0.8	0.1	99.9
20	Ukraine	0.5	< 0.05	99.9
	other countries [8]	1.4	0.1	100.0
	World	1,290.0	100.0	
	Europe	6.9	0.5	
	CIS (+ GEO, UKR)	225.4	17.5	
	Africa	83.2	6.4	
	Middle East	0.1	< 0.05	
	Austral-Asia	823.2	63.8	
	North America	98.7	7.6	
	Latin America	52.6	4.1	
	OPEC	0.2	< 0.05	
	OPEC-Gulf	0.1	< 0.05	
	OECD	530.1	41.1	
	EU-28	6.7	0.5	

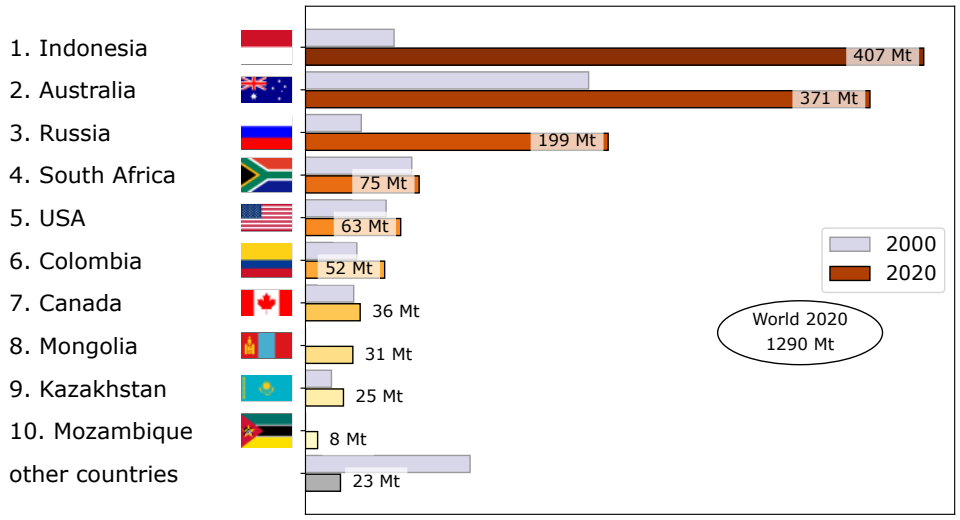


Figure A-27: Hard coal exports − top 10 countries 2000 and 2020.

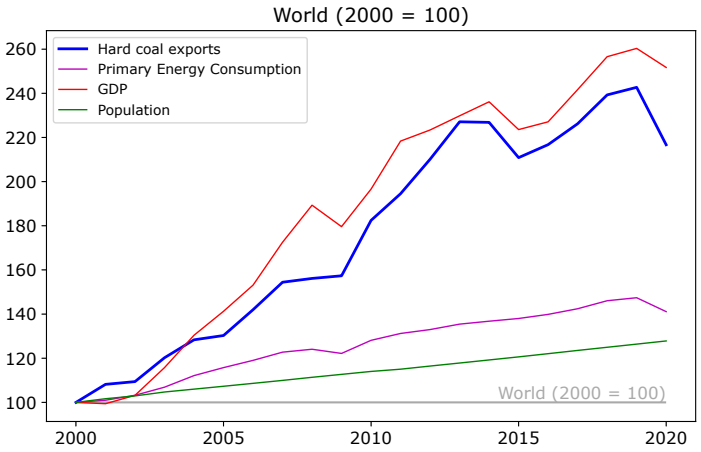


Figure A-28: Development of global hard coal exports, primary energy consumption, gross domestic product (GDP) and global population from 2000 to 2020.

Table A-28: Hard coal imports 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	China	304.0	23.1	23.1
2	India	215.0	16.3	39.4
3	Japan	173.7	13.2	52.6
4	Korea, Rep.	122.4	9.3	61.9
5	Taiwan	63.3	4.8	66.7
6	Viet Nam	54.0	4.1	70.8
7	Turkey	40.1	3.0	73.8
8	Malaysia	33.0	2.5	76.3
9	Germany	30.2	2.3	78.6
10	Philippines	29.0	2.2	80.8
11	Thailand	23.7	1.8	82.6
12	Russian Federation	22.4	1.7	84.3
13	Ukraine	17.0	1.3	85.6
14	Brazil	16.1	1.2	86.8
15	Pakistan	16.1	1.2	88.0
16	Poland	12.8	1.0	89.0
17	Chile	10.6	0.8	89.8
18	Morocco	10.0	0.8	90.6
19	Indonesia	8.8	0.7	91.2
20	Israel	7.7	0.6	91.8
	other countries [75]	107.7	8.2	100.0
	World	1,317.5	100.0	
	Europe	137.4	10.4	
	CIS (+ GEO, UKR)	42.7	3.2	
	Africa	16.7	1.3	
	Middle East	11.7	0.9	
	Austral-Asia	1,064.5	80.8	
	North America	11.6	0.9	
	Latin America	32.8	2.5	
	OPEC	3.2	0.2	
	OPEC-Gulf	3.2	0.2	
	OECD	461.3	35.0	
	EU-28	94.5	7.2	

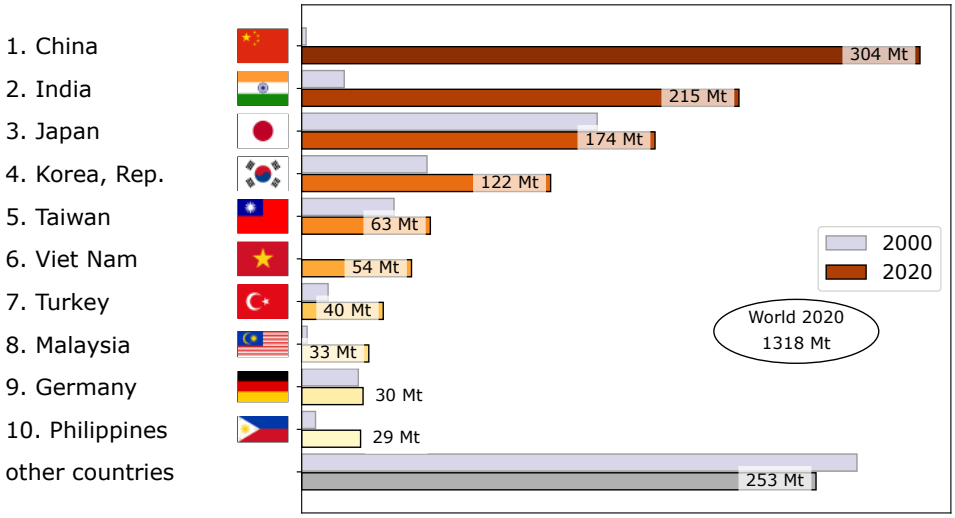


Figure A-29: Hard coal imports − top 10 countries 2000 and 2020.

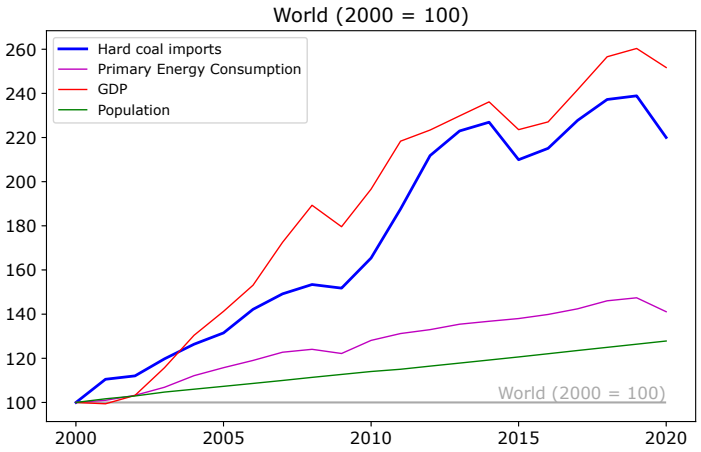


Figure A-30: Development of global hard coal imports, primary energy consumption, gross domestic product (GDP) and global population from 2000 to 2020.

Table A-29: Lignite 2020 [Mt]

	Country / Region	Production	Reserves	Resources	Remaining potential
EUROPE	Albania	0.2	522	205	727
	Austria	–	–	333	333
	Bosnia & Herzegovina	13.6	2,264	3,010	5,274
	Bulgaria	22.3	2,174	2,400	4,574
	Croatia	–	n. s.	41	41
	Czechia	29.5	2,458	7,064	9,522
	France	–	n. s.	114	114
	Germany	107.4	35,700	36,500	72,200
	Greece	13.9	2,876	3,554	6,430
	Hungary	6.1	2,633	2,704	5,337
	Italy	–	7	22	29
	Kosovo	8.5	1,564	9,262	10,826
	Macedonia	5.0	332	300	632
	Montenegro	1.7	n. s.	n. s.	n. s.
	Poland	46.0	5,752	222,393	228,145
	Portugal	–	33	33	66
	Romania	15.0	280	9,640	9,920
	Serbia	39.7	7,112	13,074	20,186
	Slovakia	1.0	135	938	1,073
	Slovenia	3.2	315	341	656
	Spain	–	319	n. s.	319
	Turkey	71.2	10,975	5,284	16,259
	United Kingdom	–	–	1,000	1,000
CIS (+ GEO, UKR)	Belarus	–	–	1,500	1,500
	Georgia	0.1	–	–	–
	Kazakhstan	5.3	n. s.	n. s.	n. s.
	Kyrgyzstan	2.1	n. s.	n. s.	n. s.
	Russian Federation	73.3	90,447	541,353	631,800
	Tajikistan	0.1	n. s.	n. s.	n. s.
	Ukraine	–	2,336	5,381	7,717
	Uzbekistan	3.7	n. s.	n. s.	n. s.

continuation of table A-29
[Mt]

	Country / Region	Production	Reserves	Resources	Remaining potential
AFRICA	Central African Rep.	–	3	n. s.	3
	Ethiopia	< 0.05	n. s.	n. s.	n. s.
	Madagascar	–	–	37	37
	Mali	–	–	3	3
	Morocco	–	–	40	40
	Niger	–	6	n. s.	6
	Nigeria	–	57	320	377
	Sierra Leone	–	–	2	2
AUSTRAL-ASIA	Australia	40.4	73,865	403,720	477,585
	Bangladesh	–	–	3	3
	China	260.0	8,250	323,849	332,099
	India	36.6	5,031	39,231	44,262
	Indonesia	60.0	14,746	36,997	51,743
	Japan	–	10	1,026	1,036
	Korea, DPR	6.0	n. s.	n. s.	n. s.
	Laos	14.4	499	22	521
	Malaysia	–	78	817	896
	Mongolia	9.8	1,350	119,426	120,776
	Myanmar	0.8	3	2	5
	New Zealand	0.3	6,750	4,600	11,350
	Pakistan	1.4	2,857	176,739	179,596
	Philippines	–	147	975	1,122
	Thailand	13.3	1,063	826	1,889
	Viet Nam	–	244	199,876	200,120
NORTH AMERICA	Canada	7.2	2,236	118,270	120,506
	Mexico	–	51	n. s.	51
	USA	44.8	29,910	1,368,149	1,398,059
LATIN AMERICA	Argentina	–	–	7,300	7,300
	Brazil	2.3	5,049	12,587	17,636
	Chile	–	n. s.	7	7
	Dominican Rep.	–	–	84	84
	Ecuador	–	24	n. s.	24
	Haiti	–	–	40	40
	Peru	–	–	100	100

continuation of table A-29
[Mt]

Country / Region	Production	Reserves	Resources	Remaining potential
World	965.9	320,462	3,681,493	4,001,955
Europe	384.3	75,451	318,212	393,663
CIS (+ GEO, UKR)	84.5	92,783	548,234	641,016
Africa	< 0.05	66	402	468
Middle East	–	–	–	–
Austral-Asia	442.8	114,892	1,308,110	1,423,002
North America	52.0	32,197	1,486,419	1,518,616
Latin America	2.3	5,073	20,118	25,191
OPEC	–	57	320	377
OPEC-Gulf	–	–	–	–
OECD	370.9	174,025	2,176,052	2,350,077
EU-28	244.3	52,682	287,077	339,759

n. s. not specified
– no production, reserves or resources

Table A-30: Lignite resources 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	USA	1,368,149	37.2	37.2
2	Russian Federation[1]	541,353	14.7	51.9
3	Australia	403,720	11.0	62.8
4	China	323,849	8.8	71.6
5	Poland	222,393	6.0	77.7
6	Viet Nam	199,876	5.4	83.1
7	Pakistan	176,739	4.8	87.9
8	Mongolia[1]	119,426	3.2	91.1
9	Canada	118,270	3.2	94.4
10	India	39,231	1.1	95.4
11	Indonesia	36,997	1.0	96.4
12	Germany	36,500	1.0	97.4
13	Serbia	13,074	0.4	97.8
14	Brazil	12,587	0.3	98.1
15	Romania	9,640	0.3	98.4
16	Kosovo	9,262	0.3	98.6
17	Argentina	7,300	0.2	98.8
18	Czechia[1]	7,064	0.2	99.0
19	Ukraine	5,381	0.1	99.2
20	Turkey	5,284	0.1	99.3
	other countries [32]	25,398	0.7	100.0
	World	3,681,493	100.0	
	Europe	318,212	8.6	
	CIS (+ GEO, UKR)	548,234	14.9	
	Africa	402	< 0.05	
	Austral-Asia	1,308,110	35.5	
	North America	1,486,419	40.4	
	Latin America	20,118	0.5	
	OPEC	320	< 0.05	
	OECD	2,176,052	59.1	
	EU-28	287,077	7.8	

[1] Lignite resources contains subbituminous coal

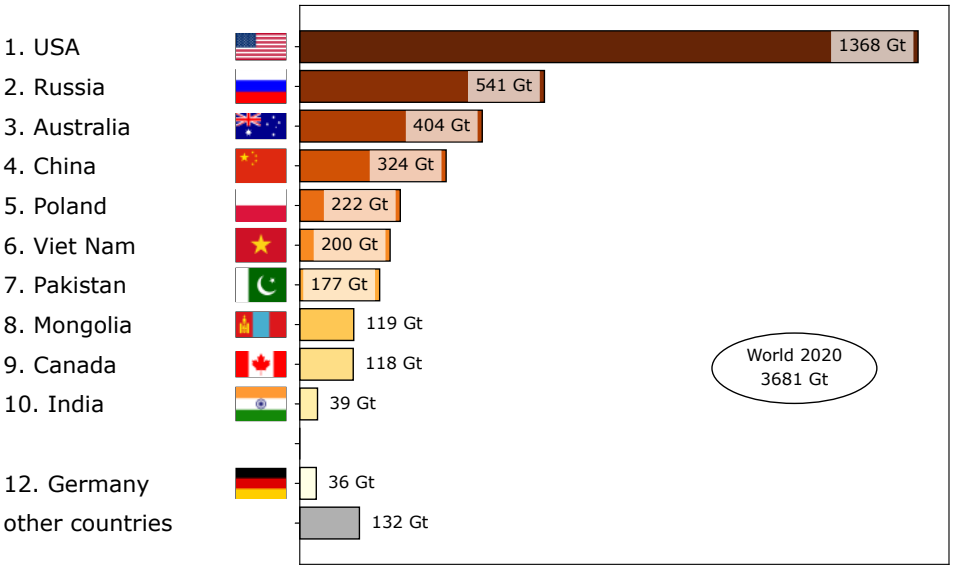


Figure A-31: Lignite resources – top 10 countries 2020.

Table A-31: Lignite reserves 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	Russian Federation[1]	90,447	28.2	28.2
2	Australia	73,865	23.0	51.3
3	Germany	35,700	11.1	62.4
4	USA	29,910	9.3	71.7
5	Indonesia	14,746	4.6	76.3
6	Turkey	10,975	3.4	79.8
7	China	8,250	2.6	82.3
8	Serbia	7,112	2.2	84.6
9	New Zealand	6,750	2.1	86.7
10	Poland	5,752	1.8	88.5
11	Brazil	5,049	1.6	90.0
12	India	5,031	1.6	91.6
13	Greece	2,876	0.9	92.5
14	Pakistan	2,857	0.9	93.4
15	Hungary	2,633	0.8	94.2
16	Czechia[1]	2,458	0.8	95.0
17	Ukraine	2,336	0.7	95.7
18	Bosnia & Herzegovina[1]	2,264	0.7	96.4
19	Canada	2,236	0.7	97.1
20	Bulgaria	2,174	0.7	97.8
	other countries [22]	7,041	2.2	100.0
	World	320,462	100.0	
	Europe	75,451	23.5	
	CIS (+ GEO, UKR)	92,783	29.0	
	Africa	66	< 0.05	
	Austral-Asia	114,892	35.9	
	North America	32,197	10.0	
	Latin America	5,073	1.6	
	OPEC	57	< 0.05	
	OECD	174,025	54.3	
	EU-28	52,682	16.4	

[1] Lignite reserves contains subbituminous coal

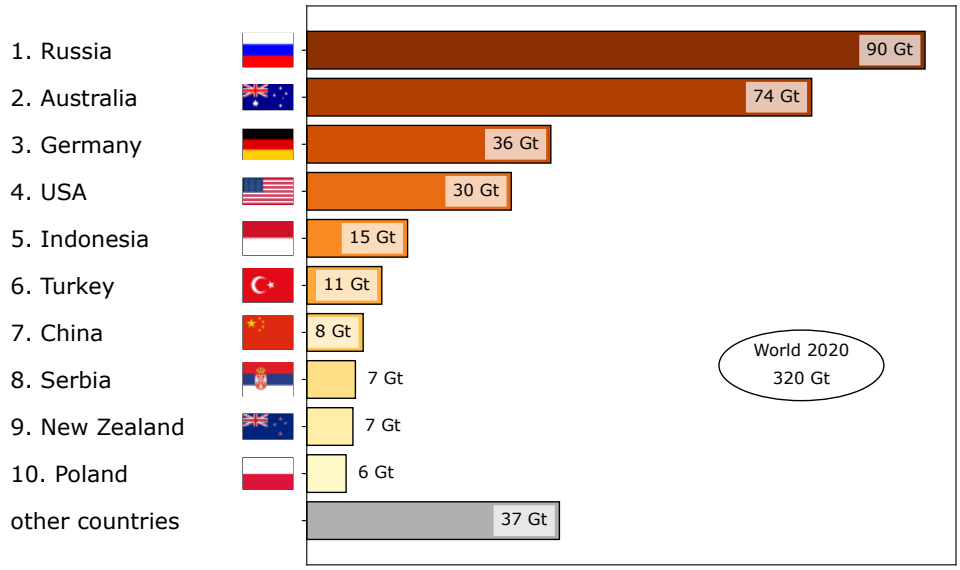


Figure A-32: Lignite reserves − top 10 countries 2020.

Table A-32: Lignite production 2015 to 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2015	2016	2017	2018	2019	2020	Share [%]		Changes	
				[Mt]				country	cum.	2019/2020	[%]
1	China	206.0	185.0	190.0	200.0	240.0	260.0	26.9	26.9	20.0	8.3
2	Germany	178.1	171.5	171.3	166.3	131.3	107.4	11.1	38.0	-23.9	-18.2
3	Russian Federation[1]	73.2	73.7	75.0	81.4	82.2	73.3	7.6	45.6	-8.9	-10.8
4	Turkey	56.1	70.2	71.5	81.1	83.7	71.2	7.4	53.0	-12.5	-14.9
5	Indonesia[1]	60.0	60.0	60.0	60.0	60.0	60.0	6.2	59.2	0.0	0.0
6	Poland	63.1	60.2	61.2	58.6	50.3	46.0	4.8	64.0	-4.3	-8.6
7	USA	64.3	64.7	61.4	51.7	48.3	44.8	4.6	68.6	-3.5	-7.2
8	Australia	61.0	59.8	56.1	45.1	42.3	40.4	4.2	72.8	-1.9	-4.5
9	Serbia[1]	37.7	38.4	39.8	37.6	38.9	39.7	4.1	76.9	0.8	2.1
10	India	43.8	45.2	46.6	44.3	42.1	36.6	3.8	80.7	-5.5	-13.0
11	Czechia[1]	38.1	38.5	39.3	39.2	37.5	29.5	3.1	83.7	-8.0	-21.3
12	Bulgaria[1]	35.9	31.2	34.4	30.3	28.0	22.3	2.3	86.1	-5.7	-20.4
13	Romania[1]	25.5	23.0	25.7	23.6	21.7	15.0	1.6	87.6	-6.7	-30.7
14	Laos	4.5	13.1	13.4	15.9	15.3	14.4	1.5	89.1	-0.9	-5.9
15	Greece	46.2	32.6	37.7	36.1	27.3	13.9	1.4	90.5	-13.4	-49.1
16	Bosnia & Herzegovina[1]	12.2	13.6	13.8	14.5	13.2	13.6	1.4	91.9	0.4	3.1
17	Thailand	15.2	17.0	16.3	14.9	14.1	13.3	1.4	93.3	-0.8	-5.9
18	Mongolia	5.8	6.7	6.8	9.1	10.2	9.8	1.0	94.3	-0.5	-4.6
19	Kosovo	8.2	8.8	7.6	7.2	8.1	8.5	0.9	95.2	0.5	5.9
20	Canada	9.2	9.2	9.2	8.7	8.8	7.2	0.7	95.9	-1.7	-18.8
	other countries [17]	45.1	44.6	41.5	41.9	40.6	39.1	4.1	100.0	-1.5	-3.6
	World	1,089.0	1,067.2	1,078.4	1,067.4	1,043.7	965.9	100.0		-77.8	-7.5
	Europe	523.4	509.2	522.1	514.1	458.5	384.3	39.8		-74.2	-16.2
	CIS (+ GEO, UKR)	84.3	85.3	87.1	94.4	94.4	84.5	8.8		-9.8	-10.4
	Africa	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05		0.0	0.0
	Austral-Asia	404.3	395.3	397.1	397.1	432.1	442.8	45.8		10.7	2.5
	North America	73.4	73.9	70.5	60.4	57.1	52.0	5.4		-5.1	-9.0
	Latin America	3.6	3.5	1.5	1.4	1.6	2.3	0.2		0.7	44.6
	OECD	530.8	521.5	521.0	499.7	441.2	370.9	38.4		-70.3	-15.9
	EU-28	401.2	371.5	382.7	366.7	307.5	244.3	25.3		-63.1	-20.5

[1] Lignite production contains subbituminous coal

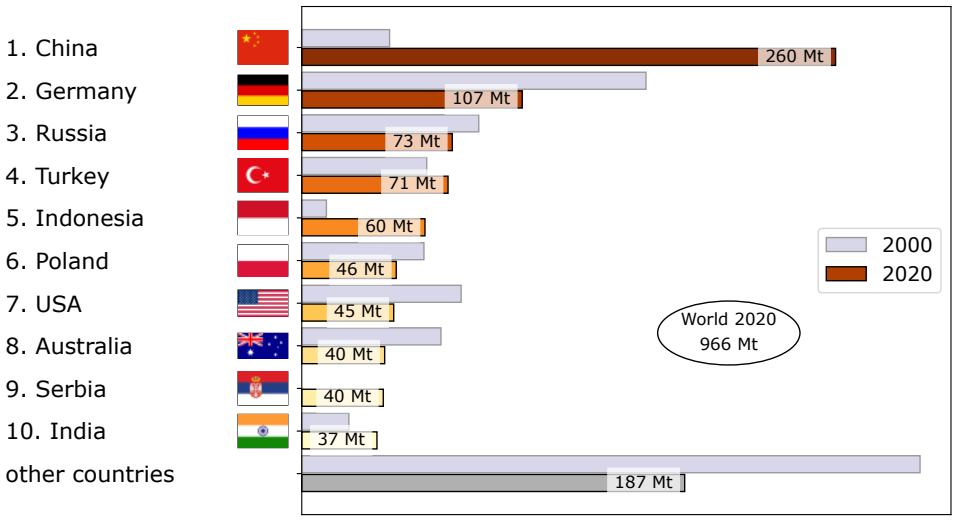


Figure A-33: Lignite production − top 10 countries 2000 and 2020.

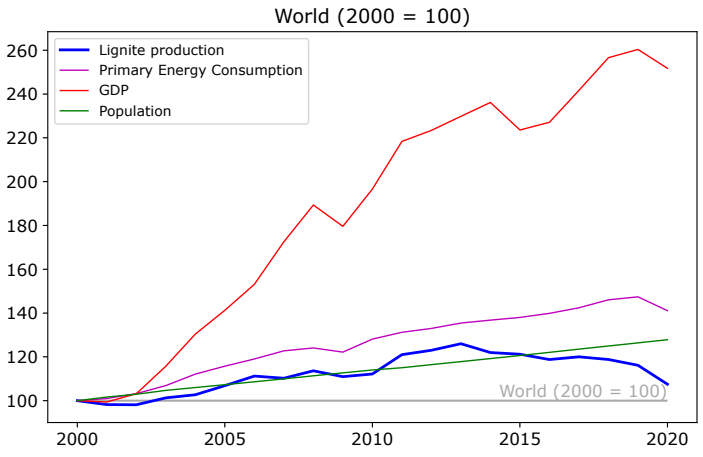


Figure A-34: Development of global lignite production, primary energy consumption, gross domestic product (GDP) and global population from 2000 to 2020.

Table A-33: Lignite consumption 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	China	260.0	26.9	26.9
2	Germany	107.4	11.1	38.0
3	Russian Federation[1]	73.3	7.6	45.6
4	Turkey	71.2	7.4	53.0
5	Indonesia[1]	60.0	6.2	59.2
6	Poland	46.0	4.8	64.0
7	USA	44.8	4.6	68.6
8	Australia	40.4	4.2	72.8
9	Serbia[1]	39.7	4.1	76.9
10	India	36.6	3.8	80.7
11	Czechia	29.5	3.1	83.7
12	Bulgaria[1]	22.3	2.3	86.0
13	Romania[1]	15.0	1.6	87.6
14	Laos	14.4	1.5	89.1
15	Greece	13.9	1.4	90.5
16	Bosnia & Herzegovina[1]	13.6	1.4	91.9
17	Thailand	13.4	1.4	93.3
18	Mongolia	9.8	1.0	94.3
19	Kosovo[1]	8.5	0.9	95.2
20	Canada	7.2	0.7	95.9
	other countries [17]	39.1	4.1	100.0
	World	966.1	100.0	
	Europe	384.3	39.8	
	CIS (+ GEO, UKR)	84.5	8.7	
	Africa	< 0.05	< 0.05	
	Austral-Asia	443.0	45.9	
	North America	52.0	5.4	
	Latin America	2.3	0.2	
	OECD	370.9	38.4	
	EU-28	244.3	25.3	

[1] Lignite consumption contains subbituminous coal

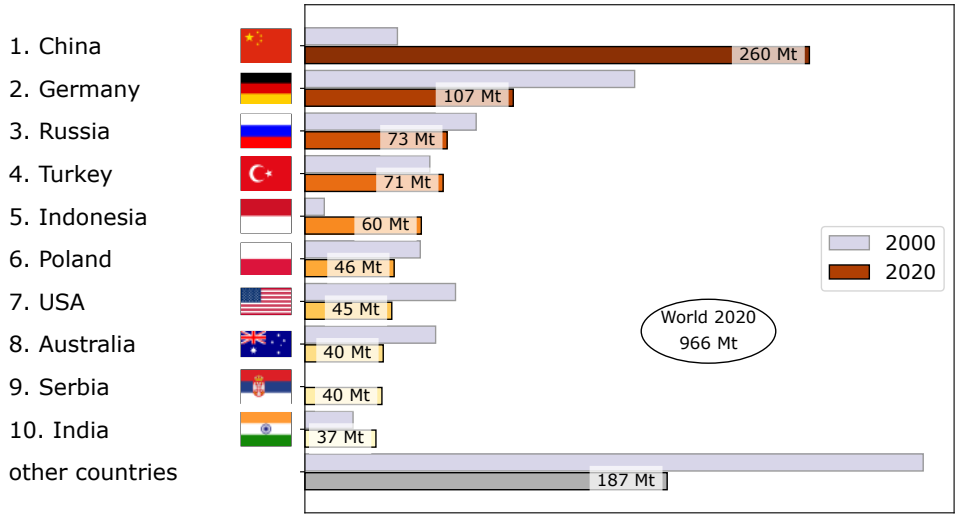


Figure A-35: Lignite consumption − top 10 countries 2000 and 2020.

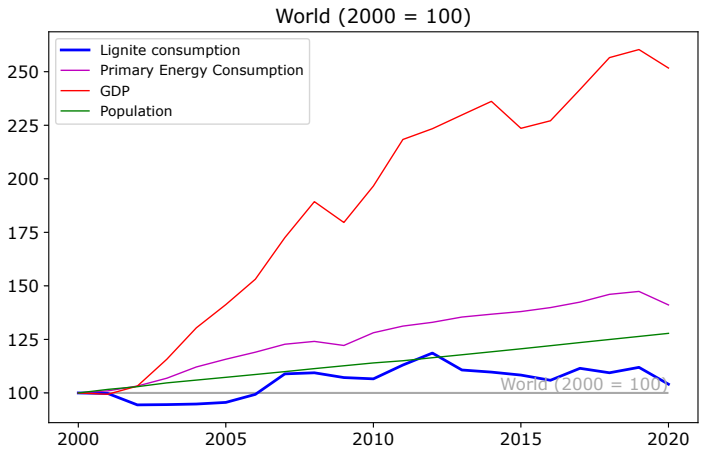


Figure A-36: Development of global lignitelconsumption, primary energy consumption, gross domestic product (GDP) and global population from 2000 to 2020.

Table A-34: Uranium 2020 [kt]

	Country / Region	Production	Cum. production	Reserves	Resources	EUR	Remaining potential
EUROPE	Bulgaria	–	–	–	25	25	25
	Czechia	< 0.05	112	–	342	454	342
	Finland	n. s.	< 0.5	–	1	1	1
	France	< 0.05	76	–	12	88	12
	Germany	< 0.05	220	–	7	227	7
	Greece	–	–	–	13	13	13
	Hungary	n. s.	21	–	27	48	27
	Italy	–	–	5	11	16	16
	Portugal	–	4	5	4	12	9
	Romania	< 0.05	19	–	13	32	13
	Slovakia	n. s.	–	9	18	26	26
	Slovenia	n. s.	–	2	9	10	10
	Spain	–	5	19	9	34	29
	Sweden	n. s.	< 0.5	–	10	10	10
	Turkey	–	–	–	14	14	14
CIS (+ GEO, UKR)	Kazakhstan	19.5	382	344	921	1,647	1,265
	Russian Federation	2.8	176	23	1,348	1,548	1,371
	Ukraine	0.4	25	46	283	354	329
	Uzbekistan	3.5	66	31	127	223	157
AFRICA	Algeria	–	–	–	20	20	20
	Botswana	–	–	–	87	87	87
	Central African Rep.	–	–	–	32	32	32
	Chad	–	–	–	2	2	2
	Congo, DR	–	26	–	3	28	3
	Egypt	–	–	–	3	3	3
	Gabon	n. s.	25	–	6	31	6
	Malawi	< 0.05	4	–	14	19	14
	Mali	–	–	–	9	9	9
	Mauritania	–	–	–	24	24	24
	Namibia	5.4	148	–	561	710	561
	Niger	3.0	156	10	494	660	504
	Senegal	–	–	–	1	1	1
	Somalia	–	–	–	8	8	8
	South Africa	0.3	162	166	851	1,180	1,018
	Tanzania	–	–	38	20	58	58

continuation of table A-34
[kt]]

	Country / Region	Production	Cum. production	Reserves	Resources	EUR	Remaining potential
AFRICA	Zambia	–	< 0.5	–	61	61	61
	Zimbabwe	–	–	–	26	26	26
MIDDLE EAST	Iran	0.1	< 0.5	–	17	18	17
	Jordan	–	–	–	103	103	103
AUSTRAL-ASIA	Australia	6.2	231	–	2,049	2,280	2,049
	China	1.9	50	65	213	327	277
	India	0.4	14	–	323	337	323
	Indonesia	–	–	2	37	39	39
	Japan	n. s.	< 0.5	–	7	7	7
	Mongolia	–	1	33	1,442	1,476	1,476
	Pakistan	< 0.05	2	–	–	2	–
	Viet Nam	–	–	–	85	85	85
NORTH AMERICA	Canada	3.9	542	259	1,465	2,265	1,723
	Greenland	–	–	–	164	164	164
	Mexico	n. s.	< 0.5	–	8	8	8
	USA	< 0.05	378	14	88	480	102
LATIN AMERICA	Argentina	–	3	5	128	136	133
	Brazil	< 0.05	4	156	421	581	577
	Chile	–	–	–	4	4	4
	Colombia	–	–	–	228	228	228
	Paraguay	–	–	–	4	4	4
	Peru	–	–	14	59	73	73
	World	47.4	2,850	1,244	12,260	16,355	13,504
	Europe	< 0.05	457	39	514	1,010	552
	CIS (+ GEO, UKR)	26.2	648	444	2,679	3,771	3,123
	Africa	8.7	521	215	2,223	2,959	2,438
	Middle East	0.1	< 0.5	–	120	120	120
	Austral-Asia	8.5	297	99	4,157	4,553	4,256
	North America	3.9	920	272	1,725	2,917	1,997
	Latin America	< 0.05	7	175	843	1,025	1,018
	OPEC	0.1	26	–	43	68	43
	OPEC-Gulf	0.1	< 0.5	–	17	18	17
	OECD	10.1	1,589	311	4,488	6,388	4,800
	EU-28	< 0.05	457	39	500	996	539

n. s. not specified
– no production, reserves or resources

Table A-35: Uranium resources 2020 (> 20 kt U) [kt]
The most important countries and distribution by regions and economic country groupings

Country / Region	Discovered		Total	Undiscovered		Total	Share [%]	
	RAR 80–260 USD / kg	inferred < 260 USD / kg		prognosticated < 260 USD / kg	speculative < 260 USD / kg		country	cumulative
1	2	3	4 ≙ 2 + 3	5	6	7 ≙ 4 + 5 + 6	8	9
Australia	1,285	765	2,049	n. s.	n. s.	2,049	16.7	16.7
Canada	394	221	615	150	700	1,465	11.9	28.7
Mongolia	27	83	110	13	1,319	1,442	11.8	40.4
Russian Federation	233	405	639	169	540	1,348	11.0	51.4
Kazakhstan	121	504	625	110	186	921	7.5	58.9
South Africa	92	190	281	159	411	851	6.9	65.9
Namibia	321	184	504	57	n. s.	561	4.6	70.5
Niger	306	124	430	14	51	494	4.0	74.5
Brazil	–	121	121	300	n. s.	421	3.4	77.9
Czechia	51	68	119	223	–	342	2.8	80.7
India	188	8	196	127	n. s.	323	2.6	83.4
Ukraine	76	65	141	23	120	283	2.3	85.7
Colombia	–	n. s.	–	11	217	228	1.9	87.5
China	58	147	205	4	4	213	1.7	89.3
Greenland	51	63	114	n. s.	50	164	1.3	90.6
Argentina	6	29	35	14	80	128	1.0	91.6
Uzbekistan	20	82	102	25	–	127	1.0	92.7
Jordan	6	47	53	–	50	103	0.8	93.5
USA	88	n. s.	88	–	–	88	0.7	94.2
Botswana	20	67	87	n. s.	n. s.	87	0.7	94.9
Viet Nam	1	3	4	81	n. s.	85	0.7	95.6
Zambia	13	18	31	30	n. s.	61	0.5	96.1
Peru	–	19	19	20	20	59	0.5	96.6
Indonesia	4	3	7	30	n. s.	37	0.3	96.9
Central African Rep.	32	n. s.	32	n. s.	n. s.	32	0.3	97.2
Hungary	–	14	14	13	n. s.	27	0.2	97.4
Zimbabwe	1	n. s.	1	–	25	26	0.2	97.6
Bulgaria	–	–	–	25	n. s.	25	0.2	97.8
Mauritania	6	19	24	–	–	24	0.2	98.0
Germany	3	4	7	–	–	7	0.1	99.7
World	3,491	3,347	6,838	1,636	3,786	12,260	100.0	
Europe	81	136	217	284	13	514	4.2	

continuation of table A-35
[kt]

Country / Region	Discovered		Total	Undiscovered		Total	Share [%]	
	RAR 80–260 USD/kg	inferred <260 USD/kg		prognosticated <260 USD/kg	speculative <260 USD/kg		coun-try	cumula-tive
1	2	3	4 ≙ 2+3	5	6	7 ≙ 4+5+6	8	9
CIS (+ GEO, UKR)	450	1,056	1,506	326	847	2,679	21.9	
Africa	837	638	1,475	261	487	2,223	18.1	
Middle East	9	51	60	10	50	120	1.0	
Austral-Asia	1,569	1,009	2,578	256	1,323	4,157	33.9	
North America	535	287	822	153	750	1,725	14.1	
Latin America	9	171	180	347	316	843	6.9	
OPEC	28	5	33	10	–	43	0.3	
OPEC-Gulf	3	4	7	10	–	17	0.1	
OECD	1,905	1,185	3,089	422	977	4,488	36.6	
EU-28	77	126	203	284	13	500	4.1	

n.s. not specified
– no resources

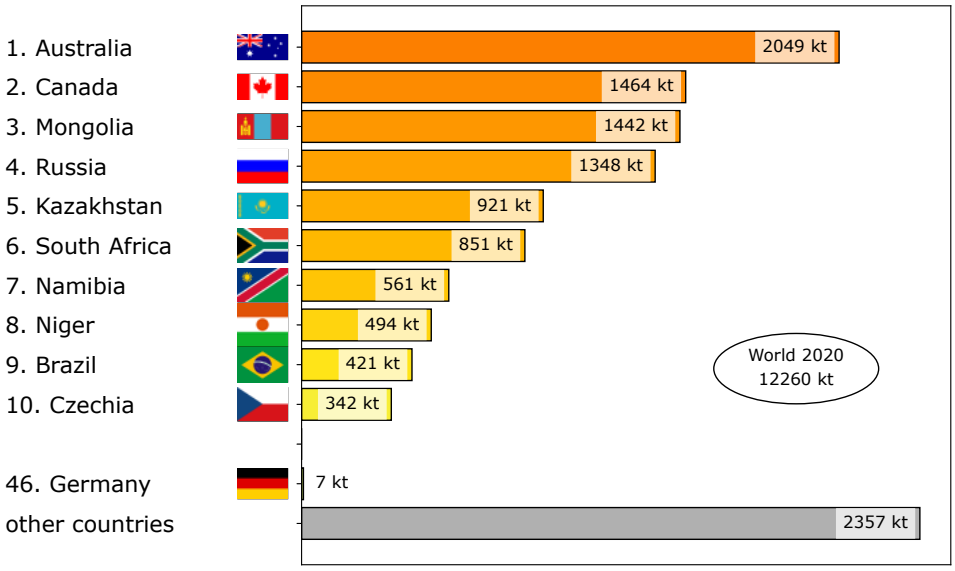


Figure A-37: Uranium resources – top 10 countries 2020. (> 20 kt U) [kt].

Table A-36: Uranium reserves 2020 (recoverable at < 80 USD / kg U)
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[kt]	Share [%]	
			country	cumulative
1	Kazakhstan	344	27.6	27.6
2	Canada	259	20.8	48.4
3	South Africa	166	13.4	61.8
4	Brazil	156	12.5	74.3
5	China	65	5.2	79.5
6	Ukraine	46	3.7	83.2
7	Tanzania	38	3.1	86.3
8	Mongolia	33	2.7	89.0
9	Uzbekistan	31	2.5	91.4
10	Russian Federation	23	1.9	93.3
11	Spain	19	1.5	94.8
12	Peru	14	1.1	96.0
13	USA	14	1.1	97.1
14	Niger	10	0.8	97.9
15	Slovakia	9	0.7	98.6
16	Argentina	5	0.4	99.0
17	Italy	5	0.4	99.4
18	Portugal	5	0.4	99.7
19	Slovenia	2	0.1	99.9
20	Indonesia	2	0.1	100.0
	World	1,244	100.0	
	Europe	39	3.1	
	CIS (+ GEO, UKR)	444	35.7	
	Africa	215	17.2	
	Austral-Asia	99	8.0	
	North America	272	21.9	
	Latin America	175	14.1	
	OECD	311	25.0	
	EU-28	39	3.1	

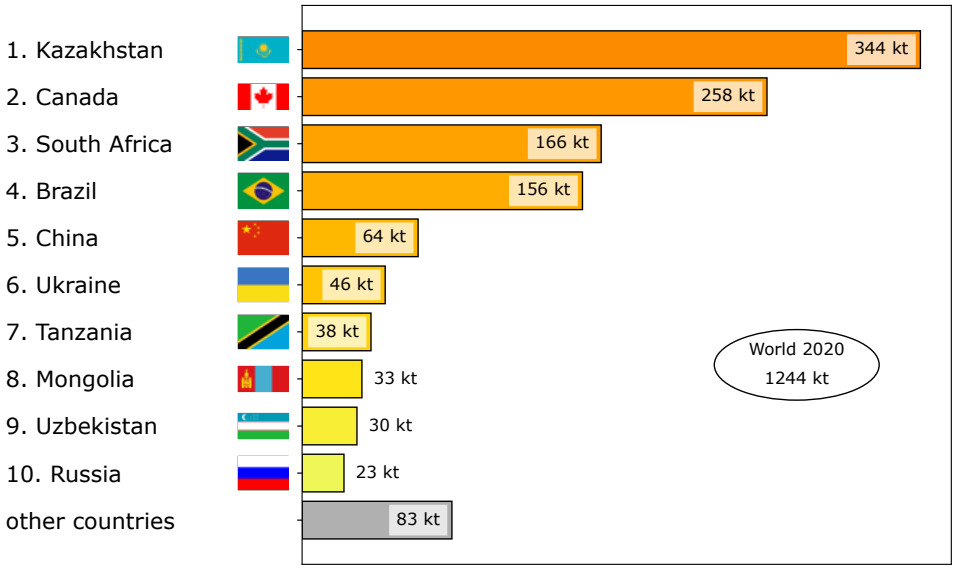


Figure A-38: Uranium reserves − top 10 countries 2020 (recoverable at < 80 USD / kg U).

Table A-37: Uranium resources 2020 (recoverable at < 130 USD / kg U)
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[kt]	Share [%]	
			country	cumulative
1	Australia	1,183.9	31.2	31.2
2	Canada	461.6	12.2	43.4
3	Kazakhstan	445.1	11.7	55.1
4	Namibia	279.4	7.4	62.5
5	Niger	238.7	6.3	68.8
6	South Africa	236.6	6.2	75.0
7	Russian Federation	211.2	5.6	80.6
8	Brazil	155.9	4.1	84.7
9	China	119.0	3.1	87.8
10	Ukraine	74.9	2.0	89.8
11	Mongolia	60.5	1.6	91.4
12	Uzbekistan	50.8	1.3	92.8
13	USA	47.9	1.3	94.0
14	Tanzania	39.7	1.0	95.1
15	Central African Rep.	32.0	0.8	95.9
16	Botswana	20.4	0.5	96.4
17	Spain	19.1	0.5	97.0
18	Peru	14.0	0.4	97.3
19	Zambia	12.8	0.3	97.7
20	Argentina	11.0	0.3	97.9
	other countries [18]	77.8	2.1	100.0
	World	3,792.3	100.0	
	Europe	54.1	1.4	
	CIS (+ GEO, UKR)	782.0	20.6	
	Africa	879.5	23.2	
	Middle East	9.2	0.2	
	Austral-Asia	1,375.3	36.3	
	North America	511.3	13.5	
	Latin America	180.9	4.8	
	OPEC	8.0	0.2	
	OPEC-Gulf	3.2	0.1	
	OECD	1,752.9	46.2	
	EU-28	50.4	1.3	

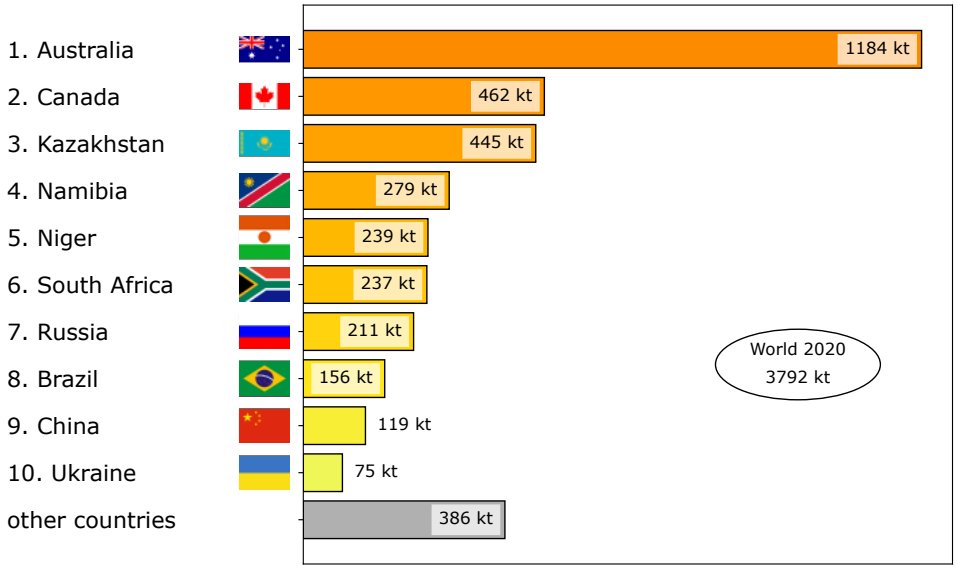


Figure A-39: Uranium resources 2020 (recoverable at < 130 USD / kg U)

Table A-38: Natural uranium production 2015 to 2020
The most important countries and distribution by regions and economic country groupings

Rank	Country / Region	2015	2016	2017	2018	2019	2020	Share [%]		Changes	
				[kt]				country	cum.	2019 / 2020	[%]
1	Kazakhstan	23.8	24.6	23.4	21.7	22.8	19.5	41.1	41.1	-3.3	-14.6
2	Australia	5.7	6.3	5.9	6.5	6.6	6.2	13.1	54.2	-0.4	-6.2
3	Namibia	3.0	3.7	4.2	5.5	5.5	5.4	11.4	65.6	-0.1	-1.2
4	Canada	13.3	14.0	13.1	7.0	6.9	3.9	8.2	73.8	-3.1	-44.1
5	Uzbekistan	2.4	2.4	2.4	2.4	2.4	3.5	7.4	81.1	1.1	45.6
6	Niger	4.1	3.5	3.4	2.9	3.0	3.0	6.3	87.4	0.0	0.3
7	Russian Federation	3.1	3.0	2.9	2.9	2.9	2.8	6.0	93.4	-0.1	-2.2
8	China	1.6	1.6	1.9	1.9	1.9	1.9	4.0	97.4	0.0	0.0
9	Ukraine	1.2	1.0	0.6	1.2	0.8	0.4	0.8	98.3	-0.4	-50.1
	India	0.4	0.4	0.4	0.4	0.3	0.4	0.8	99.1	0.1	29.9
11	South Africa	0.4	0.5	0.3	0.3	0.3	0.3	0.5	99.6	-0.1	-27.7
12	Iran	–	–	–	0.1	0.1	0.1	0.1	99.8	0.0	0.0
13	Pakistan	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.1	99.9	0.0	0.0
14	Czechia	0.2	0.1	< 0.05	< 0.05	< 0.05	< 0.05	0.1	99.9	0.0	
15	Brazil	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	100.0	0.0	
16	Germany	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	100.0	0.0	
17	USA	1.3	1.1	0.9	0.6	0.1	< 0.05	< 0.05	100.0	-0.1	-91.0
18	Belgium	–	–	–	–	–	< 0.05	< 0.05	100.0		
	Romania	0.1	0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	100.0	0.0	
	Malawi	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	100.0	0.0	
	France	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	100.0	0.0	
	World	60.5	62.4	59.6	53.5	53.7	47.4	100.0		-6.2	-11.6
	Europe	0.2	0.2	< 0.05	–	–	< 0.05	0.1			
	CIS (+ GEO, UKR)	30.4	31.0	29.3	28.2	28.9	26.2	55.3		-2.7	-9.3
	Africa	7.5	7.6	8.0	8.8	8.8	8.7	18.3		-0.2	-1.7
	Middle East	–	–	–	0.1	0.1	0.1	0.1		0.0	0.0
	Austral-Asia	7.7	8.4	8.2	8.9	8.9	8.5	18.0		-0.3	-3.6
	North America	14.6	15.2	14.1	7.6	7.0	3.9	8.2		-3.1	-44.6
	OPEC	–	–	–	0.1	0.1	0.1	0.1		0.0	0.0
	OPEC-Gulf	–	–	–	0.1	0.1	0.1	0.1		0.0	0.0
	OECD	20.4	21.7	20.0	14.1	13.6	10.1	21.4		-3.5	-25.7
	EU-28	0.2	0.2	< 0.05	–	–	< 0.05	0.1			

[1] only in the form of uranium concentrate as part of the remediation of production sites

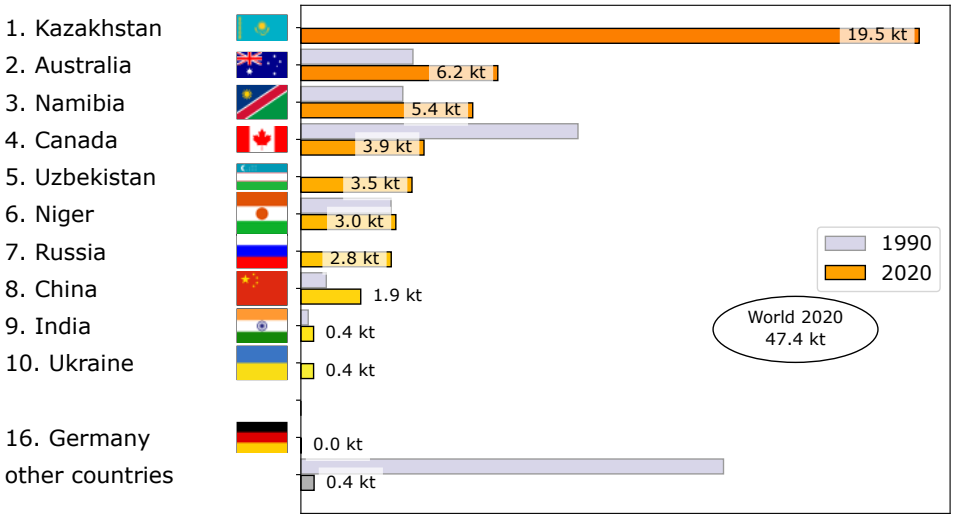


Figure A-40: Natural uranium production − top 10 countries from 1990 to 2020.

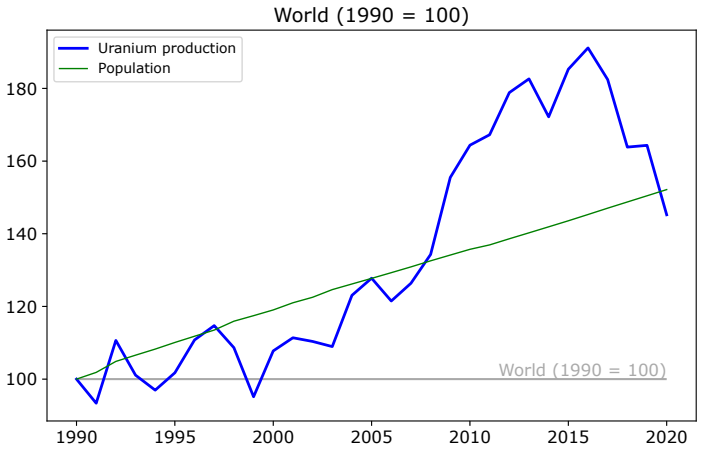


Figure A-41: Development of global uranium production and global population from 1990 to 2020.

Table A-39: Uranium consumption 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[kt]	Share [%]	
			country	cumulative
1	USA	18.30	26.8	26.8
2	China	10.81	15.8	42.6
3	France	8.70	12.7	55.4
4	Russian Federation	6.23	9.1	64.5
5	Korea, Rep.	5.12	7.5	72.0
6	Japan	2.34	3.4	75.4
7	Ukraine	1.88	2.8	78.2
8	United Kingdom	1.82	2.7	80.9
9	Canada	1.41	2.1	82.9
10	Spain	1.22	1.8	84.7
11	India	1.08	1.6	86.3
12	Sweden	0.99	1.4	87.7
13	Belgium	0.90	1.3	89.0
14	U. Arab Emirates	0.88	1.3	90.3
15	Finland	0.76	1.1	91.4
16	Czechia	0.69	1.0	92.5
17	Pakistan	0.64	0.9	93.4
18	Germany	0.59	0.9	94.2
19	Taiwan	0.48	0.7	94.9
20	Switzerland	0.45	0.7	95.6
	other countries [13]	3.01	4.4	100.0
	World	68.27	100.0	
	Europe	17.63	25.8	
	CIS (+ GEO, UKR)	8.33	12.2	
	Africa	0.29	0.4	
	Middle East	1.04	1.5	
	Austral-Asia	20.47	30.0	
	North America	19.94	29.2	
	Latin America	0.56	0.8	
	OPEC	1.04	1.5	
	OPEC-Gulf	1.04	1.5	
	OECD	44.52	65.2	
	EU-28	17.18	25.2	

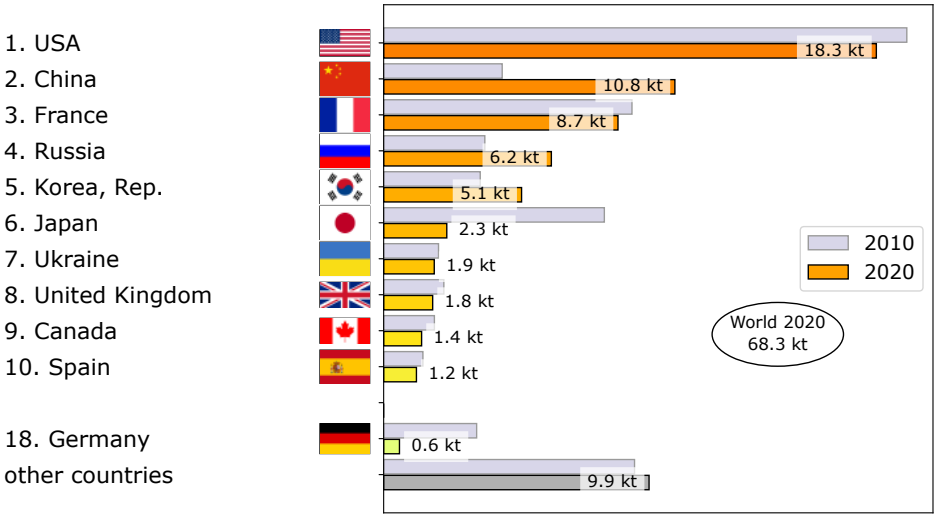


Figure A-42: Uranium consumption – top 10 countries 2010 and 2020.

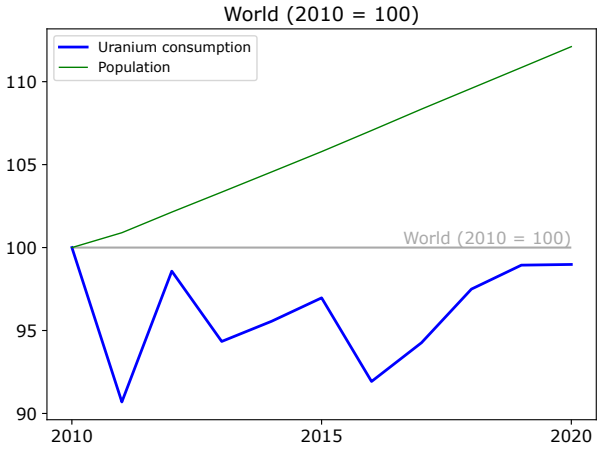


Figure A-43. Development of global uranium consumption and global population from 2010 to 2020

Table A-40: Geothermal energy 2020[1]

	Country / Region	El. power [MW_e]	El. energy consumption [GWh_e]	Therm. power without heat pumps [MW_{th}]	Therm. energy consumption without heat pumps [GWh_{th}]
EUROPE	Austria	1	2	76 (2018)	225 (2018)
	Belgium	1	2	17 (2018)	15 (2018)
	Croatia	17	76	42 (2018)	45 (2018)
	Czechia	–	–	7 (2018)	21 (2018)
	Denmark	–	–	33 (2018)	99 (2018)
	Finland	–	–	1,560 (2016; m)	5,000 (2016; m)
	France	17	136	586 (2018)	1,652 (2018)
	Germany	42	167	409	1,500
	Greece	–	–	232 (2017)	–
	Hungary	3	5	223 (2018)	636 (2018)
	Iceland	755	6,010	2,172 (2018)	7,422 (2016; m)
	Italy	916	6,100	149 (2018)	237 (2018)
	Lithuania	–	-	18 (2018)	34 (2018)
	Macedonia	–	–	43 (2018)	106 (2018)
	Netherlands	–	–	142 (2018)	–
	Norway	–	–	1,300 (2016; m)	2,295 (2016; m)
	Poland	–	–	75 (2018)	250 (2018)
	Portugal	33	216	2 (2018)	15 (2018)
	Romania	< 0.5 (2018)	< 0.5 (2018)	158 (2018)	300 (2018)
	Serbia	–	–	48 (2018)	154 (2018)
	Slovakia	–	–	22 (2018)	41 (2018)
	Slovenia	–	-	47 (2018)	124 (2018)
	Spain	–	–	3 (2018)	2 (2018)
	Sweden	–	–	44 (2018)	–
	Switzerland	–	–	12 (2018)	36 (2018)
	Turkey	1,549	8,168	1,453 (2018)	4,600 (2018)
	United Kingdom	–	2 (2018)	3 (2018)	15 (2018)
CIS (+ GEO, UKR)	Russian Federation	82	441	–	–
	Tajikistan	–	–	3 (2016; m)	15 (2016; m)
	Ukraine	–	–	1 (2017; m)	–

continuation of table A-40

	Country / Region	El. power [MW_e]	El. energy consumption [GWh_e]	Therm. power without heat pumps [MW_{th}]	Therm. energy consumption without heat pumps [GWh_{th}]
AFRICA	Ethiopia	7	58	2 (2016; m)	12 (2016; m)
	Kenya	1,193	9,930	22 (2016; m)	51 (2016; m)
	Madagascar	–	–	3 (2016; m)	21 (2016; m)
	Morocco	–	–	5 (2016; m)	–
	South Africa	–	–	2 (2016; m)	10 (2016; m)
	Tunisia	–	–	44 (2016; m)	–
MIDDLE EAST	Iran	–	–	153 (2016; m)	428 (2016; m)
	Israel	–	–	82 (2016; m)	609 (2016; m)
	Jordan	–	–	153 (2016; m)	428 (2016; m)
	Saudi Arabia	–	–	44 (2016; m)	–
	Yemen	–	–	1 (2016; m)	–
AUSTRAL-ASIA	Australia	1	2	18 (2016; m)	–
	China	35	175	17,870 (2016; m)	48,435 (2016; m)
	India	–	–	986 (2016; m)	1,195 (2016; m)
	Indonesia	2,289	15,315	2 (2016; m)	12 (2016; m)
	Japan	550	2,409	2,094 (2017)	7,250 (2017)
	Korea, Rep.	–	–	44 (2017)	165 (2017)
	Mongolia	–	–	20 (2016; m)	95 (2016; m)
	Nepal	–	–	3 (2016; m)	23 (2016; m)
	New Zealand	1,064	7,728	487 (2016; m)	2,395 (2016; m)
	Pakistan	–	–	0 (2016; m)	–
	Papua New Guinea	11	97	–	–
	Philippines	1,918	9,893	3 (2016; m)	11 (2016; m)
	Taiwan	< 0.5	3	–	–
	Thailand	< 0.5 (2017)	–	129 (2016; m)	–
	Viet Nam	–	–	31 (2016; m)	–
NORTH AMERICA	Canada	–	–	1,467 (2016; m)	3,227 (2016; m)
	Mexico	1,006	5,375	149 (2017)	1,159 (2017)
	USA	3,700	18,366	17,416 (2016; m)	21,075 (2016; m)

continuation of table A-40

	Country / Region	El. power [MW_e]	El. energy consumption [GWh_e]	Therm. power without heat pumps [MW_{th}]	Therm. energy consumption without heat pumps [GWh_{th}]
LATIN AMERICA	Argentina	–	–	164 (2016; m)	278 (2016; m)
	Brazil	–	–	360 (2016; m)	1,840 (2016; m)
	Chile	48	400	20 (2016; m)	–
	Costa Rica	262	1,559	1 (2016; m)	6 (2016; m)
	El Salvador	204	1,442	3 (2016; m)	16 (2016; m)
	Guatemala	52	237	2 (2016; m)	16 (2016; m)
	Honduras	35	297	–	–
	Nicaragua	159	492	–	–

[1] Current data outside Europe are not available for 2018; some data from 2017 and older.

– no Data available

Data based on EGEC, LIAG-GeotIS (for Germany), IRENA Renewable Statistics

Table A-41: Geothermal energy − installed electrical capacity from 2014 to 2019
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2014	2015	2016	2017	2018	2019	Share [%]		Changes	
				[MW_e]				country	cum.	2018/2019	[%]
1	USA	3,450	3,567	3,596	2,541	–	3,700	23.2	23.2		
2	Indonesia	1,340	1,404	1,590	1,946	–	2,289	14.4	37.6		
3	Philippines	1,870	1,930	1,929	1,944	–	1,918	12.0	49.6		
4	Turkey	397	624	775	1,131	1,283	1,549	9.7	59.3	266	20.7
5	Kenya	594	607	676	663	–	1,193	7.5	66.8		
6	New Zealand	1,005	973	971	996	–	1,064	6.7	73.4		
7	Mexico	1,017	1,069	907	951	–	1,006	6.3	79.7		
8	Italy	916	915	916	916	916	916	5.7	85.5	1	0.1
9	Iceland	665	661	665	708	753	755	4.7	90.2	2	0.3
10	Japan	519	540	544	486	–	550	3.4	93.7		
11	Costa Rica	207	218	208	207	–	262	1.6	95.3		
12	El Salvador	204	204	204	204	–	204	1.3	96.6		
13	Nicaragua	159	155	160	155	–	159	1.0	97.6		
14	Russian Federation	82	97	82	74	–	82	0.5	98.1		
15	Guatemala	52	49	48	49	–	52	0.3	98.4		
16	Chile	–	–	–	48	–	48	0.3	98.7		
17	Germany	27	31	38	36	37	42	0.3	99.0	5	12.5
18	Honduras	–	–	–	35	–	35	0.2	99.2		
19	China	27	27	27	26	–	35	0.2	99.4		
20	Portugal	29	23	29	33	29	33	0.2	99.6	4	13.8
	other countries [9]	76	84	82	84	38	58	0.4	100.0	20	52.8
	World	12,636	13,178	13,447	13,233	3,055	15,949	100.0		12,894	422.0
	Europe	2,133	2,273	2,440	2,845	3,055	3,333	20.9		278	9.1
	CIS (+ GEO, UKR)	82	97	82	74	–	82	0.5			
	Africa	601	614	683	670	–	1,200	7.5			
	Austral-Asia	4,812	4,930	5,119	5,454	–	5,868	36.8			
	North America	5,089	4,636	4,503	3,492	–	4,706	29.5			
	Latin America	622	626	620	698	–	760	4.8			
	OECD	8,043	8,423	8,460	7,867	3,039	9,685	60.7		6,646	218.7
	EU-28	989	988	1,000	1,006	1,019	1,029	6.5		10	1.0

Data based on BP Statistical Review and IRENA Renewable Statistics

Table A-42: Geothermal energy − resources 2020

Region	Theoretical potential up to 5 km deepth [EJ] total	Technical potential [EJ/year]		
		power	heat	total
Europe	2,342,000	37.1	3.5	40.6
CIS (+ GEO, UKR)	6,607,000	104.0	9.9	113.9
Africa	6,083,000	95.0	9.1	104.1
Middle East	1,355,000	21.0	2.0	23.0
Austral-Asia	10,544,000	164.3	15.2	179.5
North America	8,025,000	127.0	11.8	138.8
Latin America	6,886,000	109.0	9.9	118.9
World	41,842,000	657.4	61.4	718.8

Comment: BGR currently considers the use of the term „technical potential“ to make little sense because the technology for the extraction of deep geothermal energy, and for petrothermal geothermal energy in particular, has not yet been adequately developed

Table A-43: Consumption renewable energy 2020 [Mtoe]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Total	Hydropower	Renewable energy (without Hyropower)
1	China	19.53	11.74	7.79
2	USA	8.71	2.56	6.15
3	Brazil	5.53	3.52	2.01
4	Canada	3.95	3.42	0.54
5	India	2.88	1.45	1.43
6	Germany	2.37	0.17	2.21
7	Russian Federation	1.92	1.89	0.04
8	Japan	1.82	0.69	1.13
9	Norway	1.36	1.25	0.11
10	United Kingdom	1.26	0.06	1.20
11	France	1.23	0.54	0.68
12	Turkey	1.14	0.69	0.45
13	Italy	1.09	0.41	0.67
14	Sweden	1.06	0.65	0.41
15	Spain	1.01	0.24	0.77
16	Viet Nam	0.70	0.61	0.08
17	Mexico	0.59	0.24	0.36
18	Australia	0.58	0.13	0.45
19	Indonesia	0.54	0.17	0.37
20	Austria	0.50	0.36	0.14
	other countries [60]	12.08	7.35	4.74
	World	69.87	38.16	31.71
	Europe	14.76	5.82	8.94
	CIS (+ GEO, UKR)	2.44	2.36	0.08
	Africa	1.64	1.27	0.38
	Middle East	0.39	0.23	0.17
	Austral-Asia	28.76	16.41	12.36
	North America	13.26	6.22	7.04
	Latin America	8.62	5.87	2.75
	OPEC	0.57	0.49	0.08
	OPEC-Gulf	0.28	0.21	0.07
	OECD	31.18	13.14	18.04
	EU-28	11.26	3.10	8.17

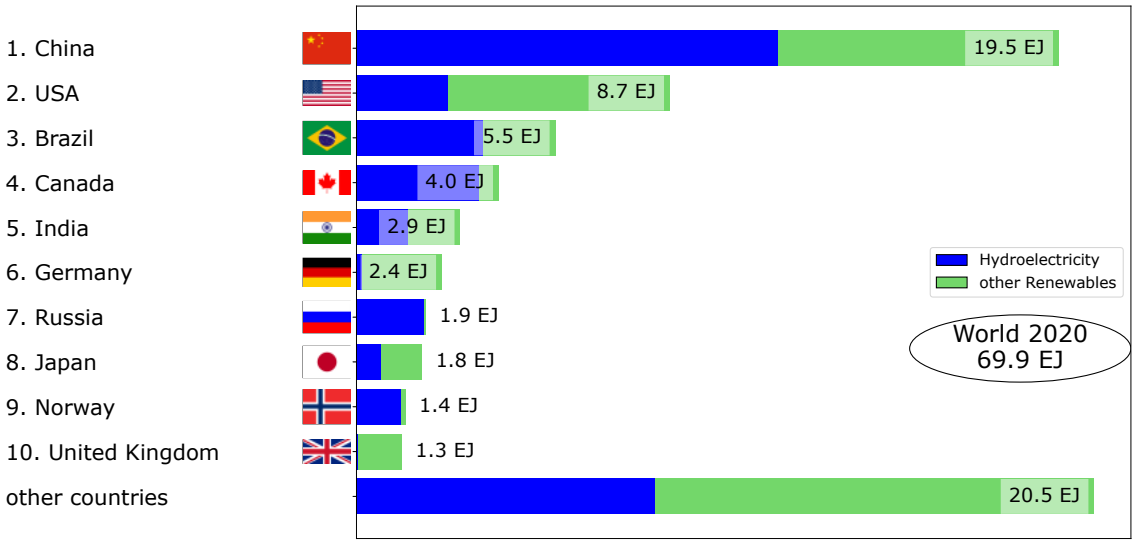


Figure A-44: Power consumption from renewables − top 10 countries hydroelectric power and other renewables 2020.

Table A-44: Renewable energy − installed electrical capacity 2020
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[MW]	Share [%]	
			country	cumulative
1	China	894,879	32.0	32.0
2	USA	292,065	10.4	42.4
3	Brazil	150,046	5.4	47.8
4	India	134,197	4.8	52.6
5	Germany	131,739	4.7	57.3
6	Japan	101,370	3.6	60.9
7	Canada	101,188	3.6	64.5
8	Spain	59,108	2.1	66.6
9	France	55,365	2.0	68.6
10	Italy	55,299	2.0	70.6
11	Russian Federation	54,274	1.9	72.5
12	Turkey	49,398	1.8	74.3
13	United Kingdom	47,676	1.7	76.0
14	Norway	37,212	1.3	77.3
15	Australia	35,690	1.3	78.6
16	Viet Nam	35,649	1.3	79.9
17	Sweden	32,883	1.2	81.0
18	Mexico	28,358	1.0	82.0
19	Austria	21,842	0.8	82.8
20	Korea, Rep.	19,589	0.7	83.5
	other countries [201]	461,191	16.5	100.0
	World	2,799,016	100.0	
	Europe	644,594	23.0	
	CIS (+ GEO, UKR)	91,104	3.3	
	Africa	53,256	1.9	
	Middle East	24,224	0.9	
	Austral-Asia	1,314,400	47.0	
	North America	421,703	15.1	
	Latin America	249,261	8.9	
	OPEC	42,352	1.5	
	OPEC-Gulf	18,470	0.7	
	OECD	1,229,901	43.9	
	EU-28	527,590	18.8	

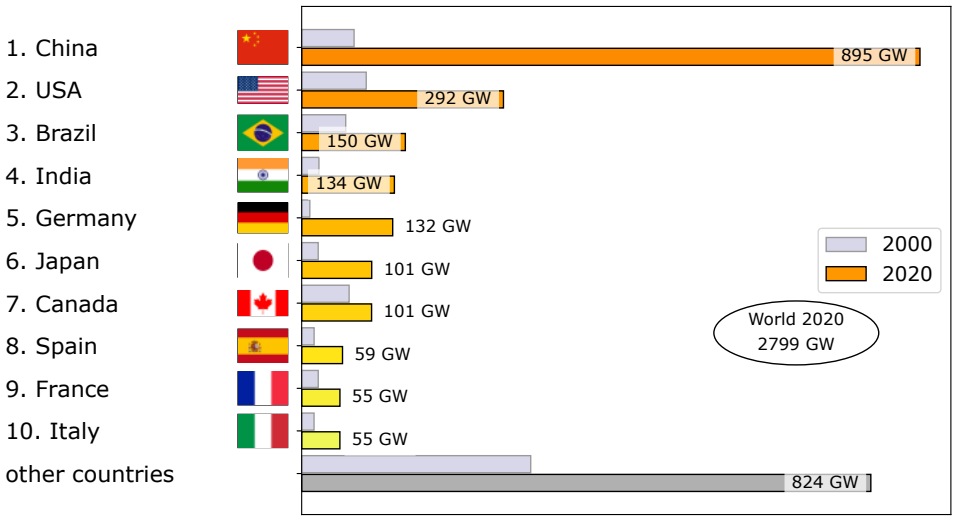


Figure A-45: Renewable energy − installed electrical capacity − top 10 countries 2000 and 2020.

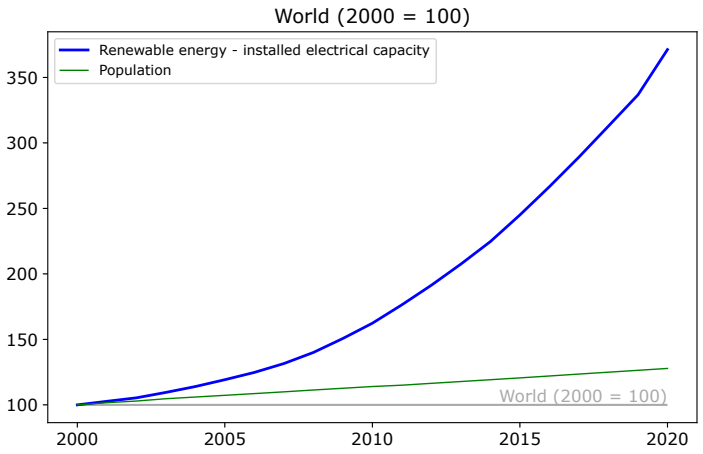


Figure A-46: Development of global renewables − installed electrical capacity and global population from 2000 to 2020.

Table A-45: Electrolysis capacity for hydrogen production

	Country / Region	Capacity in use [MW]	Capacity not in use [MW]	Capacity total [MW]	Planned for 2030 [GW]
EUROPE	Austria	6.0	4.0	10.0	–
	Belgium	1.3	2.0	3.3	–
	Denmark	3.7	2.0	5.7	–
	Estonia	2.5	< 0.05	2.5	–
	Finland	< 0.05	< 0.05	< 0.05	–
	France	1.0	0.1	1.1	6.5
	Germany	26.3	19.8	46.1	5.0
	Greece	0.1	< 0.05	0.2	–
	Hungary	–	–	–	0.2
	Iceland	< 0.05	< 0.05	< 0.05	–
	Italy	1.2	0.1	1.3	5.0
	Netherlands	2.1	2.0	4.1	[3.5]
	Norway	1.3	2.6	3.9	–
	Poland	< 0.05	< 0.05	< 0.05	2.0
	Portugal	0.3	< 0.05	0.3	2.0
	Spain	0.4	0.1	0.5	4.0
	Sweden	< 0.05	< 0.05	< 0.05	–
	Switzerland	< 0.05	2.0	2.0	–
	Turkey	< 0.05	< 0.05	< 0.05	–
	United Kingdom	1.5	1.0	2.5	5.0
	South Africa	–	3.5	3.5	–
MIDDLE EAST	Iran	0.2	< 0.05	0.2	–
	Lebanon	0.1	< 0.05	0.1	–
	Oman	< 0.05	< 0.05	< 0.05	–
	U. Arab Emirates	< 0.05	1.3	1.3	–
AUSTRAL-ASIA	Australia	0.2	2.4	2.5	–
	China	4.1	38.6	42.7	–
	Cook Islands	< 0.05	< 0.05	< 0.05	–
	India	5.3	< 0.05	5.3	–
	Japan	10.0	< 0.05	10.0	–
	Korea, Rep.	< 0.05	< 0.05	< 0.05	–
	Malaysia	0.3	< 0.05	0.3	–

continuation of table A-45

	Country/Region	Capacity in use [MW]	Capacity not in use [MW]	Capacity total [MW]	Planned for 2030 [GW]
AUSTRAL-ASIA	New Zealand	1.0	1.5	2.5	–
	Philippines	< 0.05	< 0.05	< 0.05	–
	Singapore	< 0.05	< 0.05	< 0.05	–
	Thailand	1.0	< 0.05	1.0	–
NORTH AMERICA	Canada	3.7	20.0	23.7	–
	Greenland	0.1	< 0.05	0.1	–
	USA	1.6	1.0	2.6	–
LATIN AMERICA	Argentina	0.6	< 0.05	0.6	–
	Bolivia	1.4	< 0.05	1.4	–
	Chile	< 0.05	< 0.05	< 0.05	–
	Paraguay	< 0.05	< 0.05	< 0.05	–
	World	77.1	104.0	181.1	33.2
	Europe	47.6	35.8	83.3	33.2
	CIS (+ GEO, UKR)	–	–	–	–
	Africa	–	3.5	3.5	–
	Middle East	0.3	1.3	1.6	–
	Austral-Asia	21.9	42.5	64.3	–
	North America	5.4	21.0	26.4	–
	Latin America	1.9	< 0.05	1.9	–
	OPEC	0.2	1.3	1.5	–
	OPEC-Gulf	0.2	1.3	1.5	–
	OECD	64.2	60.6	124.8	33.2
	EU-28	46.2	31.2	77.4	33.2

Sources

Anuário Estatístico Brasileiro (Brazil)

Appea Key Statistics (Australia)

Arbeitsgemeinschaft Energiebilanzen e. V. – AGEB

Arbeitsgruppe Erneuerbare Energien-Statistik – AGEE

Belorusneft (Belarus)

Bloomberg (China)

BMI Research, Oil and Gas Report (Malaysia)

British Petroleum – BP

British Geological Survey – BGS

Bundesamt für Energie (Switzerland)

Bundesamt für Strahlenschutz – BfS

Bundesamt für Wirtschaft und Ausfuhrkontrolle – BAFA

Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit – BMUB

Bundesministerium für Wirtschaft und Klimaschutz – BMWK

Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung – BMZ

Bundesnetzagentur – BNetzA

Bundesverband Geothermie – GtV

Bundesverband Wärmepumpe e. V. – BWP

Bureau of Energy, Ministry of Economic Affairs (Taiwan)

Bureau of Resources and Energy Economics – BREE (Australia)

Cameco Corporation (Canada)

Canadian Association of Petroleum Producers – CAPP (Canada)

CARBUNION (Spain)

China Coal Information Institute

Coal India Limited – CIL

Comité Professionnel Du Pétrole – CPDP (France)

CORES (Spain)

Customs Statistics of Foreign Trade (Russian Federation)

Department for Business, Energy and Industrial Strategy – BEIS (United Kingdom)

Department of Energy – DOE (Philippines)

Department of Energy (South Africa)

Department of Geological Science, Pusan National University (Republic of Korea)

Department of Natural Resources and Mines (Australia)

Department of Industry, Innovation and Science (Australia)

Department of Resources, Energy and Tourism (Australia)

Deutscher Braunkohlen-Industrie-Verein e.V. – DEBRIV

Deutsches Atomforum e. V. – DAtF

Deutsches Pelletinstitut – DEPI

Digest of UK Energy Statistics – DUKES

Direzione generale per le risorse minerarie ed energetiche –DGRME (Italy)

DTEK Annual reports (Ukraine)

Energy Fact Book (Australia)

Energy Resources Conservation Board – ERCB (Canada)

Environmental Protection Agency – EPA

Euratom Supply Agency, European Commission – ESA

European Biomass Association – AEBIOM

European Geothermal Congress – EGC

European Geothermal Energy Council – EGEC (Belgium)

Extractive Industries Transparency Initiative – EITI

Fenwei Energy Information Services

Gas Infrastructure Europe – GIE (Belgium)

Gazprom (Russian Federation)

Geological Survey of Czech Republic – ČGS

Geological Survey of India – GSI

Geological Survey of Namibia

Geoscience Australia

Geothermal Energy Association – GEA (USA)

Geothermisches Informationssystem für Deutschland – GeotIS

Gesamtverband Steinkohle e.V. – GVSt

Global Methan Initiative – GMI (USA)

Government of Australia, Australian Energy Ressource Assessment

Grubengas Deutschland e. V. – IVG

Handbook of Energy & Economics Statistics (Indonesia)

IHS McCloskey Coal Report

INA-Industrija nafte, d.d. (INA, d.d.) (Croatia)

Instituto Colombiano de Geología y Minería – INGEOMINAS

Interfax Russia & CIS

Intergovernmental Panel on Climate Change – IPCC

International Atomic Energy Agency – IAEA

International Energy Agency – IEA (France)

International Geothermal Association – IGA

International Journal of Geothermal Research and its Applications – Geothermics

International Renewable Energy Agency – IRENA

Korea Energy Economics Institute – KEEI

Kosmos Energy (Mauretania)

Landesamt für Bergbau, Energie und Geologie – LBEG

Mineral Resources and Petroleum Authority of Mongolia – MRPAM

Mineralölwirtschaftsverband e.V. – MWV

Ministerie van Economische Zaken (Netherlands)

Ministerio de Energia y Minas (Guatemala)

Ministerio de Energia y Minas (Peru)

Ministério de Minas e Energia (Brazil)

Ministerio del Poder Popular para la Energía y Petróleo (Bolivarian Republic of Venezuela)

Ministry of Business, Innovation and Employment – MBIE (New Zealand)

Ministry of Coal (India)

Ministry of Ecology, Sustainable Development and Energy (France)

Ministry of Economy, Trade and Industry – METI (Japan)

Ministry of Economic Development (New Zealand)

Ministry of Energy of the Russian Federation (Russian Federation)

Ministry of Energy and Coal Mining (Ukraine)

Ministry of Energy and Energy Industries Trinidad & Tobago

Ministry of Energy and Mineral Resources of the Republic of Indonesia – ESDM

Ministry of Energy and Mining (Algeria)

Ministry of Energy and Natural Resources (Turkey)

Ministry of Energy Myanmar

Ministry of Energy, Energy Policy and Planning Office – EPPO (Thailand)

Ministry of Energy (Islamic Republic of Iran)

Ministry of Energy (United Arab Emirates)

Minister of Energy and Mineral Resources of Kazakhstan – MEMP PK

Ministry of Land and Resources (MLR) (China)

Ministry of Minerals, Energy and Water Resources, Department of Mines (Botswana)

Ministry of Mining and Energy of the Republic of Serbia (Serbia)

Ministry of Mines and Energy – MME (Brazil)

Ministry of Petroleum and Natural Gas (India)

Ministry of Science, Energy & Technology (Jamaica)

Ministry of Statistics and Programme Implementation – MOSPI (India)

Nacionalni naftni komitet Srbije (Serbia)

NAFTA (Slovakai)

National Coal and Mineral Industries Holding Corporation – Vinacomin (Vietnam)

National Coal Mining Engineering Technology Research Institute (China)

National Energy Board (Canada)

National Oil & Gas Authority – NOGA (Bahrain)

Natural Gas Europe – NGE

Natural Gas World (Namibia)

National Rating Agency (Russian Federation)

Norsk Petroleum (Norway)

Norwegian Petroleum Directorate – NPD

Nuclear Energy Agency – NEA

Oberbergamt des Saarlandes

Oil and Gas Authority (United Kingdom)

Oil & Gas Journal

Organization for Economic, Co-operation and Development – OECD

Organization of the Petroleum Exporting Countries – OPEC

Oxford Institute for Energy Studies (United Kingdom)

Petrobangla (Bangladesh)

Petróleos Mexicanos – PEMEX (Mexico)

Petroleum Association of Japan (Japan)

Petróleos de Venezuela S. A – PDVSA (Bolivarian Republic of Venezuela)

Petrol İşleri Genel Müdürlüğü – PIGM (Turkey)

Philippine Department of Energy – DOE

Polish Geological Institute – National Research Institute; Department of Deposits and Mining Areas Information – PSH (Poland)

Proceedings World Geothermal Congress 2010 – WGC2010

Proceedings World Geothermal Congress 2015 – WGC2015

Renewable Energy Policy Network for the 21st Century – REN21

Saudi Arabian Oil Company – Saudi Aramco (Saudi Arabia)

Secretaría de Energía, Ministerium für Energie in Mexiko – SENER

Servico Geológico Mexicano – SGM

Servicio Nacional de Geología y Minería – Sernageomin (Chile)

Singapore Energy Statistics - SES (Singapore)

Sino Gas & Energy Holdings Limited (China)

State Oil Company of Azerbaijan Republic – SOCAR (Azerbaijan)

State Statistic Service of Ukraine (Ukraine)

Statistics Africa

Statistics Bosnia and Herzegovina

Statistics Bulgaria

Statistics Canada

Statistics China

Statistics Croatia

Statistics Czech Republic

Statistics Finland

Statistics Hong Kong

Statistics Israel

Statistics Japan

Statistics Kasachstan

Statistics Kosovo

Statistics Macedonia

Statistics Malaysia

Statistics Montenegro

Statistics Netherlands – CBS

Statistics Norway

Statistics Pakistan

Statistics Peru

Statistics Poland

Statistics Romania

Statistics Russian Federation

Statistics Slovakia

Statistics Slovenia

Statistics Taiwan

Statistics Thailand

Statistics Vietnam

Statistik der Kohlenwirtschaft e.V. – SdK

Statistisches Bundesamt – DESTATIS

Tansania Chamber of Minerals and Energy

The Coal Authority (United Kingdom)

The Human-Induced Earthquake Database

TÜRKİYE KÖMÜR İŞLETMELERİ KURUMU – TKI

Türkiye Taşkömürleri Kurumu – TTK (Turkey Coal Company)

Unidad de Planeación Minero Energética – UPME (Columbia)

U.S. Energy Information Administration – EIA

U.S. Geological Survey – USGS

Verein der Kohlenimporteure e.V. – VDKi

Wirtschaftskammer Österreich – WKO (Austria)

Wismut GmbH

World Coal Association

World Energy Council – WEC

World Geothermal Congress – WGC

World Nuclear Association – WNA

Hydrogen: Fundamentals

Hydrogen is currently being used primarily for the refining process of crude oil and the production of ammonium fertiliser and methanol. Since no climate gases are released during the combustion of hydrogen, it is a climate-friendly energy carrier that is expected to play an important role in the decarbonisation of the energy and economic systems in the heating and transport sectors, but also in other industrial applications. In contrast to fossil fuels, hydrogen is not a resource, but an energy carrier that only occurs in nature in bound form. Apart from a few non-commercial, natural deposits, hydrogen is not extracted like fossil energy resources, but must be obtained by expending energy through material conversion.

Up to now, hydrogen has been produced worldwide almost exclusively from fossil energy sources. However, it is the declared goal of the German government to produce hydrogen with low emissions from primarily renewable sources. To support this development path, hydrogen strategies have been adopted worldwide in recent years in which targets for the use and production of CO_2-free or low-CO_2 hydrogen have been set. Therefore, a considerable increase in the global demand for hydrogen is foreseeable. The planned use of hydrogen as an energy carrier on a large scale and as a feedstock for the chemical industry is associated with major technological and infrastructural challenges.

The data situation on individual areas of the hydrogen economy is partly based on estimates or older publications. International structures that enable a largely standardised and regular collection of data are currently being established.

Depending on the energy resource used, its production or its natural origin, hydrogen is divided into groups to which colours are assigned (Fig. A-47). In addition to the production methods shown, there are other ways of producing hydrogen that are still at an early stage of development.

If hydrogen is produced by electrolysis processes and the electricity required for this comes exclusively from renewable energies, it is designated as green. Emissions only occur in the upstream chain of electricity generation.

Hydrogen that is produced from fossil energy sources without capturing the resulting carbon dioxide is called grey hydrogen. During production, synthesis (or syngas) containing hydrogen is produced from natural gas, coal or biomass using various processes.

For the production of hydrogen from natural gas, the most important resource for its production to date, either steam reforming (SMR) or autothermal reforming (ATR) are primarily used. The production of hydrogen by steam reforming of natural gas is currently the most frequently used process worldwide. Both hard coal and lignite can be gasified. At high temperatures and pressures, a gas mixture of carbon monoxide and hydrogen is produced together with water vapour and oxygen.

If the carbon dioxide produced during the production of hydrogen from fossil energy sources is captured and returned to the geological subsurface for storage, we speak of blue or low-CO_2 hydrogen. In the production of blue hydrogen, autothermal reforming is favoured as a process, since the CO_2 produced can be captured more efficiently (up to 95 %) according to the state of the art (IRENA 2020). The technologies used in this process are referred to as carbon capture and storage (CCS) or, if the CO_2 is intended to be used as a chemical feedstock, as carbon capture, utilisation and storage (CCUS). However, losses in the upstream chain of hydrogen production are still climate-relevant.

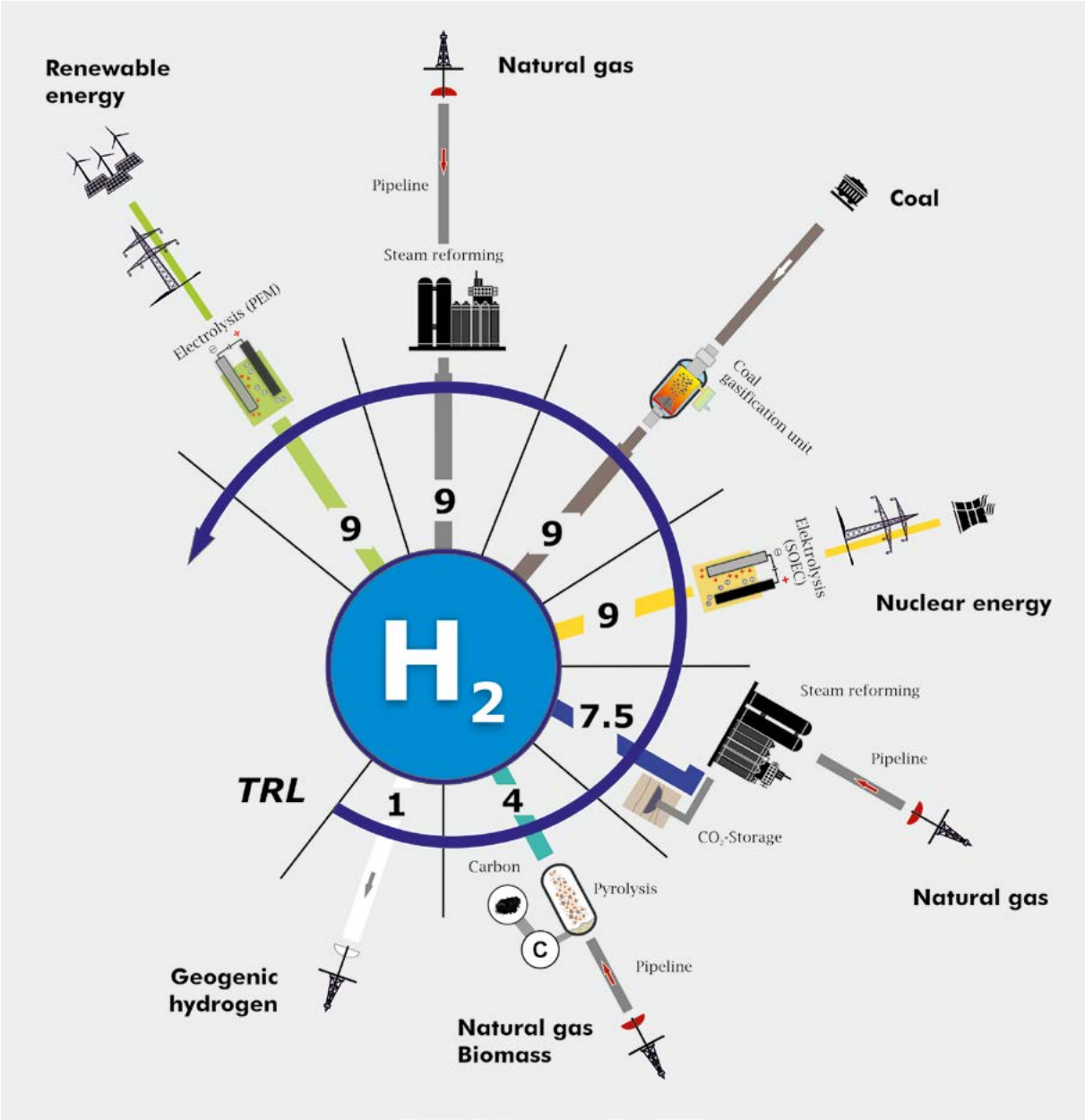


Figure A-47: Processes for the production of hydrogen (TRL - technology readiness level, according to Parkinson et al. 2019).

The captured CO_2 can be injected via pipelines into suitable horizons of the geological subsurface for permanent storage. These include, for example, depleted natural gas and oil reservoirs or saline aquifers. CCS technology has been used on an industrial scale off the coast of Norway since 1996. Since then, further CO_2 storage facilities have been put into operation, mainly in North America.

Methane pyrolysis is the largely climate-neutral splitting of methane under high temperatures into turquoise hydrogen and solid carbon. The main advantages of this process are that neither CO_2 is released nor is water required, and considerably less electrical energy is consumed to produce the same amount of hydrogen compared to electrolysis (Timmerberg et al. 2020).

Nuclear energy can also be used to produce hydrogen (pink, yellow, red). Various processes can be used: water electrolysis at ambient temperature, high-temperature electrolysis (SOEC), in which the electricity requirement is around 30 % lower than in conventional electrolysis due to the use of nuclear process heat, and other thermochemical processes (Forschungszentrum Jülich 2007).

Natural (geogenic) processes in the deep underground also produce hydrogen, which is also referred to as white hydrogen. Significant geogenic formation processes are serpentinisation and radiolysis (BGR 2020). However, the deposits known so far have been comparatively little explored. Whether natural hydrogen can make a substantial contribution to meeting the demand for hydrogen has not yet been conclusively clarified.

Although no greenhouse gas emissions are produced when hydrogen is burnt, they do occur in the upstream chain of hydrogen production (production, extraction and transport). The level of these emissions depends on the production process, the resource used and the respective electricity mix. The production of green hydrogen also indirectly causes greenhouse gas emissions, which occur in the manufacturing process of the electrolysis plants and in the provision of the resources required for this. The carbon footprint of these production processes can be improved by integrating low-emission energy sources.

The costs for the production of hydrogen depend on the production process, the energy resources used and the location. Production by means of electrolysis is currently the most cost-intensive. However, technological developments and economies of scale are expected to lead to significant cost reductions of electrolysis processes in the future (Valente et al. 2021; Parkinson et al. 2019). The ranges of costs for the different processes are sometimes very large and vary in different studies (Fig. A-48).

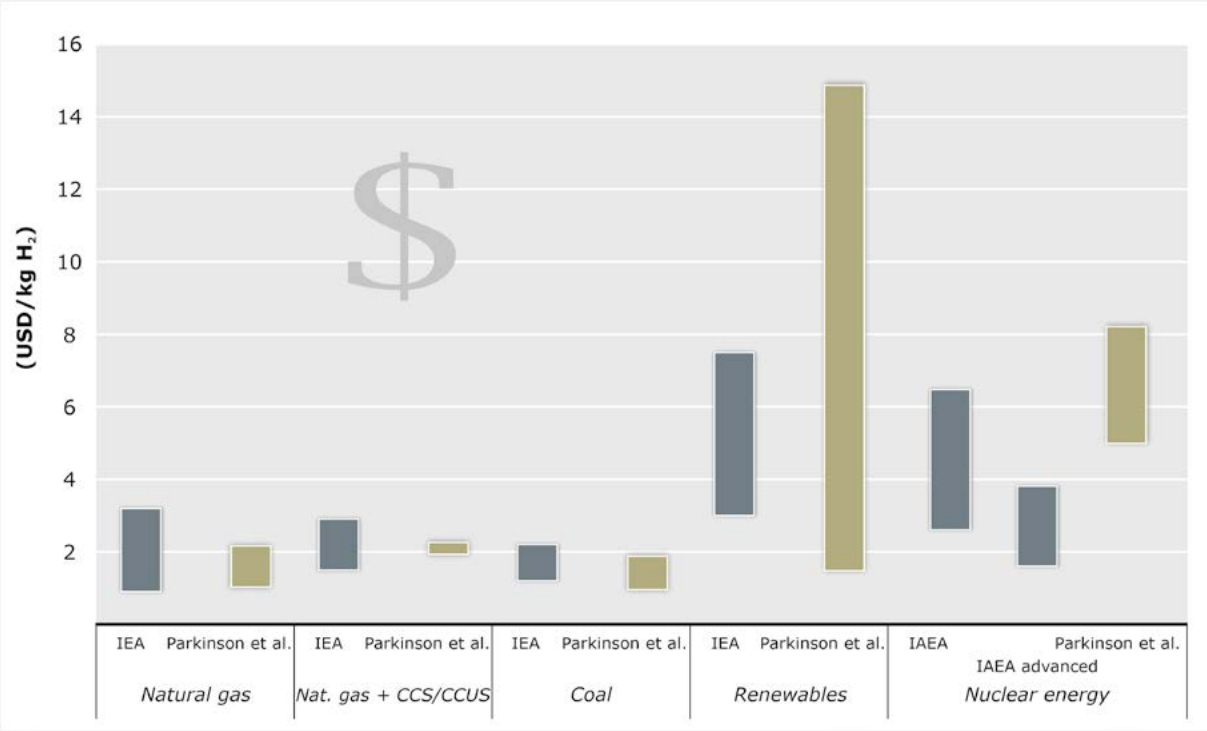


Figure A-48: Price ranges of hydrogen production costs according to IEA, IAEA (grey) and Parkinson et al (green) for steam reforming (natural gas with and without CCS), coal gasification and electrolysis with electricity from renewables or nuclear energy (IEA 2018, IEA 2019, IAEA 2018, Parkinson et al 2019).

References

BGR – Bundesanstalt für Geowissenschaften und Rohstoffe (2020): Wasserstoffvorkommen im geologischen Untergrund.
https://www.bgr.bund.de/DE/Gemeinsames/Produkte/Downloads/Commodity_Top_News/Energie/63_wasserstoffvorkommen_im_geologischen_untergrund.html;jsessionid=D2383482AF32F3EBCA4D02A588EFE928.2_cid321?nn=1542132&__blob=publicationFile&v=2 [accessed on: 11.2021]

Forschungszentrum Jülich (2007): Nuclear Energy from Hydrogen Production.
https://juser.fz-juelich.de/record/58871/files/Energietechnik_58.pdf [accessed on: 11.2021]

IAEA – International Atomic Energy Agency (2018): Examining the Technoeconomics of Nuclear Hydrogen Production and Benchmark Analysis of the IAEA HEEP Software, IAEA-TECDOC-1859. – 228 p.; Wien, Austria.
https://www-pub.iaea.org/MTCD/Publications/PDF/TE-1859web.pdf [accessed on: 11.2021]

IEA – International Energy Agency (2018): Hydrogen production costs by production source, 2018. Hydrogen production costs by production source, 2018 – Charts; Paris, France.
https://www.iea.org/data-and-statistics/charts/hydrogen-production-costs-by-production-source-2018 [accessed on: 11.2021]

– (2019): The Future of Hydrogen. – 203 p.; Paris, France.
https://www.iea.org/reports/the-future-of-hydrogen [accessed on: 11.2021]

IRENA – International Renewable Energy Agency (2020): Green Hydrogen: A guide to policy making, International Renewable Energy Agency. – 52 p.; Abu Dhabi, United Arab Emirates.
https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Nov/IRENA_Green_hydrogen_policy_2020.pdf [accessed on: 11.2021]

Parkinson, B., Balcombe, P., Speirs, J.F., Hawkes, A.D. & Hellgardt, K. (2019): Levelized cost of CO_2 mitigation from hydrogen production routes. – In: Energy & Environmental Science 12, 19-40.
https://doi.org/10.1039/C8EE02079E [accessed on: 11.2021]

Timmerberg, S., Kaltschmitt, M. & Finkbeiner, M. (2020): Hydrogen and hydrogen-derived fuels through methane decomposition of natural gas – GHG emissions and costs. – In: Energy Conversion and Management: X, 7.
https://doi: 10.1016/j.ecmx.2020.100043. [accessed on: 11.2021]

Valente, A., Iribarren, D. & Dufour, J. (2021): Comparative life cycle sustainability assessment of renewable and conventional hydrogen. – In: Science of the Total Environment 756.
https://doi.org/10.1016/j.scitotenv.2020.144132 (accessed on: 11.2021}

Glossary / List of abbreviations

AGEB	Arbeitsgemeinschaft Energiebilanzen e. V. (Energy Balance Group), headquarters in Berlin
AGEE-Stat	Arbeitsgruppe Erneuerbare Energien-Statistik (Working Group on Renewables Statistics), headquarters in Berlin
Aquifer	an underground layer of rock which is permeable enough to allow the movement of fluids
Aquifergas	natural gas dissolved in groundwater
API	American Petroleum Institute; umbrella organisation of the oil, gas and petroleum industry in the USA
°API	unit for the density of liquid hydrocarbons: the lower the degree, the heavier the oil
ARA	abbreviation for Amsterdam, Rotterdam, Antwerp
ATR	Synthesis gas production (autothermal reforming)
b, bbl	barrel; standard American unit for crude oil and oil products; cf. Units
Binary	a binary circuit, with a lower boiling point than water, is heated up via a heat exchanger. This vapourises and drives a turbine
Biofuels	liquid and gaseous fuels produced from biomass: e.g. bioethanol, biodiesel and biomethane
Biodiesel	a fuel that has similar burning qualities to mineral diesel fuel. It is made from oleaginous plants (e.g. rapeseed, soy) by transesterification the oil and adding methanol or ethanol. It can also be obtained from algae or cellulose-containing (→ biomass), such as plant waste (cornstalk, wheat straw)
Biomass	the biodegradable part of products, waste and residues from agriculture of biological origin (including animal and vegetable substances), forestry and related industries including fishing industry and aquaculture. The biodegradable part of waste from industry and households also belongs to biomass
BMUB	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety), located in Berlin
BMWi	Bundesministerium für Wirtschaft und Energie (Federal Ministry of Economic Affairs and Energy), located in Berlin
boe	barrel(s) oil equivalent; energy unit corresponding to the amount of energy released when combusting one barrel of oil

BP	British Petroleum; internationally active energy corporation, headquarters in London
Brent	the most important crude oil type in Europe. Forms the reference price for the European market
BTL	biomass to liquid; synthetic fuel made from biomass
BTU	British thermal unit(s); energy unit
BWP	Bundesverband Wärmepumpe e. V., headquaters in Berlin
CBM	coal-bed methane; gas contained in coal, including methane
CCS	Underground carbon dioxide storage (Carbon Capture and Storage)
CCUS	Carbon Capture, Utilisation and Storage (CCS) is a technology for the capture, utilisation and storage of carbon.
cif	cost, insurance, freight; a typical transport clause incorporated in maritime transport transactions, corresponding to the `free on board` clause where the seller also bears the cost of delivery, insurance and freight to a defined port
Condensate	liquid constituents of natural gas which are gaseous in the reservoir, and can be separated after production. Also known as natural gas liquids (NGL) (density >45°API or < 0.80 g/cm³)
Consumption	energy and material use of energy resources. If no statistical data on consumption are available, this is determined in a simplified manner from the sum of production and imports minus exports. Changes in stocks of energy resources in stockpiles, warehouses or storage facilities are included if sufficient data are available
Crude oil	natural occurring mixture of liquid hydrocarbons. Liquid hydrocarbons such as natural gas liquids (NGL) and condensates co-produced from natural gas wells are also categorised as oil production. *Conventional crude oil:* Generally used to describe oil that can be produced by relatively simple methods and inexpensively thanks to its low viscosity and a density of less than 1g per cm³ (heavy oil, light oil, condensate). *Unconventional crude oil:* Hydrocarbons that cannot be produced using conventional methods, but which require more complicated technology to produce them from the ground. In the reservoir itself, this oil is either incapable of flowing or can only flow marginally because of its high viscosity and/or density (extra heavy oil, bitumen), or because of the very low permeability of the reservoir rock (crude oil in tight rocks, tight oil, shale oil). In the case of oil shale, the oil is still in the form of kerogen in an early maturation stage.

Crude oil gas	gas dissolved in the oil in the reservoir which is released when the oil is produced.
CTL	coal to liquid; coal-derived synthetic fuel.
Cumulative production	total production since the start of production operations
dena	German Energy Agency; located in Berlin
deposit	part of the earth's crust with a natural concentration of economically extractable mineral and/or energy commodities
DOE	Department of Energy (USA)
downstream	activities in the production chain after the oil or gas has been produced from the production well: such as processing, transport, handling, sales
EEG 2017	Renewable Energy Sources Act in Germany
EGC	European Geothermal Congress
EGS	enhanced geothermal systems: geothermal systems artificially enlarged by fracking and with insufficient naturally convecting fluids
EIA	U.S. Energy Information Administration
EIB	European Investment Bank
EITI	Extractive Industries Transparency Initiative
Energy consumption	energetic and material use of energy resources. If there is no statistical data, consumption is determined from the sum of production and imports minus exports. Changes in inventory of energy resources such as stockpiles or in storage facilities are included, if there is sufficient data available
EOR	enhanced oil recovery: processes used to improve the natural recovery rate of an oilfield
ESA	Euratom Supply Agency – European Commission
EUR	Estimated ultimate recovery. Estimated total amount of an energy commodity that can be extracted from a deposit
Field growth	increase/growth in original reserves during the production of a crude oil or natural gas field as a result of improvements in production technology, and a better understanding of the reservoir and production processes (→ reserve growth)
Gas hydrate	solid (snow-like) molecular compound consisting of gas and water which is stable under high pressures and low temperatures

Geothermal energy	Geothermal heat comprises the original heat of the earth and the heat generated by the decay of radioactive isotopes beneath the surface of the earth. A general distinction is made between shallow geothermal energy down to a depth of 400 m, and deep geothermal energy below depths of 400 m. Both of these zones are used for heating purposes (direct utilisation). Only deep geothermal energy is suitable for generating electrical power because of the higher temperatures in deeper underground rock formations and the associated adequate temperature difference compared to air temperatures. A distinction is made between deep geothermal energy systems associated with hydrothermal and petrothermal sources depending on whether geothermal heat is used primarily in the form of the heat of circulating thermal water (hydrothermal), or heat in the hot deep rock (petrothermal). Geothermal energy is considered to be a baseload-capable, needs-centric, low emission, innovative technology which is geopolitically attractive, and can make a contribution to solving climate problems. It is classified as a renewable energy resource. *Hydrothermal geothermal energy* The energy which harnesses the heat energy stored in natural deep thermalwater- filled horizons (hydrothermal).
GeotIS	Geothermal Information System, Leibnitz Institut für Angewandte Geophysik, Hannover
GDC	Geothermal Development Company
Giant, Super-Giant, Mega-Giant	categories of crude oil and natural gas fields depending on the size of their reserves: Giant: > 68 million t oil or > 85 billion m³ natural gas, Super-Giant: > 680 million t oil or > 850 billion m³ natural gas, Mega-Giant: > 6,800 million t oil or > 8,500 billion m³ natural gas
Global production	sum of known individual country values. Countries for which no values are available or whose production or production data are confidential are not included.
GRMF	Geothermal Risk Mitigation Facility
GTL	gas to liquid; using different methods to produce synthetic fuels from natural gas. Methods include Fischer-Tropsch synthesis
GW_e	Gigawatt electricity
GW_{th}	Gigawatt thermal
GWh	Gigawatt hours
Hard coal	anthracite, bituminous coal, hard lignite with an energy content >16,500 kJ/kg (ash-free)

HEU	highly enriched uranium (> 90 % U-235), mainly used for military purposes
High-enthalpy reservoir	geothermal reservoir with a large thermal anomaly. The high temperature differences support a high degree of efficiency when generating electricity. Reservoirs of this kind are usually found in the vicinity of active plate margins
Hydropower	(also hydro energy) is the use of kinetic or potential energy of water by using hydropower plants
IAEA	International Atomic Energy Agency; UN agency; headquarters in Vienna. cf. Economic country groupings
IEA	International Energy Agency OECD organisation; headquarters in Paris
IMF	International Monetary Fund
Initial reserves	cumulative production plus remaining reserves
in-place	total natural resource contained in a deposit/field (volume figure)
in-situ	located within the deposit: also refers to a reaction or a process occurring at the point of origin; also a synonym for in-place
Installed capacity	the nominal capacity or maximum capacity of a power plant. The associated SI unit is the Watt
IOC	International oil companies, including the super majors: Chevron Corp., Exxon Mobil Corp., BP plc, Shell plc, Total Energies, etc.
IR	inferred resources; resources of uranium comprising those proven resources which do not satisfy the reserves criteria. Corresponds to the now obsolete class EAR I (estimated additional resources)
IRENA	International Renewable Energy Agency
J	joule; cf. Units
kWh	Kilowatt hours
LBEG	Landesamt für Bergbau, Energie und Geologie, located in Hannover (State Office of Mining, Energy and Geology)
LEU	low enriched uranium
LIAG	Leibniz-Institut für Angewandte Geopysik (Leibniz Institute for Applied Geophyics), located in Hannover
Lignite	raw coal with an energy content (ash free) < 16,500 kJ/kg

LNG	liquefied natural gas. Natural gas liquefied at -162 °C for transport (1 t LNG contains approx. 1,400 Nm³ natural gas, 1 m³ LNG weighs approx. 0.42 t)
Marine energy	(or ocean power) refers to the energy carried by large ocean currents, such as the Gulf Stream, the tidal flow or the flow of individual waves. Special power plants are used for each of these flow types
MENA	country Group (Algeria, Bahrain, Djibouti, Egypt, Iran (Islamic Rep.), Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestinian territories, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, United Arab Emirates, Yemen)
Methane	simplest hydrocarbon (CH_4)
MFAT	New Zealand Ministry of Foreign Affairs and Trade
Mine gas	gases which are released during the mining of coal. Primarily methane, carbon dioxide, carbon monoxide, nitric oxides, and in some cases hydrogen
Mineral oil	oil and petroleum products produced in refineries
MW_e	Megawatt of electricity
Natural gas	gas occurring naturally underground or flowing out at the surface. Combustible gases with variable chemical compositions. *Wet natural gas* contains methane as well as longer chain hydrocarbon constituents *Dry natural gas* only contains gaseous components and mainly consists of methane *Sour natural gas* contains varying amounts of hydrogen sulphide (H2S) in the ppm range *Conventional natural gas*: free natural gas or crude oil gas in structural or stratigraphic traps *Natural gas from unconventional deposits* (in short: unconventional natural gas): Due to the nature and properties of the reservoir, the gas does not usually flow in adequate quantities into the production well without undertaking additional technical measures, either because it is not present in the rock in a free gas phase, or because the reservoir is not sufficiently permeable. These unconventional deposits of natural gas include shale gas, tight gas, coal bed methane (CBM), aquifer gas and gas from gas hydrates
NCG	non-condensable gases
NDB	North German Basin
NEA	Nuclear Energy Agency; part of OECD, headquarters in Paris

NGL	natural gas liquids (→ condensate)
NGPL	natural gas plant liquids: constituents of produced natural gas which are liquefied separately in the processing plant (→ condensate)
NWR	National Hydrogen Council; independent, non-partisan advisory body from business, science and civil society to the Federal Government for the further development and implementation of the National Hydrogen Strategy
OECD	Organisation for Economic Co-operation and Development, headquarters in Paris; cf. Economic country groupings
Oil recovery rate	percentage of recoverable oil from a deposit
OPEC	Organization of Petroleum Exporting Countries, headquarters in Vienna; cf. Economic country groupings
OPEC basket price	average price of the different qualities of crude oil produced by OPEC members
ORG	Oberrheingraben
Peak Oil	time when maximum crude oil production level is reached
PEC	primary energy consumption; describes the total amount of energy required to supply an economy
Permeability	measure of the hydraulic transmissivity of a rock; unit: Darcy [D]; symbol: k; cf.: Units
Photovoltaics	describes the electrical use of (→ solar energy). Light is converted directly into electricity by using solar cells
Porosity	pore space in a rock: unit: [%]
Potential	total potential: cumulative production plus reserves plus resources
Primary energy	primary energy is the energy directly present in the energy resources, for instance hard coal, lignite, crude oil, natural gas, water, wind, nuclear fuel, solar radiation. Primary energy is converted to end energy in power plants or refineries for instance. Some primary energy is used for non-energetic purposes (for instance, crude oil for the plastics industry)
Pure gas	standardized natural gas with a calorific value of 9.7692 kWh / Nm^3 in Germany
Raw gas	untreated natural gas recovered during production

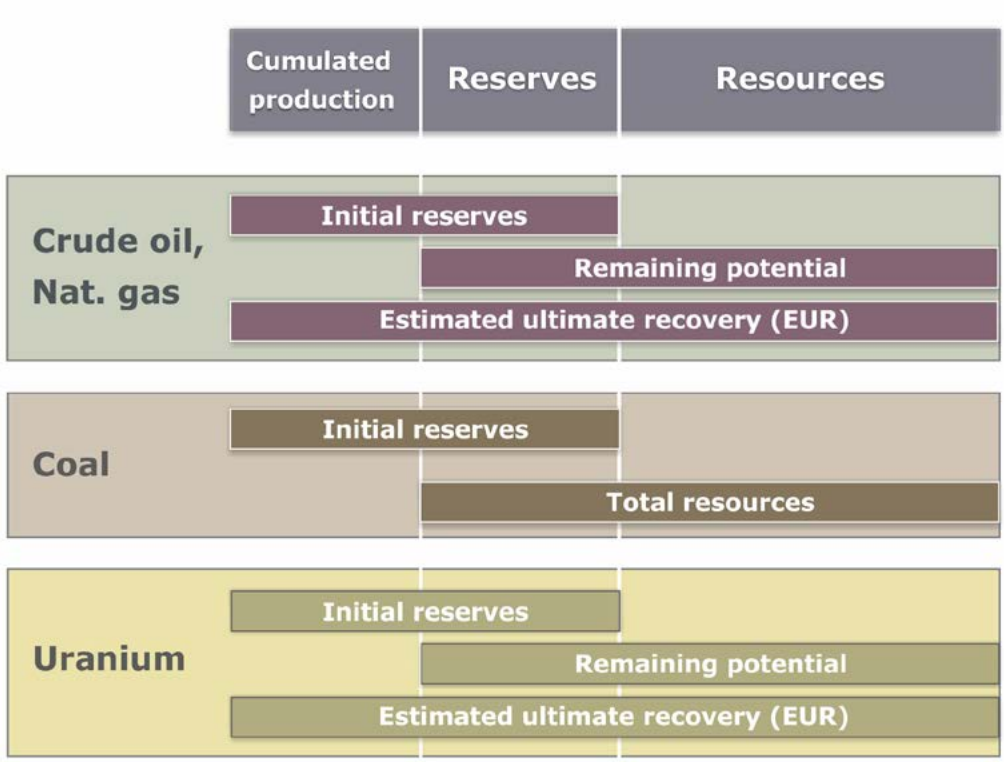
REEGLE	Renewable Energy and Energy Efficiency Partnership
REmap 2030	Renewable Energy Roadmap
REN21	Renewable Energy Policy Network for the 21st Century
Renewable energy	these encompass a very wide range of energy resources. Because they are virtually inexhaustible, or renew themselves relatively quickly, they differ from fossil energy resources which only regenerate over periods of millions of years. They include biomass, geothermal energy, marine energy, solar power, hydropower and windpower
Reserves	proven volumes of energy resources economically exploitable at today's prices and using today's technology *Original reserves:* cumulative production plus remaining reserves
Reserve growth	→ *field growth*
Ressources	proven amounts of energy resources which cannot currently be exploited for technical and/or economic reasons, as well as unproven but geologically possible energy resources which may be exploitable in future
Shale gas	natural gas from fine-grained rocks (shales)
Single Flash	hydrothermal fluid >182°C which condenses in a tank at low pressure and subsequently powers a turbine
SMR	Steam Methane Reforming
SOEC	Solid oxide electrolyzer cell
Solar energy	is radiant energy from the sun that is harnessed using a range of technologies such as (→ photovoltaics) converting radiation directly into electricity, or via absorption to generate heat (→ solar thermal)
Solar thermal	thermal use of (→ solar energy)
SPE	Society of Petroleum Engineers
Synfuel	synthetic fuel; liquid fuels can be synthesised by various technical processes. Important technologies are coal and gas liquefaction, as well as the production of fuels from biomass (→ biofuels)
tce	tons coal equivalent, corresponds to approx. 29.308 x 10^9 Joules; cf.: Conversion factors
Tight gas	natural gas from tight sandstones and limestones

TRL	Technology Readiness Level; Assessment of the state of development of new technologies
toe	ton(s) oil equivalent: an energy unit corresponding to the energy released when burning one tonne of crude oil. cf.: Conversion factors
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFC	United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources
UNFCCC	United Nations Framework Convention on Climate Change
upstream	all activities in the production chain which take place before hydrocarbons leave the production well: exploration, development and exploitation/production
Uranium	a natural constituent of rocks in the earth's crust. Natural uranium [Unat] (standard uranium) is the uranium which occurs naturally with an isotope composition of U-238 (99.2739 %), U-235 (0.7205 %) and U-234 (0.0056 %). Uranium has to be present in a deposit in concentrated form to enable it to be extracted economically. The following deposit (dps) types are currently of economic importance: discordancy-related vein dps, dps in sandstones, hydrothermal vein dps, dps in quartz conglomerates, Proterozoic conglomerates, breccia complex dps, intragranitic and metasomatic dps *Uranium from unconventional deposits (in short: unonventional uranium):* uranium resources in which the uranium is exclusively subordinate, and is extracted as a by-product. These deposits include uranium in phosphates, nonmetals, carbonates, black shales, and lignites. Uranium is also dissolved in seawater in concentrations of around 3 ppb (3 µg/l) and is theoretically *ractable*
USAID	United States Agency for International Development
USD	US-Dollar; currency of the United States of America
USGS	United States Geological Survey
VDKi	Verein der Kohlenimporteure e.V. (Coal Importer Association); headquarters in Berlin
WEC	World Energy Council, headquarters in London; organises the World Energy Congress

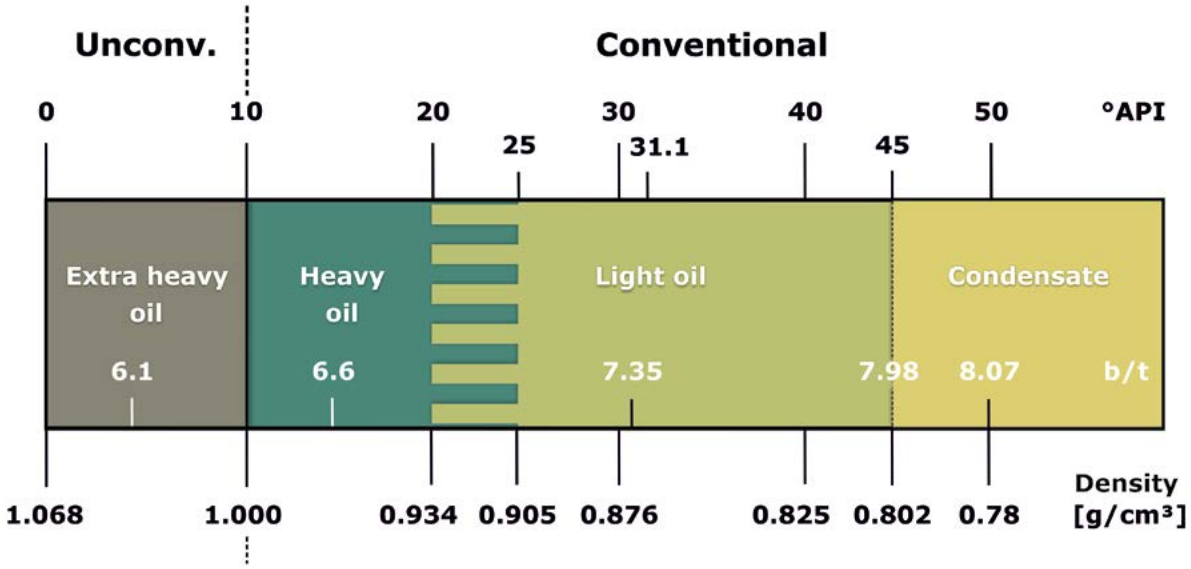
WGC	World Geothermal Congress: takes place every five years. Discussions on geothermal issues take place between global representatives from science, engineering, business, and society. In the run-up to the congress, comprehensive data are collected at a national level on the current situation regarding shallow and deep geothermal energy. These data are presented at the congress
Wind energy	(or wind power) is the use of wind through wind turbines to turn electric generators. In addition, the use of wind for traditionally mechanical use, like sailing, is common
WNA	World Nuclear Association, headquarters in London
WPC	World Petroleum Council; headquarters in London; organises the World Petroleum Congress
WTI	West Texas Intermediate: reference price of crude oil for the American market

Definitions

Distinction between reserves and resources



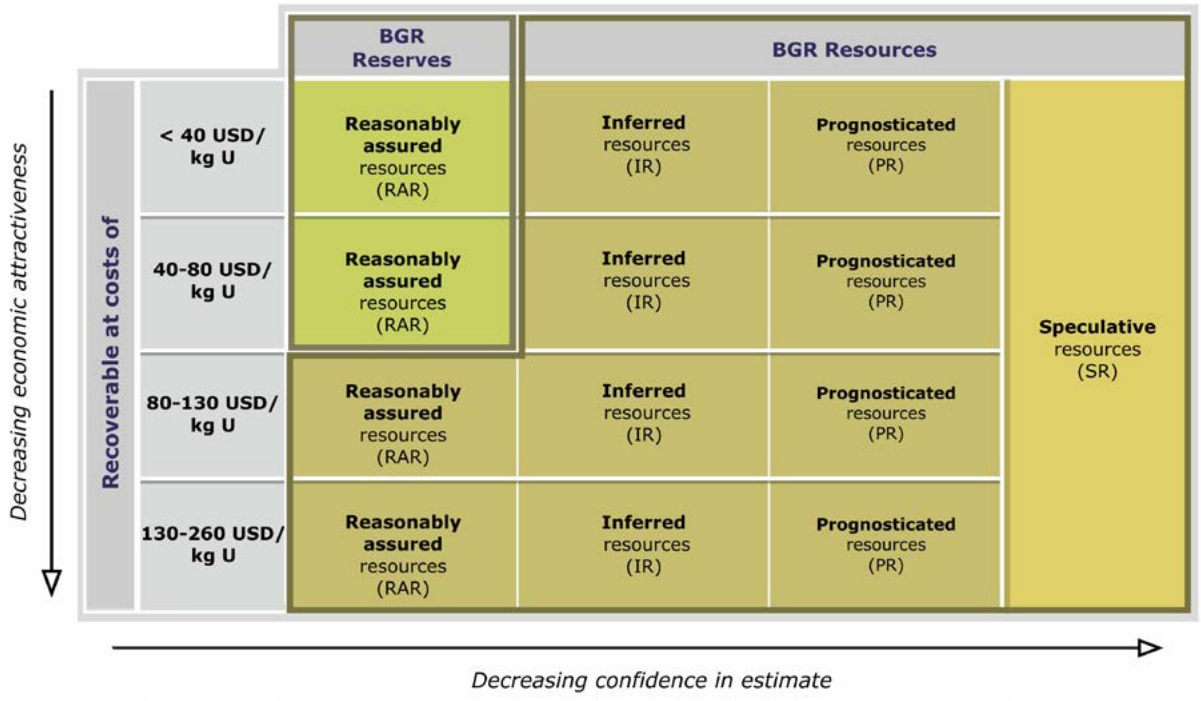
Classification of crude oil according to its density



Uranium reserves classification according to cost categories

Unlike other fuels, uranium reserves are classified according to production costs. According to the definition of reserves, the limit for the extraction costs is currently < 80 USD/kg U. However, the production costs in many countries are already much higher than this level. The following diagram illustrates the relationship between the various resource categories. The horizontal axis describes the amount of geological information available, and the certainty of there being a certain volume of resources. The vertical axis shows the economic cost of extracting the resource in US dollars.The system should be considered as dynamic. Changes in resource classifications can be the consequence of new (e.g. about size and position) of uranium deposits, but could also be due to increasing technical and economic criteria and extraction costs. This means that the resources category as well as the class of extraction costs could be redefined for parts of the resources. The most reliable details are in the RAR cost category < 80 USD kg U, which according to BGR's current definition as reserves (green). BGR classifies all resources with higher extraction costs are classified as resources (brown).

Diagram showing uranium reserves classification according to cost categories
(modified after IAEA and OECD 2014)



(Largely) climate-neutral hydrogen

Provided that no greenhouse gases are released into the atmosphere during production, the hydrogen produced is described as climate-neutral. According to the definition of the National Hydrogen Council (NWR), there are two types of largely climate-neutral hydrogen. On the one hand, this refers to "hydrogen produced with electric power if the electricity can be classified as climate-neutral according to the applicable legal rules. On the other hand, hydrogen that is produced on the basis of fossil fuels, but during the production of which no more than ten percent of the carbon contained in the fossil fuels is released into the earth's atmosphere as a greenhouse gas, is also referred to as largely climate-neutral".

Country groups of the BGR energy study

Europe

Albania, Andorra, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Faroe Islands, Finland, France, Germany, Gibraltar, Greece, Guernsey, Hungary, Isle of Man, Ireland, Iceland, Italy, Jersey, Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia (former Yugoslav Republic), Malta, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, Vatican City State

CIS incl. Georgia

Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova (Republic), Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan

Africa

Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cap Verde, Central African Republic, Chad, Comoros, Congo (Democratic Republic), Congo (Republic), Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau,Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mayotte, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Saint Helena, Ascension and Tristan da Cunha, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania (United Republic), Togo, Tunisia, Uganda, Western Sahara, Zambia, Zimbabwe

Middle East

Bahrain, Iran (Islamic Republic), Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen

Austral-Asia

„Austral"-Part:

Australia, Cook Islands, Fiji, French-Polynesia (Territory), Guam, Kiribati, Marshall Islands, Micronesia (Federated States), Nauru, New Caledonia, New Zealand, Northern Mariana, Norfolk Island, Palau, Pacific Islands (USA), Pitcairn, Ryukyu Islands, Salomon Islands, Samoa, Timor-Leste, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna, West-Timor (Indonesia)

„Asia"-Part:

Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Hong Kong, India, Indonesia, Japan, Korea (Democratic People's Republic), Korea (Republic), Laos (People's Democratic Republic), Macao, Malaysia, Maledives, Mongolia, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, Viet Nam

North America

Canada, Greenland, Mexico, United States

Latin America (Middle- and South America without Mexico)

Anguilla, Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermudas, Bolivia (Plurinational State), Brazil, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic,

Ecuador, El Salvador, Falkland Islands (Islas Malvinas), Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, St. Kitts and Nevis, St. Lucia, St. Pierre and Miquelon, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay, Venezuela (Bolivarian Republic)

Ecconomic country goupings status: 2020

BRICS-nations

Brazil, **R**ussian Federation, **I**ndia, **C**hina, **S**outh Africa

European Union

EU-28	European Union (from 01.07.2013) Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Laivia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom
EU-27	European Union (from 01.02.2020) without United Kingdom

IAEA (International Atomic Energy Agency; 172 countries)

Afghanistan (Islamic Republic), Albania, Algeria, Angola, Antigua and Barbuda, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bolivia (Plurinational State), Bosnia and Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Cap Verde, Central African Republic, Chad, Chile, China, Colombia, Comoros, Congo (Democratic Republic), Congo (Republic), Costa Rica, Côte d'Ivoire, Croatia, Cuba, Cyprus, Czechia, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Eritrea, Estonia, Eswatini, Ethiopia, Fiji, Finland, France, Gabon, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Iran (Islamic Republic), Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kyrgyzstan, Korea (Republic), Kuwait, Lao (People's Democratic Republic), Latvia, Lebanon, Lesotho, Liberia, Libya, Liechtenstein, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Mali, Malta, Marshall Islands, Mauritania, Mauritius, Macedonia (former Yugoslav Republic), Mexico, Moldova (Republic), Monaco, Mongolia, Montenegro, Morocco, Mozambique, Myanmar, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Rwanda, Russian Federation, Saint Lucia, Saint Vincent and the Grenadines, San Marino, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, South Africa, Spain, Sri Lanka, Sudan, Sweden, Switzerland, Syrian Arab Republic, Tajikistan, Tanzania (United Republic), Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Uzbekistan, Vanuatu, Vatican City State, Venezuela (Bolivarian Republic), Viet Nam, Yemen, Zambia, Zimbabwe

NAFTA (North American Free Trade Agreement)

Canada, Mexico, United States

OECD (Organization for Economic Co-operation and Development; 37 countries)

Australia, Austria, Belgium, Canada, Chile, Colombia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea (Republic), Lativa, Lithuania, Luxembourg, Mexico, New Zealand, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States

OPEC (Organization of the Petroleum Exporting Countries; 13 countries)

Algeria, Angola, Congo (Republic), Equatorial Guinea, Indonesia, Iran (Islamic Republic), Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, United Arab Emirates, Venezuela (Bolivarian Republic)

OPEC-Gulf

Iran (Islamic Republic), Iraq, Kuwait, Saudi Arabia, United Arab Emirates

Units

b, bbl	barrel	1 bbl = 158.984 liters
cf	cubic foot	1 cf = 0.02832 m^3
J	Joule	1 J = 0.2388 cal = 1 Ws
kJ	Kilojoule	1 kJ = 10^3 J
MJ	Megajoule	1 MJ = 10^6 J
GJ	Gigajoule	1 GJ = 10^9 J = 278 kWh = 0.0341 t tce
TJ	Terajoule	1 TJ = 10^{12} J = 278 x 10^3 kWh = 34.1 t tce
PJ	Petajoule	1 PJ = 10^{15} J = 278 x 10^6 kWh = 34.1 x 10^3 t tce
EJ	Exajoule	1 EJ = 10^{18} J = 278 x 10^9 kWh = 34.1 x 10^6 t tce
m^3	cubic meter	
Nm^3	standard cubic meter	Volume of Gas 1 m^3 at 0° C and 1.01325 bar [also m^3(Vn) abbreviated]
Mio. m^3	million cubic meter	1 Mio. m^3 = 10^6 m^3
Mrd. m^3	milliarden cubic meter	1 Mrd. m^3 = 10^9 m^3
Bill. m^3	billion cubic meter	1 Bill. m^3 = 10^{12} m^3
lb	pound	1 lb = 453.59237 g

t	ton	1 t = 10^3 kg
t / a	metric ton(s) per year	
toe	tons of oil equivalent	
kt	Kiloton	1 kt = 10^3 t
Mt	Megaton	1 Mt = 10^6 t
Gt	Gigaton	1 Gt = 10^9 t
Tt	Teraton	1 Tt = 10^{12} t
W	Watt	1 W = 1 J/s = 1 kg m^2 /s^3
MW_e	Megawatt electric	1 MW = 10^6 W
MW_{th}	Megawatt thermal	1 MW = 10^6 W
Wh	Watt hour	1 Wh = 3.6 kWs = 3.6 kJ
GWh_e	Gigawatt hour elektric	3.6 10^9 kJ
GWh_{th}	Gigawatt hour thermal	3.6 10^9 kJ
k	Kilo	10^3
M	Mega	10^6
G	Giga	10^9
T	Tera	10^{12}
P	Peta	10^{15}
E	Exa	10^{18}

Conversion factors

1 t crude oil	1 toe ≙ 7.35 bbl ≙ 1.428 tce ≙ 1,101 m^3 natural gas ≙ 41.8 x 10^9 J
1 t heavy oil	1 toe ≙ 6.19 bbl ≙ 1.428 tce ≙ 1.101 m^3 natural gas ≙ 41.8 x 10^9 J
1 t NGL/ condensat	1 toe ≙ 10.4 bbl ≙ 1.428 tce ≙ 1.101 m^3 natural gas ≙ 41.8 x 10^9 J
1 t LNG	1,380 m^3 natural gas ≙ 1.06 toe ≙ 1.52 tce ≙ 44.4 x 10^9 J
1,000 Nm^3 nat. gas	35,315 cf ≙ 0.9082 toe ≙ 1.297 tce ≙ 0.735 t LNG ≙ 38 x 10^9 J
1 tce	0.70 toe ≙ 770.7 m^3 natural gas ≙ 29.3 x 10^9 J
1 EJ (10^{18} J)	34.1 Mtce ≙ 23.9 Mtoe ≙ 26.3 Mrd. m^3 natural gas ≙ 278 billion TWh
1 t uranium (nat.)	14,000 - 23,000 tce; value varies depending on degree of capacity utilisation
1 kg uranium (nat.)	2.6 lb U_3O_8
1 Nm^3 hydrogen	0.0898 kg ≙ 3.0 kWh (lower calorific value)

Federal Institut for Geosciences and
Natural Resources
(Bundesanstalt für Geowissenschaften
und Rohstoffe – BGR)
Stilleweg 2
30655 Hannover, Germany

email: energierohstoffe@bgr.de
web: http://www.bgr.bund.de

ISBN: 978-3-9823438-4-6