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BGR ENERGY STUDY

Data and Developments Concerning German and Global Energy Supplies

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Federal Ministry for Economic Affairs and Energy

The Federal Institute for Geoscience and Natural Resources (BGR) is a technical and scientific agency of the Federal Ministry for Economic Affairs and Energy (BMWi).

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

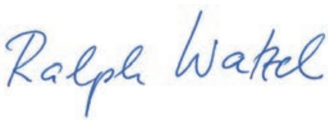
The high global demand for energy remains unchanged. Global primary energy consumption has risen again year-on-year. More than three quarters of consumption continues to be covered by fossil fuels, whilst the proportion of renewables lies at around 18 %. Reducing the emissions of greenhouse gases from fossil fuels therefore remains the primary objective of the Paris Agreement on climate change. Each country follows a different strategy to achieve the stipulated reduction goals, at the same time as permitting prosperity, growth and development. Qualified data and facts are the crucial foundation for the strategic orientation of future energy systems. In our annually published Energy Study, we provide politicians, industry and the public with a comprehensive overview of the utilisation and availability of energy resources.

The new Energy Study provides up-to-date data on the supplies of energy resources and the global trade in non-renewable energy resources, as well as on the generation of renewables. From a geological point of view, extensive reserves of energy resources are available. However, the global supply of energy currently faces new challenges because of shifting geopolitical conditions in particular. Key aspects here are climate protection and the reduction of greenhouse gas emissions, measures for environmental and socially acceptable production and use, and the necessary expansion and conversion of the technical infrastructure.

The expansion of renewables for power production worldwide is making progress: their share in the expansion of power production capacities in 2017 accounted for around 70 %, so that renewables now contribute around 30 % to global power production. In Germany, around 33 % of the electricity is produced by renewables. Compared to 2001 there has been a four-fold increase in the share of renewables in German primary energy consumption. Germany has set itself the target of reducing its emissions by at least 55 % by 2030 compared to 1990. The aims of the conversion of the energy systems to renewables are to use the available options to optimally achieve the goals of safeguarding prosperity, satisfying environmental concerns, and involvement, and thus balancing out conflicting objectives. This also applies in the light of the continuing rise in the global human population, in particular in Africa, where so far only few people have reliable access to energy.

There has been a noteworthy boost of almost 5 % in the global production of natural gas. This increase is attributable to the development of new and unconventional gas fields in the USA, as well as the production of natural gas from conventional fields, primarily in the Russian Federation and the Middle East. In parallel, there is also a strengthening trend to transport natural gas as liquefied natural gas (LNG) in tankers. This opens up increasing opportunities for countries in south Asia and the Far East in particular which have previously not been able to be supplied with natural gas via pipelines, and thus to convert their primary energy supplies to a base-load capable and relatively low emissions energy resource.

Yours



(Prof. Dr. Ralph Watzel, President)

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1 ABSTRACT

Introduction – Global energy consumption grew further in 2017. The rise in the global population and the increase in overall living standards will probably give rise to an increase in energy demand, in the long term as well, despite increasing energy efficiency. The growth in energy consumption has been covered in the meantime by similar proportions of renewables and fossil energy resources, although crude oil, natural gas and coal still provide the main basis for global energy supplies. Part of the energy supply system will therefore continue to be covered by fossil energy resources in the foreseeable future as well. A decline in the global competition for energy resources is therefore not expected against this background. For Germany as well, the increase in the high import dependency of fossil energy resources is foreseeable despite the high growth rates achieved by renewables. Crude oil, natural gas, hard coal and lignite with a share of around 80 %, still easily make the largest contribution to covering German primary energy consumption.

Methodology – The latest Energy Study issued by the Federal Institute for Geosciences and Natural Resources (BGR) contains statements and analyses as at the end of 2017 on the situation of the energy resources crude oil, natural gas, coal, nuclear fuels, and renewable energy, including deep geothermal energy. The main focus of the report is estimating the geological inventory of energy resources by making reliable assessments of reserves and resources. The natural resource markets are also analysed with respect to the development of production, exports, imports, and the consumption of energy and fossil energy resources, and a detailed look is also taken at topical and socially relevant energy issues. The study is the basis for the natural resource industry advice given to the Federal Ministry for Economic Affairs and Energy (BMWi), German industry, and the general public.

The datasets published in the BGR Energy Study are a classified and evaluated extract of BGR's energy resources database, and were compiled from information in technical journals, scientific publications, reports issued by industry, specialist organisations and political bodies, and internet sources, and the results of our own surveys. If not explicitly mentioned otherwise, all of the data presented here is derived from BGR's energy resources database.

Results – All of the renewables together cover around 18 % of global energy consumption. This is primarily based on the "classic" renewables such as hydropower and biomass. The "modern" renewables such as photovoltaics and wind power have the greatest future growth potential. But fossil energy resources were also used worldwide in larger amounts in 2017 as well. More than 40 % of global primary energy consumption was accounted for by Austral-Asia – a region in which hard coal is primarily used to satisfy demand. North America (around 21 %) and Europe (around 15 %) follow in second and third place, whereby crude oil and natural gas are the main energy resources used here to cover primary energy consumption (Fig. 1-1) (BP 2018).

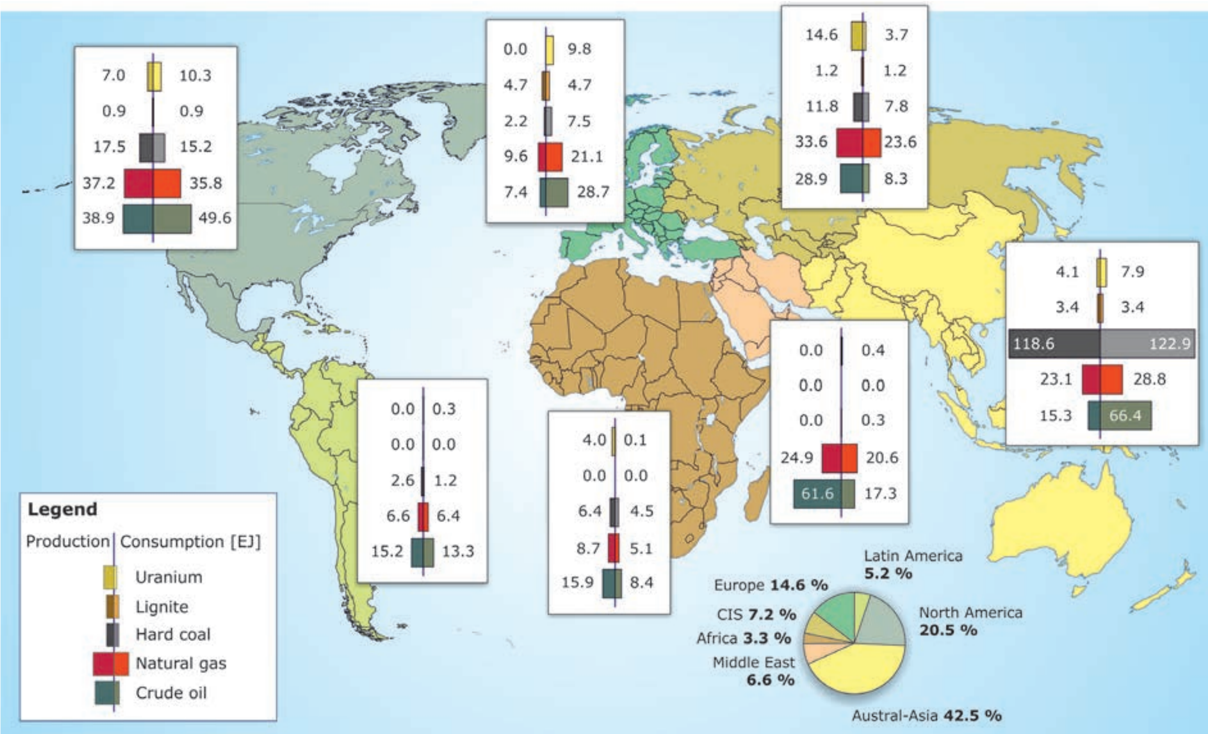

Figure 1-1: Regional distribution of the production and consumption of crude oil, natural gas, hard coal, lignite and uranium 2017 (BGR energy resources database) as well as regional share of global primary energy consumption (BP 2018).

The global comparison of the energy resources produced to date and therefore consumed, with the still available reserves and resources, reveals that there is still considerable potential for fossil energy resources (including uranium) in all regions around the world (Fig. 1-2). These are primarily large coal deposits which are found on all continents, and which are not limited to just a few regions, as is the case for conventional crude oil and natural gas. In addition, there are also enormous potential reserves of renewables whose quantities cannot be adequately quantified.

With a share of 550,183 Exajoules (EJ; 10^{18} Joule), the largest share of global non-renewable energy resources is defined as resources, and exceeds reserves many times over. This applies to all energy resources with the exception of conventional crude oil – which highlights the special role of this energy resource. Overall, there are only minor changes (minus 0.1 %) compared to the previous year which have no influence on the global resource figures. The energy content of all reserves rose last year to 40,237 EJ (plus 1.8 %) in particular because of a re-evaluation of the hard coal deposits in Indonesia. In terms of energy content, coal is the dominant energy resource with respect to resources and reserves. Crude oil, however, continues to dominate consumption and production. Because of the larger unconventional portions in comparison to natural gas, crude oil is also in second place in terms of reserves after coal. Fossil fuels continue to dominate the overall global energy mix, i. e. the actual energy consumed including renewables. In terms of geological

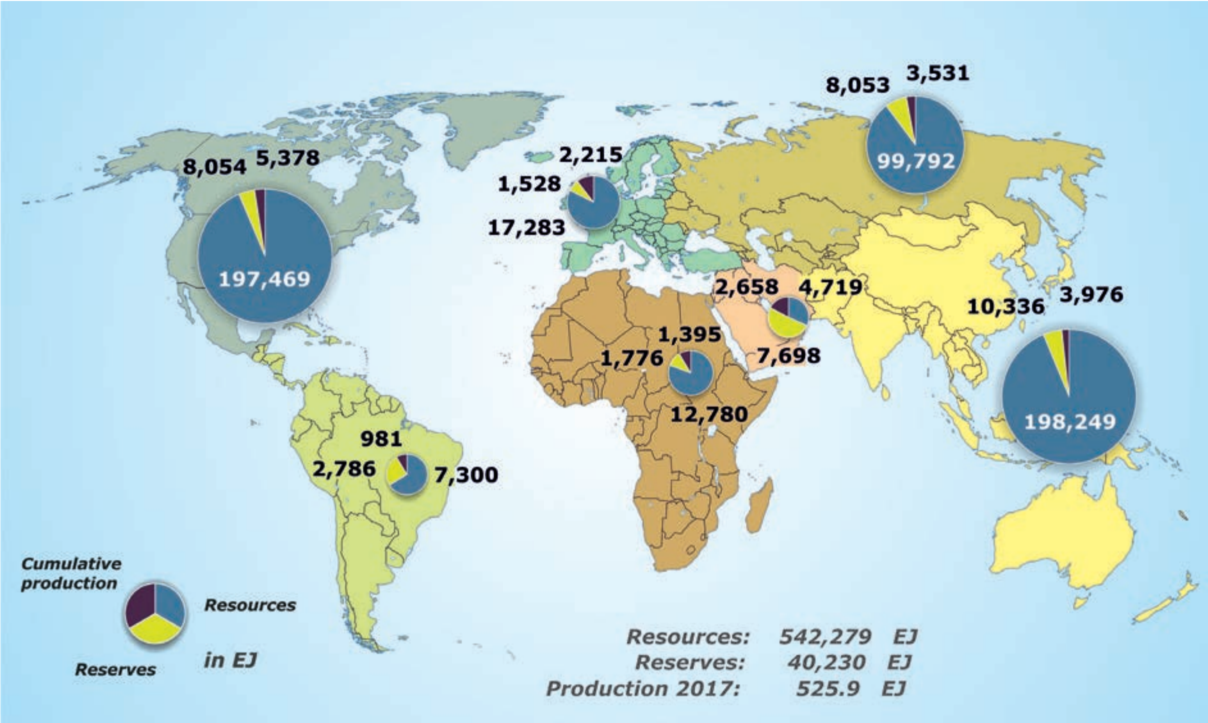

Figure 1-2: Total potential of fossil energy resources including uranium for 2017. (Does not take into consideration resources in the Antarctic, or aquifer gas, natural gas from gas hydrates and thorium, because these cannot be assigned regionally. The cumulative production of coal is estimated from 1950).

availability, the known reserves of energy resources are capable of covering the growth in demand for natural gas, coal and nuclear fuels in the long term as well, and can thus safeguard the change to a low-carbon energy system. Conventional crude oil is the only energy resource whose availability appears to be limited.

Key conclusions on crude oil, natural gas, coal, nuclear fuels, deep geothermal energy and other renewables:

Crude oil

- **Crude oil is the most important energy resource in the world, and will continue to be so in the foreseeable future.** Its share in primary energy consumption was 30.5 % in 2017.

- **From a geological point of view, a moderate rise in demand can be satisfied in the next few years. The reserves situation remains largely constant.** Nevertheless, supply shortages cannot be excluded in the medium term because investments in new E&P projects have dropped to relatively low levels since the strong decline in crude oil prices in 2014, notwithstanding the fact that the global demand for petroleum is expected to rise further.

- **China has become the largest crude oil importer in the world.** Crude oil production in the People's Republic of China has declined significantly in the last two years whilst consumption has continued to grow. Aspects of supply security is increasingly reflected in the country's geopolitical strategy.

- **German crude oil supplies are widely diversified with 33 supplying countries.** The two most important sources of crude oil remain the Russian Federation and Norway, which together account for 48.5 % of German crude oil imports.

- **East Asia, the USA and Europe have a particularly high level of dependence on crude oil imports.** Because of its large reserves of conventional crude oil, the Middle East will continue to remain the most important region for supplying the world with crude oil in the coming decades**.**

- With the exception of Venezuela, **the continuous rise in the price of crude oil over the course of the year** led to economic stabilisation in those countries where the oil sector accounts for a large proportion of economic output and exports.

Natrual gas

- **Natural gas is a flexible bridge technology for the transition to renewable energy supplies.** Natural gas is the fossil fuel with the lowest specific CO_2 emissions.

- **From a geological point of view, the global demand for natural gas can be satisfied for many more decades. T**his is highlighted by the following two figures: annual production in 2017 totalled around 3.8 trillion m^3 whilst global natural gas reserves total around 200 trillion m^3.

- **Global natural gas consumption rose by around three per cent compared to the previous year.** The growing demand was covered by new reserves.

- **Over 80 % of global natural gas reserves are located in OPEC countries and the CIS, and are found almost exclusively in conventional deposits.** The global share of unconventional reserves amounts to around 5 %.

- **The global trade in liquefied natural gas (LNG) grew again in 2017 and accounts for one third of natural gas transport.** The largest proportion of LNG is exported to Asia. LNG imported by countries in the European Union in 2017 largely came from Qatar, Algeria, Nigeria and Norway.

- **Because of the decline in natural gas production in the EU, as well as in Germany, there is a growing dependency on imports.** Europe has access to a large proportion of the global natural gas market via pipelines and LNG terminals.

- **With a growth in consumption to 106 billion m³, Germany is the seventh-largest natural gas consumer world-wide.** Primarily used in Germany for heat generation, over 90 % of the demand is covered by imports. Germany is one of the world's largest importers of natural gas.

Coal

- **Despite intense efforts to expand renewables, coal is still used globally in very large amounts.** Of all of the fossil energy resources, coal is the fossil fuel with the highest specific CO_2 emissions, as well as the energy resource with the largest global reserves and resources. There was a further increase in the demand for coal worldwide in 2017. The demand for coal will remain at a constant level in the medium term.

- **Global coal production increased by 3.5 % in 2017,** and preliminary estimates indicate that it could rise by another three percent in 2018 compared to 2017.

- **The world market prices for hard coal remained at a relatively high level for the last two years.** However, coal prices, and coking coal prices in particular, are subject to a large degree of volatility. This situation is not expected to change in the short term, subject to the reservation of a potential global recession occurring due to the expanding trade conflict between the USA and China, because investments in export mines dropped to a relatively low level.

- **The development in the global and therefore also European coal prices, will, as in previous years, be largely determined by the situation in Asia, and in China in particular.** China increased its coal imports by 6 % in 2017 to around 271 Mt. Other countries also, and particularly in south-east Asia, reported significant increases in coal imports. However, a foreseeable expansion in Chinese and Indian production, accompanied by a decline in imports to both of these countries, could lead to a drop in prices in the global coal market in the medium term.

- **European hard coal production continues to decline and its share of global hard coal production in 2017 was 1.3 % (around 82 Mt).** At the same time, European countries imported a total of 212 Mt hard coal to cover more than 70 % of their hard coal demand.

- **The two last German hard coal mines closed at the end of 2018.** This marks the end of over 200 years of industrial hard coal production in the Ruhr area and Germany as a whole.

- **Germany reduced its imports of hard coal by almost 11 % in 2017 to around 49 Mt.** As in the previous year, Germany imported around 93 % of its demand for hard coal and hard coal products.

Nuclear fuels

- **The uranium market continues to be affected by relatively low spot market prices, which jeopardise the profitability of various mines and exploration projects.** As a consequence of the reactor accidents in Fukushima in 2011, there was a global collapse in the uranium market and a decline in uranium prices. This price trend has, however, levelled off significantly after six years.

- **Global uranium production has declined for the first time in many years.** Because of the stagnating demand, many mines have reduced their production or shut down production completely this year, including market-dominating mines in Canada, Kazakhstan and Australia. The planned reduction in the production from some mines introduced as a measure to regulate the market, is aimed at reducing the current large volumes of uranium on the world market.

- **There continues to be a growing interest in the use of nuclear fuels for the generation of energy worldwide. 56 nuclear reactors were under construction in 16 countries at the end of 2017.** 40 of these alone are in Asia. The demand for uranium will continue to increase in the long term in Asia, as well as in the Middle East. Numerous countries are planning to start or expand the generation of electricity using nuclear power.

- **From a geological point of view, no shortage is expected in the supply of nuclear fuels.** Despite the continuing recession in the uranium market, there are still very comprehensive global stocks currently totalling 1.2 Mt reserves (cost category < 80 USD/kg U) and 11.7 Mt uranium resources.

- **The complete withdrawal from nuclear power for commercial electricity generation was laid down in law in Germany.** Ten of Germany's 17 nuclear power plants have been switched off since the change to the Atomic Energy Act in 2011. Withdrawal is scheduled to be completed at the end of 2022. The Gundremmingen B nuclear power plant in Bavaria was disconnected from the grid at the end of 2017.

Deep geothermal energy

- **Deep geothermal energy is a successfully tested type of energy production, which is attractive from a geopolitical point of view, as well as in the context of climate change.** The technology is base-load capable and innovative with low emissions and has a comparatively small surface footprint.

- **The global geothermal energy potential is very high although so far, it has only been exploited to a very minor extent.** In 2017, the share of geothermal energy in global power production amounted to around 0.3 %. The worldwide potential for geothermal energy down to a depth of 3 km is estimated to appriximately 300 EJ/a for heat generation and 100 EJ/a for power generation.

- **With the exception of geothermally favourable regions, the practical implementation and profitability of geothermal projects is currently still considered to be difficult.** There are considerable variations in investment costs, which are quite difficult to estimate in advance. Amortisation periods run typically to about 25 years.

- **Globally, the use of geothermal energy varies extremely.** Countries with high enthalpy deposits provide favourable conditions. Geothermal energy may become important particularly in developing countries, where it can contribute to electricity and heat supply in regions with modest infrastructure.

- **In Germany, the use of geothermal energy has declined slightly year-on-year in Germany for the first time in ten years.** The installed capacity for thermal generation decreased slightly by around 1 % to now 374 MW_{th}. The installed electrical capacity was reduced by around 36.2 MW_e, equivalent to 5 %. The share of primary energy consumption continues to remain low at 0.3 %. Geothermal energy is subsidised in Germany under the Renewable Energy Act (EEG).

Renewable energy

- **The expansion of power generation capacities is globally dominated by renewables.** 70 % of the global expansion of installed electricity power generation capacities is currently accounted for by the expansion of renewables. International activities to promote renewables remain high. Around 179 countries have currently formulated specific objectives to expand renewables further. Investments in new projects were primarily instigated in emerging and developing economies in particular in 2017.

- **The share of renewables in global energy supplies continues to expand.** Around 18 % of global primary energy consumption was accounted for by renewables in 2017 and primarily by "classic“ renewable energy sources such as solid biomass and hydroelectric power. The proportion of "modern" energy resources such as windpower and photovoltaics is still relatively low despite the enormous global expansion.

- **The globally installed power generation capacity has reached new record levels.** 2,179 GW of renewables are installed worldwide for power generation. This corresponds to around 30 % of estimated global power generation capacities. Photovoltaics again boast the highest growth rates. The new installed capacity totals 98 GW, of which around 54 % was accounted for by China alone.

- **Renewables in Germany account for the largest proportion of electrical energy generation.** The share of renewables in the German power mix reached 33 % in 2017 and accounted for around 13 % of primary energy consumption. Windpower, biomass and photovoltaics accounted for the main share. A further expansion in renewables in the electricity, transport and heat sector is expected in the future.

2 ENERGY SITUATION IN GERMANY

2.1 Primary energy consumption and energy supplies

Primary energy consumption (PEC) rose slightly in 2017 to 13,550 PJ (0.328 Gtoe) and therefore up 0.9 % year-on-year, and almost 12 % below the maximum reached in 1979 (Fig. 2-1). The development in consumption was favoured by the continuing relatively low prices for fossil fuels (AGEB 2018a).

The most important primary fuel as in the previous decades continues to be petroleum (34.5 %) followed by natural gas (23.8 %), coal (10.9 % hard coal and 11.1 % lignite), renewables (13.1 %) and nuclear power (6.1 %) (Fig. 2-1). The rise in energy consumption in the reported year is primarily attributable to the macroeconomic growth, the increase in energy consumption by the manufacturing industry, as well as the continuing growth in population. The weather, however, had hardly any impact (AGEB 2018a).

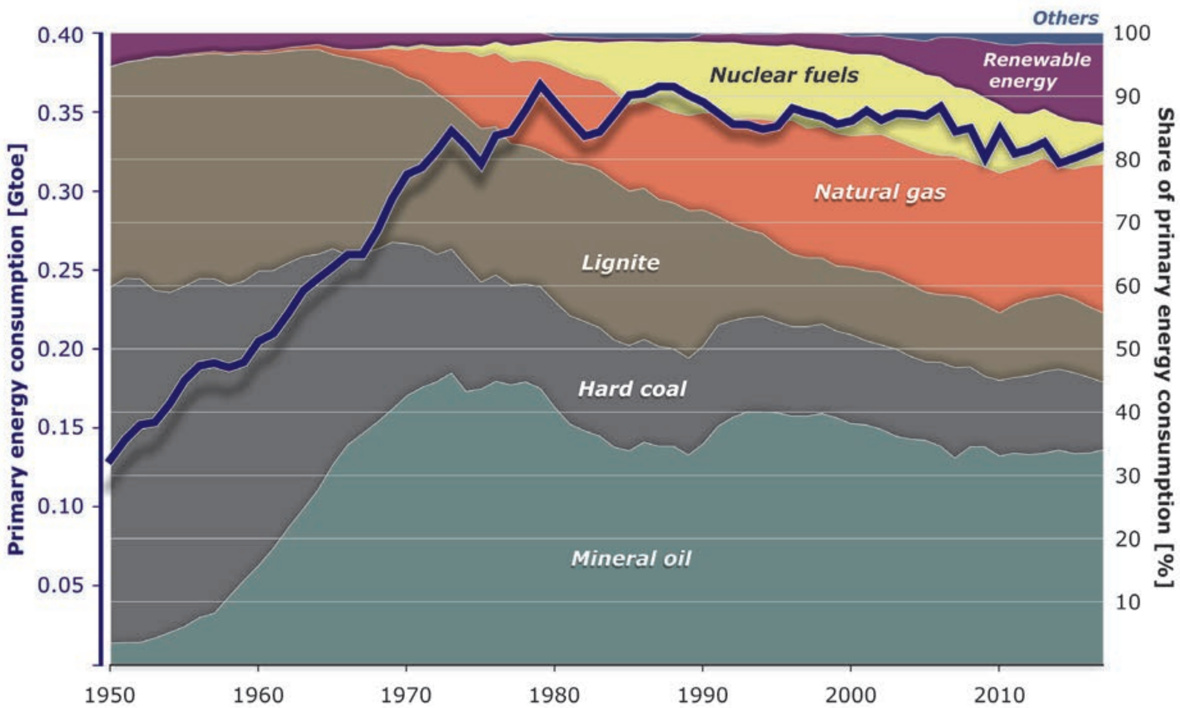

Figure 2-1: Development of German primary energy consumption from 1950 to 2017 (AGEB 2018a).

The rise in energy demand was primarily covered by a growth in the consumption of natural gas (plus 6.2 %), renewables (plus 6.1 %) and petroleum (plus 2.7 %). Declines were reported for hard coal (minus 11.3 %), nuclear power (minus 9.8 %), and lignite (minus 0.6 %). Despite the considerable decline in hard coal, the share of fossil fuels in primary energy consumption remained at a consistently high level of around 80 % as in the past 10 years. The share of renewables in total energy consumption in Germany rose to 13.1 % in 2017 (AGEB 2018a).

As a highly developed industrial country, Germany is one of the world's largest energy consumers, and covers most of its energy demand (around 70 %) by importing energy resources. Domestic production in 2017 accounted for around 2 % of the crude oil and 7 % of the natural gas (Fig. 2-2), and the trend continues downwards. The decline in production is primarily attributable to the increasing depletion of the fields and the absence of any new discoveries. The number of exploration wells drilled in comparison to the previous year has declined by half (2017 four wells), and the number of metres drilled reached the lowest level for over thirty years (LBEG 2018).

Hard coal had the strongest decline in production, and the planned end of subsidised hard coal production at the end of 2018 will lead to the complete disappearance of this share of domestic energy production. In 2017, domestic production accounted for 7 % of hard coal consumption. The foreseeable continuing demand for hard coal will then have to be completely covered by imports. Lignite production also declined slightly. Renewables have established themselves as the most significant domestic energy resource (almost 45 %), followed by lignite with around 38 %. Both were well ahead in the rankings in 2017 compared to natural gas, hard coal and crude oil (AGEB 2018). In addition to the further expansion of renewables, an increase in the share of natural gas in the energy mix in the short to medium term is also expected to have a positive influence on the reduction of CO_2 emissions.

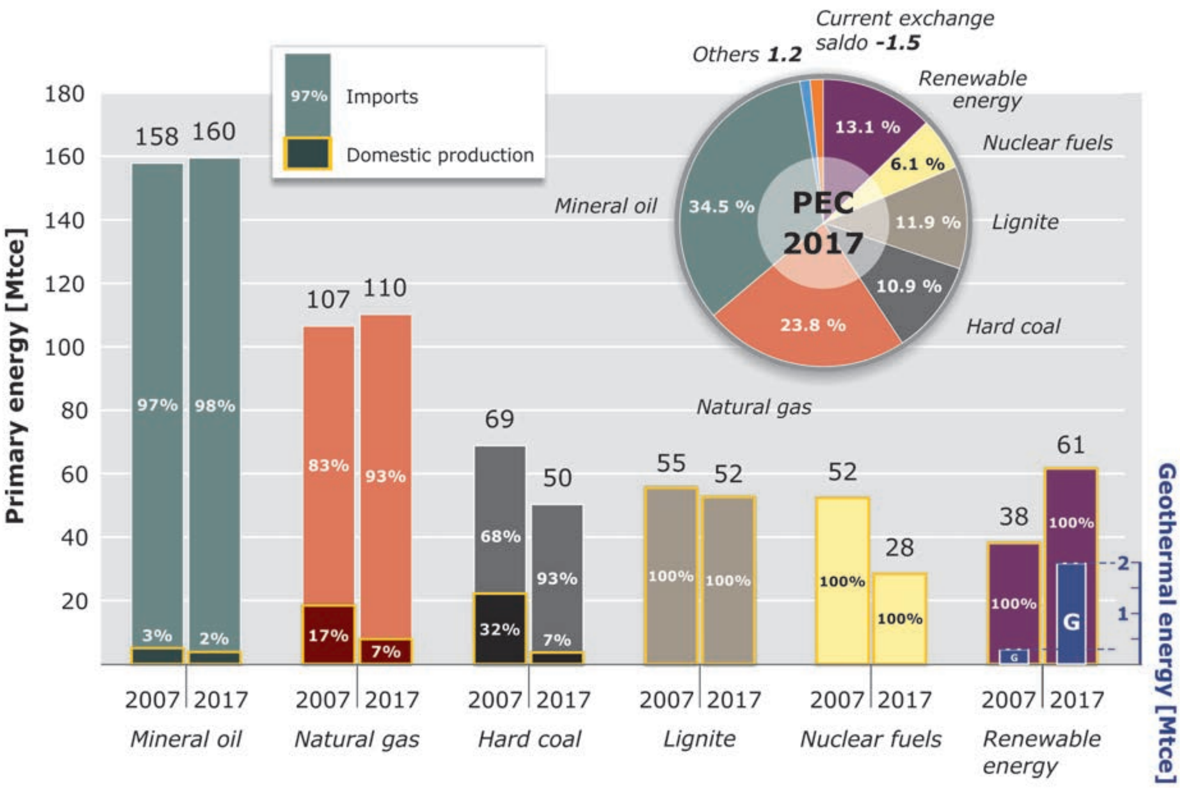

Figure 2-2: Import dependence and self-sufficiency level in Germany of some primary energy resources in 2007 and 2017 (AGEB 2018a, BMU 2013).

The 10-year comparison of the various energy resources contributing to primary energy consumption revealed a changing picture. Unlike hard coal, lignite and nuclear power, only petroleum and natural gas showed a slight increase in consumption amongst the non-renewable energy resources. This is attributable amongst other factors to relatively low consumption due to the mild weather in 2017. The share of renewables continued to grow thanks to favourable wind conditions and the increasing expansion (Fig. 2-2). As a consequence of the declining production of domestic conventional crude oil and natural gas, and the end to subsidised hard coal production, there is also a continuing decline in the amount that can be satisfied by domestic energy resources. Against this background, a further increase in Germany‘s high dependence on imports of fossil fuels is foreseeable.

2.2 Energy resources and energies individually analysed

Crude oil

With a share of almost 35 % of primary energy consumption, crude oil easily remains the most important fuel in Germany (AGEB 2018b), and will continue to make an important contribution to the German energy suppliy in the following decades as well. Crude oil products are primarily used as fuel in the transport sector. Petroleum products accounted for around 94 % of the final energy consumption in the transport sector (AGEB 2018b). Moreover, crude oil is also the most important raw material for the organic-chemical industry (VCL 2017). The German government‘s goal in the transport sector is to reduce final energy consumption by 10 % by 2020 compared to 2005 and by 40 % by 2050 (BMWi 2018a). Furthermore, greenhouse gas emissions should be reduced by 2030 by around 40 % compared to the reference year 1990 (BMUB 2016). Achieving these goals will require the implementation of a step-wise conversion to alternative drives, the increased use of climate-friendly natural gas, as well as the use of synthetic fuels.

The proven and probable crude oil reserves at the end of 2017 were around 28.3 Mt and therefore around 3.5 Mt respectively 11 % lower than the previous year (Tab. A-10 in the Appendix). This reduction is primarily due to the latest evaluation of the reserves in the existing fields. The amount of oil produced during 2017 could therefore only be partially replaced by the development of new reservoirs parts in the oil fields. The German crude oil reserves are mainly located in the North German Basin, with over 70 % of German reserves alone in Schleswig-Holstein (48.1 %) and Lower Saxony (26.5 %) (LBEG 2018).

Crude oil and condensate production in Germany declined again in 2017 to 2.22 Mt (2016: 2.35 Mt). 50 oil fields were in production at the end of 2017. The number of oil producing wells rose by 9 to the current total of 1,000 production wells. Over 87 % of the total crude oil production came from the 10 most productive oil fields. Production from the biggest German oil field, Mittelplate/Dieksand, declined by 5 % to 1.23 Mt, and therefore accounted for around 55 % of domestic oil production as in the previous year. The share of condensate in total production in 2017 reached 13,062 t. This corresponds to 0.6 % of total production. 19 % alone of German condensate production came from the only German offshore natural gas field, A6/B4 in the German North Sea (LBEG 2018).

The Emlichheim, Georgsdorf and Rühle fields are subjected to tertiary production measures such as steam and hot/warm water flooding − so-called Enhanced Oil Recovery (EOR) measures − to boost the rate of recovery. The production achieved by EOR measures accounted for 13 % of total production (LBEG 2018).

Because of the higher crude oil and natural gas price compared to the previous year, production royalties paid by the oil and gas producers to the federal states in Germany rose to € 249 million (plus 6 %). € 81 million of these royalties were accounted by oil production. Domestic drilling activity decreased slightly year-on-year and remains at a very low level with 24 active wells. In detail, four exploration wells and 20 field development wells were drilled (LBEG 2018).

The most important oil production companies and their production in Germany in 2017 according to consortium shares were (BVEG 2018):

- Wintershall Holding GmbH 875,137 t
- DEA Deutsche Erdoel AG 636,890 t
- ENGIE E&P Deutschland GmbH 293,248 t
- BEB Erdgas und Erdöl GmbH & Co. KG 233,865 t

As one of the largest petroleum consumers worldwide, Germany is almost completely dependent on imports of crude oil and crude oil products. Crude oil imports in 2017 declined slightly by 0.5 Mt (minus 0.6 %) to 90.7 Mt. Although Germany imports crude oil from over 33 countries, only three countries are particularly relevant for German crude oil supplies as in previous years: the Russian Federation, Norway and the United Kingdom. These countries together cover almost 58 % of German crude oil imports (Fig. 2-3). The main supply regions continue to be the CIS (48.6 %), Europe (22.6 %) and Africa (19.1 %).

There were increases in the amounts imported from Libya (plus 5.1 Mt), Nigeria (plus 1.1 Mt), and Iraq (plus 1.5 Mt). Smaller amounts were imported from the Russian Federation (minus 2.5 Mt), Norway (minus 0.9 Mt) and the United Kingdom (minus 0.7 Mt) (BAFA 2018a). An overview of all crude oil supplying countries in 2017 is shown in Table A-5 in the Appendix.

No crude oil was exported. The trade in petroleum products mostly involved EU countries. Exports of petroleum products rose by 3 % to 23.5 Mt whilst imports rose by almost 6 % to 41.1 Mt (BAFA 2018a).

German companies produced around 7.8 Mt crude oil overseas in 2017 (BVEG 2018). Wintershall Holding GmbH was able to boost its foreign production by 0.176 Mt year-on-year. DEA Deutsche Erdoel AG, however, reported a significant decline (minus 0.5 Mt).

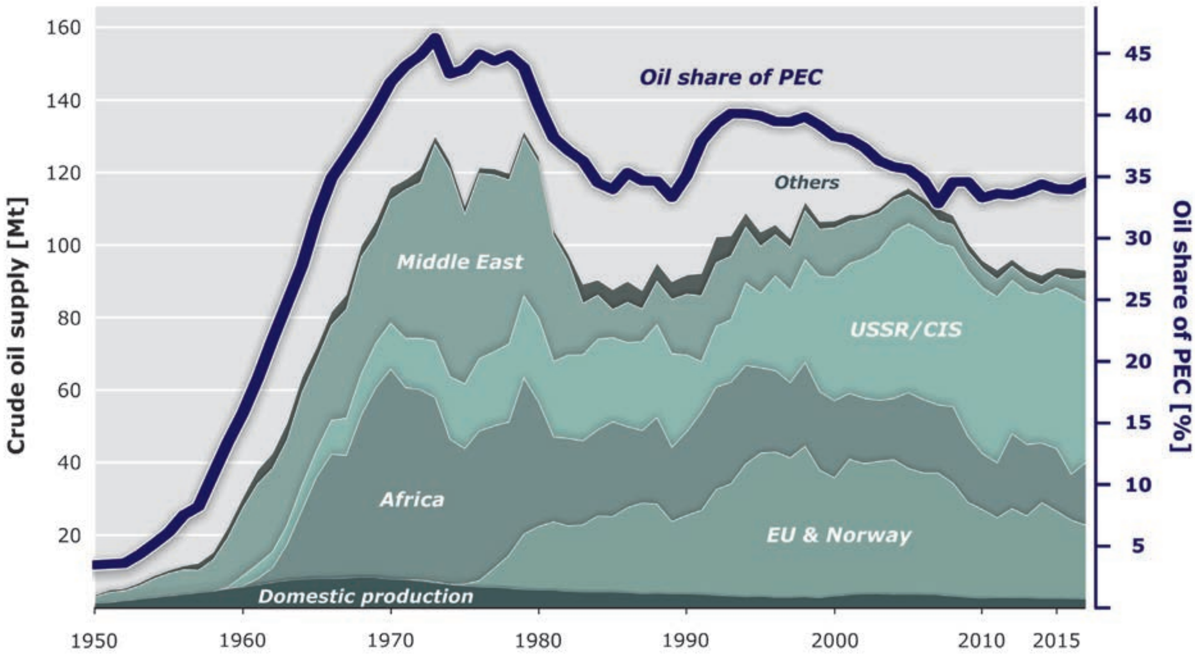

Figure 2-3: German crude oil supplies from 1950 to 2017 (AGEB 2018a, BAFA 2018a).

The most important German crude oil production companies and their overseas production in 2017 according to their consortium shares were (BVEG 2018):

- Wintershall Holding GmbH 5.76 Mt
- DEA Deutsche Erdoel AG 2.01 Mt

German energy suppliers restructured their upstream shareholdings in recent years or sold them off completely. Bayerngas Norge AS merged with the E&P division of Centria plc from the UK in December 2017 to create the independent Spirit Energy company. The German share in the new E&P company is 31 %.

The Federal Republic of Germany has been and remains almost completely dependent on imports of crude oil and crude oil products. Because of this dependence, the creation of an obligatory federal reserve was decided in 1966, and was put into legal force in 1978 by the Crude Oil Strategic Reserve Act (ErdölBevG) (EBV 2008). The statutorily prescribed minimum size of the strategic reserves corresponds to the daily average net imports for 90 days with respect to the last three calendar years preceding the respective period. The strategic reserves contain crude oil as well as petroleum products. These are stored in various facilities including caverns, tank or strategic storage facilities of refineries (BMJV 2017). As of 01 April 2017, the strategic reserves contained 14.2 Mt crude oil and 11.5 Mt petroleum products (EBV 2017). Although strategic reserves are stored in all German federal states, the reserves are concentrated in northwest Germany where the geological conditions allow storage in caverns. Major cavern storages are located in Willhelmshaven-Rüstlingen, Heide, Lesum and Sottorf.

E-fuels – the new climate-friendly fuel?

E-fuels are synthetic fuels generated using electrical energy from carbon-based materials such as carbon dioxide and water. Synthesis produces either gaseous fuels (power-to-gas, PtG) or liquids fuels (power-to-liquid, PtL). These are lumped together as power-to-x or PtX. Depending on the method used, the generation of synthetic fuels through electricity produces either hydrogen, methane or long-chain hydrocarbons. The necessary electrical energy is provided either by renewables or conventional power generation plants. If E-fuels are generated exclusively using renewables, then the synthetic fuels are largely CO_2-neutral. A major challenge for the large-scale and economic generation of E-fuels is the currently very low efficiency of the conversion process because production involves several energy-intensive processing steps. In addition, the provision of the most important raw materials which include purified water and carbon dioxide, is associated with a significant amount of energy input. Fuels today are primarily produced from the fossil fuels crude oil and natural gas. A significant substitution of these fuels by E-fuels will require the construction of significant additional power generation capacities, especially if these are based on renewable energy technologies. Because the base-load-capable hydroelectric power and biomass potential for power production is limited in Germany, the current choices primarily include photovoltaic and windpower plants to generate the additional electrical energy required. However, these are not base-load-capable and therefore only of restricted suitability for providing the energy needed for E-fuel synthesis plants. In 2017, around 113 GW of power generation capacities from renewable energy plants were installed (BNetzA 2018a), which generated around 216 billion kWh electricity (AGEB 2018c). The final energy consumption in Germany in the transport sector was around 2,755 PJ (AGEB 2018b), which corresponds to a calculated power equivalent of 766 billion kWh. The amount of energy required by the transport sector will remain very high in future as well, even if further increases in efficiency and savings are assumed. According to a Prognos AG study, the use of synthetic fuels in the transport sector in 2050 could be 1,570 PJ with a PtX share of 80 % (PtX 80 scenario), or 1,884 PJ with a PtX share of 95 % (PtX 95 scenario). Around 94 % in each case would be accounted for by liquid synthetic fuels (PtL) (Prognos AG 2018). Given the fact of the process-related low final efficiency when synthesising E-fuels, before it is used as a fuel, this would require the installation of many times the amount of renewable power generation capacity installed today. As an alternative, synfuels could be imported from countries with more favourable production conditions. The extent to which this could be realised, especially when these countries implement their own climate targets, and require newly installed capacities of renewable power for their domestic supplies, is currently not foreseeable. From today's point of view, the economic production of E-fuels not only requires a climate-neutral and base-load-capable power generation technology, but also a cheap technology capable of providing the enormous amounts of electricity required.

Natural gas

Natural gas will make an important contribution to energy supplies in Germany in the following decades. Natural gas produces the lowest specific CO_2 emissions during combustion of all of the other fossil fuels, and is therefore considered to be the most climate-friendly fossil fuel. The most important market for natural gas by far continues to be the heat market. In addition, natural gas is not only a raw material for the chemical industry, but also a flexible fuel for power generation.

The total reasonably assured and probable natural gas reserves in Germany at the end of 2017 were 63.1 bcm (Vn) crude gas (minus 10 %). The reserves have thus declined again, and even more strongly than in the previous year. In terms of the geological formations in which the reserves are located, around 80 % of German natural gas reserves are found in Permian reservoirs, of which 43 % in Rotliegend sandstones and 37 % in Zechstein limestones. A comparison of the federal states in Germany reveals that 98.5 % of the crude gas reserves in Germany are located in Lower Saxony (LBEG 2018).

The production of natural gas in Germany has been declining continually for more than a decade, and is down to around a third of the levels produced in 2003. Natural gas production in Germany in the 2017 reporting year declined further by 0.7 bcm (Vn) to 7.9 bcm (Vn) crude gas. This corresponds to a reduction of 8.6 % compared to the previous year. Share of Lower Saxony crude gas production in Germany in 2017 was around 94 %. In addition to natural gas from pure gas fields, around 0.35 bcm of mine gas was also produced (as at 2017). The accompanying gas produced during oil production accounts for around 62 mcm (Vn) of the natural gas production. This was mainly produced in Lower Saxony (63.6 %) and Schleswig-Holstein (27.9 %). A total of 449 production wells (previous year 469) were in operation in 77 fields in the reporting year (LBEG 2018).

The further decline in natural gas reserves, as well as the level of production, was mainly attributable to the increasing depletion of the existing gas fields. There have been no significant new discoveries of fields in recent years. The exploration for shale gas deposits has not taken place, or proved to be unsuccessful in coal seam deposits (LBEG 2018).

Six companies accounted for around 99 % of domestic crude gas production in 2017 according to their consortium shares. These are as follows according to BVEG (2018):

- BEB Erdgas und Erdöl GmbH & Co. KG 2,935 bcm (40,46 %)
- Mobil Erdgas-Erdöl GmbH 1,744 bcm (24,04 %)
- DEA Deutsche Erdoel AG 1,290 bcm (17,78 %)
- Wintershall Holding GmbH 0,532 bcm (7,34 %)
- ENGIE E&P Deutschland GmbH 0,493 bcm (6,80 %)
- Vermilion Energy Germany GmbH & Co. KG 0,198 bcm (2,73 %)

The uneconomically producible conventional natural gas volumes in Germany today (resources) are estimated to be around 1.36 tcm. The share of natural gas from shale gas deposits is around 0.32 tcm to 2.03 tcm within the depth range from 1,000 m to 5,000 m (BGR 2016). Additional potential is seen in tight gas deposits (0.9 tcm, coal bed methane 0.45 m³, as well as a residual potential of 0.02 tcm in conventional natural gas resources (BGR 2017).

During the 2017 reporting period, imports of natural gas totalled 4,778 Petajoule (PJ) according to the preliminary calculations of BAFA (2018a) and were thus up around 15 % on the imports in 2016 (4,156 PJ). The total supply (imports and domestic production) in 2017 were 5,049 PJ (Fig. 2-4). With respect to the volume of natural gas (crude gas), the total volume rose 8.2 % year-on-year to a calculated amount of 130.5 bcm. More natural gas was also re-exported in 2017 compared to the previous year, and more natural gas was drawn from the German natural gas storages. Overall, this equates to an increase in consumption of 4.4 % year-on-year to around 105.9 bcm. 7.5 % of the natural gas volume consumed in Germany was derived from domestic crude gas production (Tab. A-6 in the Appendix).

The natural gas production of German companies overseas (CIS, America, Europe, Africa) is primarily generated by the companies Wintershall Holding GmbH and DEA Deutsche Erdoel AG. These two companies produced around 19.6 billion m³ overseas in 2017, and thus slightly more than the previous year.

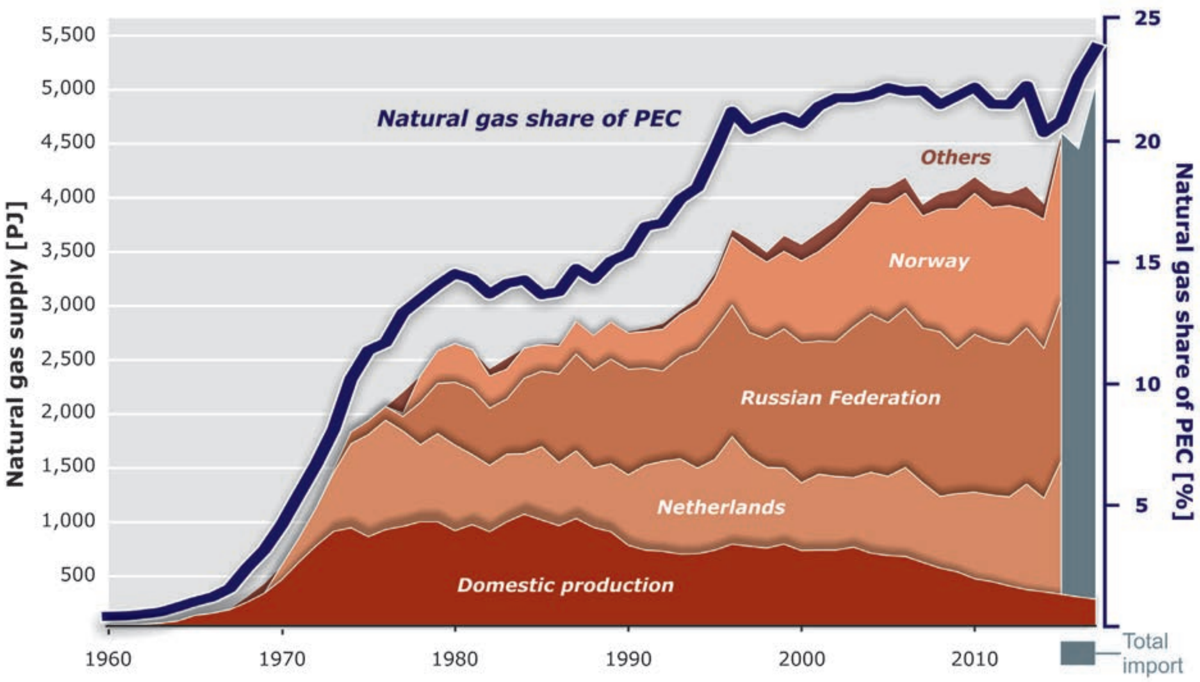

Figure 2-4: Germany's natural gas supplies from 1960 to 2017, and natural gas proportion of PEC (BAFA, AGEB). (BAFA has not published any details on the amounts supplied by some export countries since 2016).

Hard coal

For climate-protection reasons, the step-wise withdrawal from coal-fired power generation is one of the declared objectives of the German government. This is to be accomplished in parallel by an increase in the expansion of renewables (BMUB 2016). In addition to the use of coal for power generation, the other uses of coal are in the heat market, coal gasification and liquefaction, and cokemaking. The use of coke in particular produced from coking coal, for use in the manufacture of pig iron and therefore for the steel industry, cannot be replaced by alternatives to any large extent.

In Germany, 3.7 Mt of saleable hard coal was mined in 2017 (Fig. 2-5). Domestic hard coal has been replaced in past decades by crude oil, natural gas and uranium, and in particular by imported hard coal (Fig. 2-6). Growth in the use of renewables has also led to a decline in the use of hard coal for power generation in recent years. Germany has total hard coal resources (total of reserves and resources) of around 83 Gt.

In the Ruhr coalfield, the Prosper-Haniel mine produced around three quarters (2.7 Mt saleable output) of the total German hard coal production in 2017. In the Ibbenbüren coalfield, the Ibbenbüren mine produced around one quarter (1 Mt saleable output) of the total German hard coal production (Fig. 2-5). Because of the scheduled decommissioning of the Auguste Victoria mine in the Ruhr coalfield on 1 January 2016, the number of active German hard coal mines decreased to just two mines. Hard coal production in the Saar coalfield ended back in June 2012.

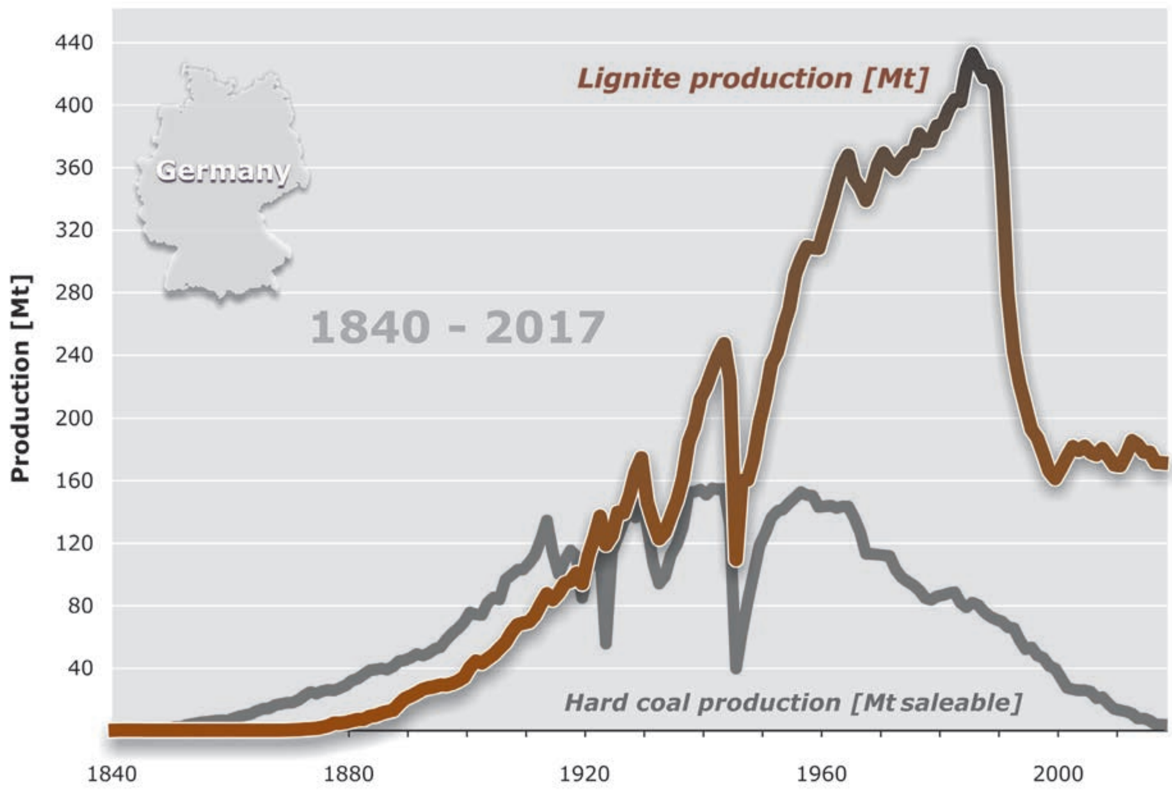

Figure 2-5: Development of German coal production from 1840 to 2017 (after SdK 2018).

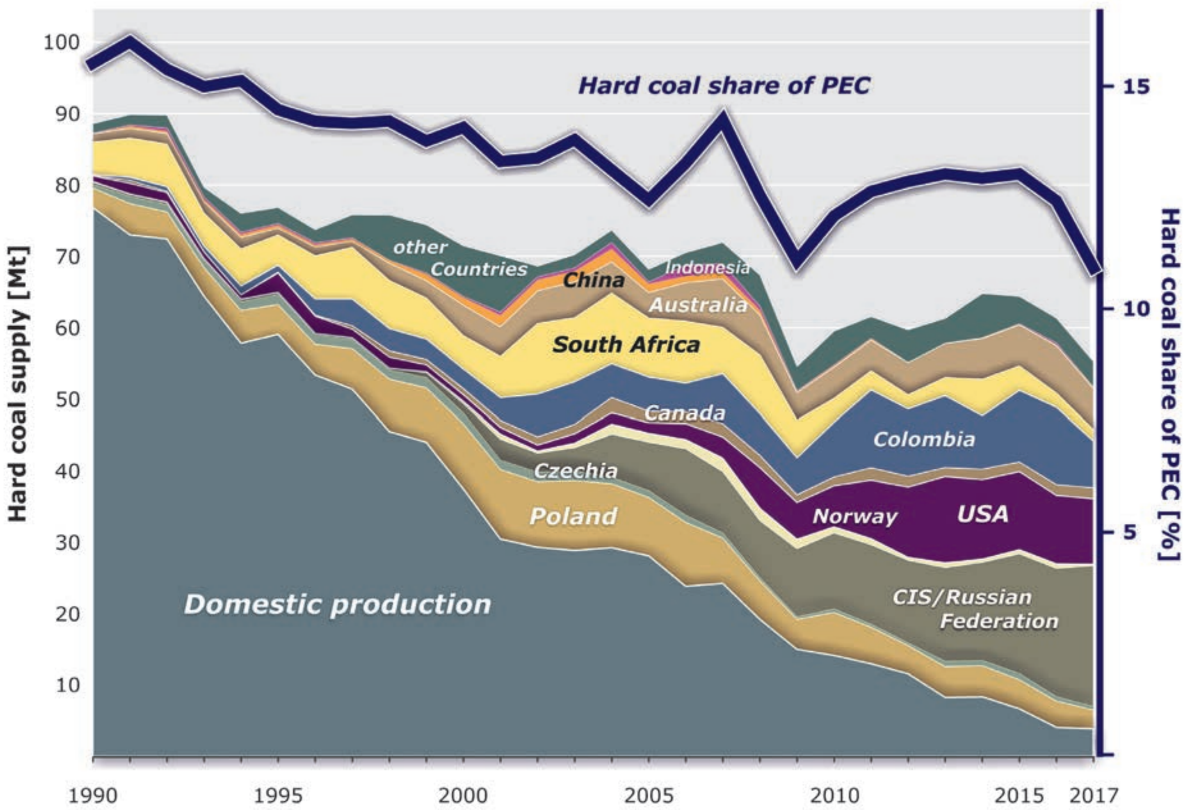

Figure 2-6: Germany's hard coal supplies from 1990 to 2017 (AGEB 2018a, IEA 2018a, SdK 2018, VDKI 2018a).

German hard coal mining has not been internationally competitive for many years, mainly due to the unfavourable geological conditions. According to the Association of Coal Importers (Verein der Kohlenimporteure e.V., VdKi), the average German production costs in 2017 were 180 €/tce. This contrasts with the annual average price of imported steam coal of 91.82 €/tce (BAFA 2018c). Therefore, to make a contribution to supplying power plants and steel works with hard coal, as well as for job market policy reasons, domestic hard coal mining has been supported by public subsidies.

€ 1,181.5 million of public funding was assigned to hard coal mining during the 2017 reporting year (BMWi 2018). In February 2007, the German government, the state of Northrhine-Westphalia and the Saarland, reached an agreement to end the subsidised production of hard coal in Germany in a socially acceptable way by the end of 2018. One of the provisions of this agreement was that it should be reviewed by the German parliament in 2012. Recourse to this amendment clause was waived as a result of changes to the Hard Coal Financing Act in spring 2011. The maximum subsidies – for which an act granting the subsidies has already been adopted – will decline to € 1,015 million in 2019 (BMWi 2018). Whilst the subsidies until 2018 include both decommissioning grants for ending production, and grants to cover extraordinary costs, the subsidies from 2019 onwards will only comprise decommissioning costs (EC 2010, GVSt 2018a).

According to the preliminary figures, hard coal consumption in Germany declined in the reporting year compared to 2016. It dropped by more than 11 % to around 50.3 Mtce. This means that the proportion of hard coal of primary energy consumption sank to 10.9 % compared to 12.4 % the previous year (AGEB 2018a). The total sales of German hard coal declined only marginally by around 0.4 % in the reporting year. It dropped by around 17,000 t to 4.68 Mt (GVSt 2018b, SdK 2018). Around 7 % of the hard coal consumed in Germany in 2017 came from domestic production. Imports of hard coal and hard coal products declined by around 10.2 % year-on-year to 51.2 Mt (Fig. 2-6). Of this, 36.1 Mt or around 70 % involved imported steam coal which is primarily used in power plants for the generation of electricity. Coking coal used to produce coke and therefore for the production of pig iron/steel, accounted for around 25 % of the imports (12.9 Mt). Whilst the imports of steam coal have continually declined since 2015 because of the reduction in the amount of hard coal used in power generation, the imports of coking coal have risen slightly almost continually in the recent past. In addition to steam and coking coal, a minor amount of coke is also imported. This totalled around 2.3 Mt (5 %) in 2017. The hard coal and hard coal products imported to Germany primarily came from the Russian Federation, the USA, Colombia, Australia, Poland and South Africa. In 2017, the Russian Federation was again the largest supplier with around 19.7 Mt (38.5 %), followed by the USA (17.8 %) and Colombia (12.7 %). Imports from Poland dropped to around 2.7 Mt, of which around 1.4 Mt were accounted for by coke (VDKi 2018a). The proportion of imports of the total hard coal turned over in Germany was around 93 % as in the previous year. With the closure of the last two mines at Ibbenbüren and Prosper-Haniel at the end of 2018, hard coal mining came to an end in Germany (van de Loo & Sitte 2018). This marked the end of an over 200 year long era of industrial hard coal production in the Ruhr area and across Germany.

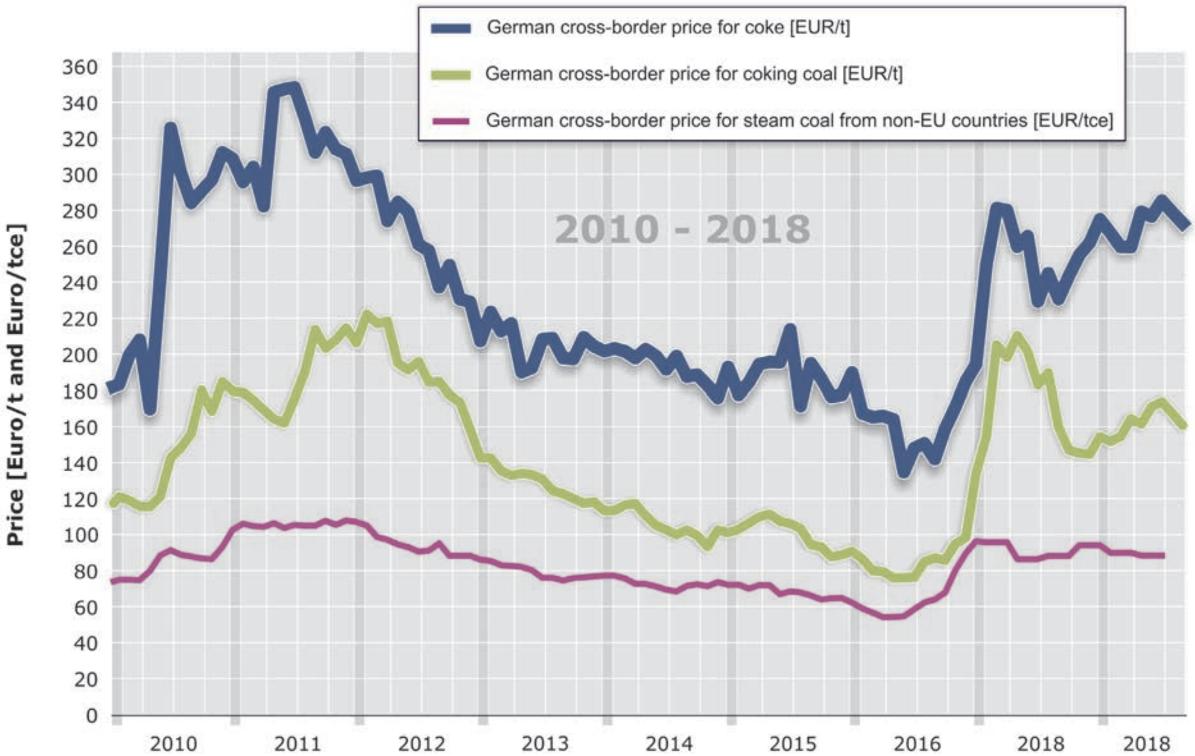

Figure 2-7: Development of cross-border prices for steam and coking coal and coke imported to Germany since 2010 (BAFA 2018c, VDKI 2018b).

The price (in this case: cross-border price) for imported steam coal in 2017 ranged between around 86 €/tce and around 96 €/tce, and thus at a relatively high price level (Fig. 2-7). The annual average price was 91.82 €/tce (plus 36.9 % compared to 2016). The rise in the price of coking coal and coke was much higher. The annual average price for coking coal nearly doubled compared to the previous year from 87.68 €/t to 174.84 €/t, a rise of 99.4 %. The price of coke rose by around 60.4 % year-on-year with an annual average price of 256.34 €/t (BAFA 2018c, VDKi 2018 a, b).

Lignite

Lignite is the fossil fuel with the highest specific CO_2 emissions. In its climate protection plan 2050 (BMUB 2016), the German government therefore pursues the objective of further expanding renewables and to withdraw step-wise from the generation of electricity in coal-fired or lignite-fired power plants.

Since the beginning of industrial lignite production at the end of the 19th century, Germany has been the largest producer of lignite world-wide. The favourable geological conditions at the lignite deposits enables the use of efficient opencast mining technology so that large quantities can be sold at competitive market prices to the nearby power plants. Around 4.2 Gt of lignite reserves are accessible in Germany via developed and planned surface mines. Additional reserves total around 32 Gt. Resources total 36.5 Gt.

Until the end of production in the Helmstedt lignite field in summer 2016, lignite was produced in Germany in four fields. Total lignite production across the country in 2017 was 171.3 Mt and thus 0.2 % down on the previous year (Fig. 2-5). In the Rhenish lignite field, RWE Power AG operates three surface mines at Garzweiler, Hambach and Inden, which had a total lignite production of 91.2 Mt in 2017. The Garzweiler and Hambach surface mines supply lignite by rail to the Frimmersdorf, Goldenberg, Neurath and Niederaußem power plants, whereby the Frimmersdorf power plant was put into safety standby mode from 1 October 2017, and power plant blocks E and F of the Niederaußem power plant went into safety standby mode on 1 October 2018. This means that the power plant is no longer used to supply the market and is only allowed to be started up when requested by the transmission grid operator which is responsible for the system stability of the transmission/power grids. The Weisweiler power plant is supplied by the Inden surface mine. Production in the Lusatian lignite field totalled 61.2 Mt and came from four surface mines in Jänschwalde, Welzow-Süd, Nochten and Reichwalde. The lignite is almost completely utilised by the modernised or new Jänschwalde, Boxberg and Schwarze Pumpe power plants. In spring 2016, the previous operator Vattenfall announced the sale of the Lusatian lignite mines (Vattenfall Europe Mining AG) and the Jänschwalde, Boxberg, Lippendorf/Block R and Schwarze Pumpe power plants (Vattenfall Europe Generation AG & Co. KG) to the Czech energy company Energetický a Průmyslový Holding (EPH), and its finance partner PPF Investments. The change of ownership came into force on 30 September after the EU cartel authority gave the green light after having no reservations on competition grounds. At the beginning of October 2016 an announcement was made that the lignite surface mines and the lignite power plants would trade in future under the new name of Lausitz Energie Bergbau AG and Lausitz Energie Kraftwerke AG respectively. Both companies report under the joint brand name LEAG (2017).

The production of 18.8 Mt from the central German lignite field in 2017 primarily came from the two surface mines at Profen and Vereinigtes Schleenhain operated by the Mitteldeutsche Braunkohlengesellschaft mbH (MIBRAG), which has been a 100 % subsidiary of the Czech EPH group since 2012. Most of the lignite produced in the two surface mines is fired in the Schkopau and Lippendorf power plants. The 0.5 Mt lignite produced in the Amsdorf surface mine operated by ROMONTA GmbH was primarily used for the production of montane waxes (DEBRIV 2017, Kaltenbach & Maaßen 2018, Maaßen & Schiffer 2018, SdK 2018). Lignite production in the Schöningen surface mine in the Helmstedt lignite field ended on 30 August 2016 because of the depletion of the lignite reserves. This ended over 150 years of mining history in the Helmstedt lignite field (HSR 2016a), and at the same time, lignite production in Lower Saxony. The Buschhaus power plant was decommissioned on 24 September 2016 and put into safety standby mode for four years from 1 October 2016 as the first German lignite power plant of its kind to be converted to this status (HSR 2016b).

The total sales of lignite declined only slightly by 0.2 % in the reporting year to 171.3 Mt. Its share of primary energy consumption also declined slightly year-on-year to 11.1 % (51.5 Mtce). Whilst the sales of lignite briquettes rose by 8.8 % to 1.7 Mt alongside a rise in the processing product lignite dust by 3.3 % to 4.9 Mt year-on-year, sales of the processing product lignite coke sank by 2.9 % to 155,000 t. The external trade balance with lignite and lignite products was positive in 2017 albeit at a relatively low level. Total imports declined to 31,700 t. At the same time, exports (briquettes, coke, dust and lignite) rose by 7.7 % year-on-year to 1.487 Mt. The main purchasers are countries within the EU-28 (SdK 2018).

Nuclear power

The key factor in the energy transition is the withdrawal from nuclear power production. With the 13th amendment to the Atomic Energy Act adopted on 6 August 2011, the German government sealed the end of the use of nuclear power for commercial power generation. The act stipulates that the last nuclear power plant in Germany will be switched off in 2022 at the latest. The withdrawal takes place in phases with specific shut-down dates. The switching off of the Gundremmingen B nuclear power plant (gross capacity 1,344 MW_e) on 31.12.2017 was the latest step in implementing the withdrawal from nuclear energy. A total of 37 nuclear power plants were built in Germany starting in 1962 for the commercial generation of electricity. Only seven are currently still in operation. They will be switched off according to the following time schedule at the end of the year mentioned: 2019: Philippsburg 2, 2021: Grohnde, Gundremmingen C and Brokdorf, 2022: Isar 2, Emsland and Neckarwestheim 2.

Switching off the nuclear power plants marks the start of the long dismantling process. Decommissioning of each of the nuclear power plants actually begins a few years after they are switched off. There is first a post-operational phase of approx. five years (decay time and transport to the fuel element intermediate storage at the site) before nuclear plant components can be dismantled. The dismantling process has to be authorised by the nuclear supervisory body and the costs of dismantling nuclear power plants are paid for by the operators according to the Atomic Energy Act. Three nuclear power plants have already been completely dismantled in Germany (BfS 2015). Of the nuclear power plants switched off as part of the German government‘s withdrawal from nuclear power in 2011, five have so far been issued with their decommissioning and dismantling authorisations: Biblis A and B, Isar 1, Neckarwestheim 1 and Philippsburg 1. 10 to 15 years are scheduled for the dismantling of the nuclear facilities following the post-operational phase (DAtF 2018a).

Nuclear power‘s share of primary energy consumption declined further in 2017 to 833 PJ (2016: 923 PJ), which corresponds to 28.4 Mtce (Fig. 2-2). It therefore had a share of primary energy consumption of 6.1 % (2016: 6.9 %). Nuclear power accounted for a share of 11.7 % of public electricity supplies and was therefore in fifth position behind renewables (33.3 %), lignite (22.5 %), hard coal (14.1 %) and natural gas (13.2 %).

654.8 TWh electricity were produced in Germany in total in 2017. The power generation was therefore at a similar level to the previous year (plus 0.6 %; 2016: 650.6 TWh). The proportion of nuclear power of gross power generation declined further by 9.8 % to 76.3 TWh compared to 2016 with 84.6 TWh. Net power generation was 72.2 TWh (2016: 80.1 TWh). Before the switching off of eight nuclear power plants in 2011, 17 nuclear power plants were installed with a gross capacity of 21,517 MW_e. Currently the seven nuclear power plants with 10,013 MW_e (gross) are connected to the grid. The temporal and productive production availabilities were 81.95 % (2016: 88.91 %) and 80.21 % (2016: 88.40 %) respectively.

The demand for natural uranium in nuclear fuel was 1,480 t. This demand was covered by imports and from inventories. The amounts of natural uranium required for fuel production were almost exclusively derived on the basis of long-term contracts with producers in France, the United Kingdom, Canada, the Netherlands, Sweden and the USA.

After the closure of the Sowjetisch-Deutsche Aktiengesellschaft (SDAG) WISMUT in 1990, there has been no mined production of natural uranium in Germany. However, as part of the flood water treatment of the Königstein clean-up operation, natural uranium was separated out in recent years (2017: 34 t).

The remediation of former production sites and facilities operated by SDAG WISMUT entered the 27th year of clean-up operations in 2017. The work is undertaken on behalf of the Federal Ministry for Economic Affairs and Energy by Wismut GmbH, and the work is technically supported and evaluated by the Federal Institute for Geosciences and Natural Resources (BGR). The main remediation objectives (decommissioning of the mines, flooding of the underground workings, water treatment, dismantling and demolition of contaminated facilities and buildings, remediation of tips and slurry ponds, environmental monitoring) are now more than 90 % complete. Of the € 7.1 billion set aside for this major project, around 90 % (€ 6.4 billion) had already been spent by the end of 2017.

One of the remaining major issues is treating the contaminated water from the flooded underground workings, and the remediation of the industrial settling facilities. 15.8 mcm of contaminated water was treated in the six water treatment plants in 2017, and discharged into the nearest suitable rivers.

- After a European-wide tendering process, the contract for the conversion of the existing water treatment facility at the Königstein site was successfully awarded. The construction of a new technical building at the same site was completed in the second quarter of 2018.
- Authorisations for construction and operation of the Helmsdorf industrial settling plant (ISP) at the Crossen site were issued. This new facility is required because of the change in the water quality combined with the decrease in water volumes after removing the free water of the ISP.
- The work on the intermediate covering barrier of the Culmitzsch ISP at the Seelingstädt site was completed. This involved moving approx. 3.7 mcm of soil in total. The work involved in contouring and installing the final covering barrier continued. The authorisation process for connecting the Culmitzsch ISP to the river drainage system is currently ongoing.
- After modernising and expanding the system to contain the floodwater rising up at the Ronneburg site in Gessental, the Ronneburg water treatment works was shut down for 3 months. This initiated the planned recontainment of the mine water with the effect that the water level in the mine has risen ever since. The rising mine water in Gessental has now been contained again and fed to the Ronneburg water treatment works for processing.
- Work at the Aue site is concentrated on underground activities to secure zones at the Marcus-Semmler level and continuing the post plugging and abandonment of shaft 38. At the same time, the physical preparation work for the plugging and abandonment of shaft 208 has begun, one of the last remaining open shafts extending to the surface at the Aue site. Shaft 208 is to be permanently sealed with a plug.
- The Schlema-Alberoda water treatment works is used to control the completed flooding of the Schlema-Alberode mine.

Deep geothermal energy

The use of deep geothermal energy in Germany is limited to only six federal states (Baden-Württemberg, Bavaria, Brandenburg, Mecklenburg Western Pomerania, Lower Saxony, and Rhineland Palatinate). In this context, Bavaria plays a prominent role not least because of its particularly favourable geological conditions. In the last 15 years, over 50 wells investigating deep geothermal energy were drilled in the South German Molasse Basin (Schulz et al. 2017). Currently, there exits a total of 30 projects ondeep geothermal energy in Germany, among them are 22 situated in Bavaria. A closer look at the utilisation categories of all of the plants throughout Germany (Weber & Moeck 2018) reveals that most of the plants in operation are sites with district heating (18). Of the remaining twelve plants, nine generate electrical power, totalling almost 160 GWh_e in the year 2017 with an installed capacity of around 36 MW_e (LIAG 2018). Three plants are still out of service

(Neustadt-Glewe, Simbach-Braunau, Taufkirchen). Five of the aforementioned nine power generating plants (Oberhaching-Laufzorn/Grünwald, Unterhaching, Sauerlach, Traunreut, and Landau), generate power and heat. The remaining four plants are used solely for power generation (Bruchsal, Dürrnhaar, Insheim, Kirchstockach). Two projects are currently under construction and approximately another 30 projects are in the planning stage. Five operational pilot plants have been used for research and a sixth location is currently being under investigation in Saxony (see blue box).

The total geothermally generated energy in 2017 amounted to about 1540 $GWh_{e,th}$. Here, the contribution of electrical power reached approximately 160 GWh_e, which was generated with an installed capacity of around 36 MW_e (LIAG 2018). This is equivalent to a decline of nearly 15 GWh_e compared to the previous year, corresponding to a reduction of around 10 %. Accordingly, the amount of greenhouse gas emissions avoided by using deep geothermal energy decreased compared to the previous year, now totalling 0.87 Mt CO_2 eq (2016: 0.99 Mt CO_2 eq) (BMWi 2018c, d).

GIGS — Geothermal energy in Saxony's granite

In order to be able to assess the future economic impact of geothermal energy in Germany in a more comprehensive way, the Federal Ministry for Economic Affairs and Energy is initiating investigations on the potential of the crystaline basement. These endeavours complement the karst zones of the Alpine foreland, the tectonically active zones of the Upper Rhine Graben, and the sediments of the North German Basin; which are all already successfully utilised for geothermal energy. A preliminary study at a location in the Erzgebirge is currently ongoing with the aim of enhancing the understanding of these petrothermal reservoirs. The target of the research project is the central tectonic element of the Gera-Jáchymov-fault zone, the so-called Roter Kamm, in the region of Bad Schlema, Schneeberg, and Wildbach. The consortium, under the direction of BGR, comprises the Leibniz Institute for Applied Geophysics (LIAG), the two technical universities Bergakademie Freiberg (TU BAF) and Clausthal (TUC), as well as the Helmholtz centres Dresden-Rossendorf (HZDR) and the German Georesearch Centre Potsdam (GFZ). Support for this project comes also from the State Agency for the Environment, Agriculture, and Geology in Saxony, and the Wismut GmbH. The scientific aspects cover geology, mineralogy, fluid and isotope geochemistry, geomechanics, geophysics, and petrology. Of particular interest are the following four aspects

- *Evaluating the 3D seismic survey performed in the area of interest between 2010 to 2012;*
- *Characterising the dominant fault zone „Roter Kamm“ in the Erzgebirge and its seismically identified, associated elements;*
- *Testing drilling technology and completion technologies in granite rock;*
- *Economic analysis assessing the geothermal potential for future energy generation based on granite rock formations in Germany.*

After completion of the 18-month-long pre-project in summer 2019, the next step will include the technical planning for the "Silberberg" pilot well to be drilled through the Roter Kamm fault zone and the completion of the scientific programme. Realisation is scheduled for a subsequent main project aimed at testing the future suitability of the site for geothermal energy generation. Drilling is expected to begin 2020 at the earliest.

Compared to this, the amount of thermally generated energy is as expected much higher, at around 1,380 GWh_{th}. Nevertheless, direct heat utilisation only increased slightly by approximately 24 GWh compared to the previous year. By contrast, the rise between 2015 and 2016 amounted to almost 200 GWh_{th},i.e. around an order of magnitude higher. The thermally generated energy consists of district heating (around 893 GWh_{th}, 64.8 %), thermal baths (475 GWh_{th}, 34.5 %) and heating of buildings (10 GWh_{th}, 0.7 %). After years of continuous growth, 2017 marked a decline in installed thermal capacity and in growth of thermally generated energy (Fig. 2-8). At the moment, it cannot be stated whether this is or is not a one-time event similar to the stagnation in 2010.

Energy derived in the year 2017 from geothermal sources accounted with about 0.1 % again only for a very small proportion of the total primary energy consumption in Germany, which totals 13.5 TJ. With respect to power generation, the contribution of geothermal power plants to gross power generation accounted for 0.02 % of the total amount of generated power of 655 TWh_e (BMWi 2018d).

In future, a considerably larger share of geothermal energy in energy supplies will be required. In order to achieve the climate protection targets, renewables, including geothermal energy, need to be expanded further. In the scenarios elaborated by BCG (2018), and depending on the reduction path (reference scenario, i.e. reduction of 80 % or 95 %), geothermal heat generation of the order of about 5 TWh will be necessary from 2030 onwards. By the year 2050, an even further rise in district heating of 10 TWh to 12 TWh by 2050 should be reached. The higher figures in the forecast become significant when compared to the share of geothermal energy in 2017, which at almost 0.9 TWh, is approximately one order of magnitude lower.

The reasons for the continuing minor realisation of geothermal projects remain unchanged: the uncertainty in predicting the crucial parameters for geothermal energy in the subsurface, high exploration risks compared to other energy sources, risks associated with induced seismicity, and the potential escape of gases such as radon or hydrogen sulphide. These in turn lead to hesitancy amongst investors, a lack of public support, and economic problems. The latter include significant maintenance costs (Janczik and Kaltschmitt 2017) and difficulties in connecting up to existing or

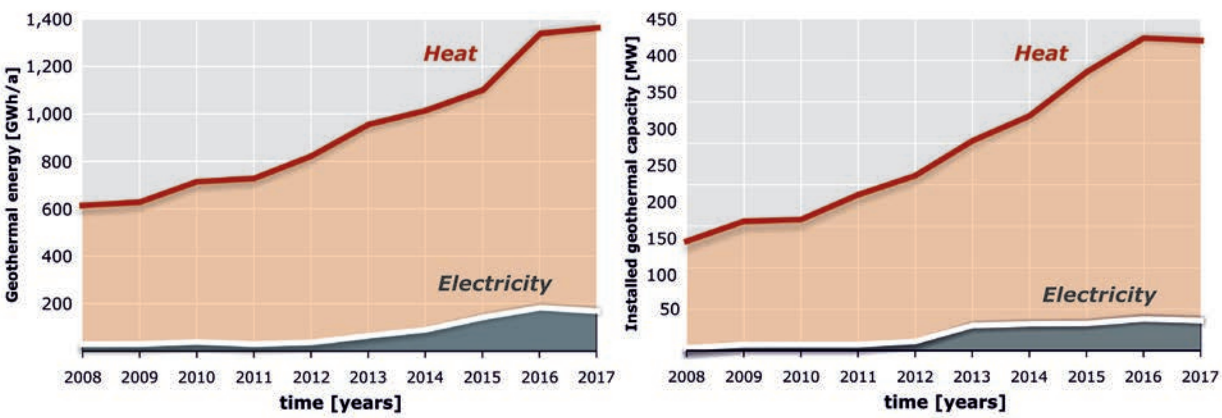

Figure 2-8: Development of geothermally generated electrical (blue) and thermal (red) energy (left) as well as installed geothermal electrical (blue) and thermal (red) capacity (right) over the course of the last ten years in Germany (data LIAG 2018).

yet-to-be constructed district heating networks. BMWi also lists the major technical problems, low competition intensity, and long planning and development time periods as reasons for the relatively minor expansion of geothermal energy (BMWi 2015).

All of the players need to work together for deep geothermal energy to occupy a more prominent position in the energy mix. Costs for geothermal energy projects are currently high compared to other energy resources, and the potential for reducing these costs is currently difficult to assess because of the relatively small number of plants in operation (BMWi 2015). Nevertheless, significant increases in efficiency, and in particular with regard to exploration and drilling costs, are expected in future.

Renewables

The proportion of renewable energy in Germany's energy supply mix is growing. This is due to the Renewable Energy Act (EEG) adopted on 1 April 2000, and amended in 2014 and again in 2017. The German government has the aim of generating 40 % to 45 % of the electricity used in Germany from renewable energy by 2025 (BMWi 2017; BMWi 2018e). The target for 2030 is 65, and rises further to 80 % by 2050 (Fig. 2-9). The second pillar of the energy transition alongside the expansion of renewables is energy efficiency. The demand for primary energy in Germany is to be slashed to 50 % of the 2008 figure by 2050 (BMWi 2018f).

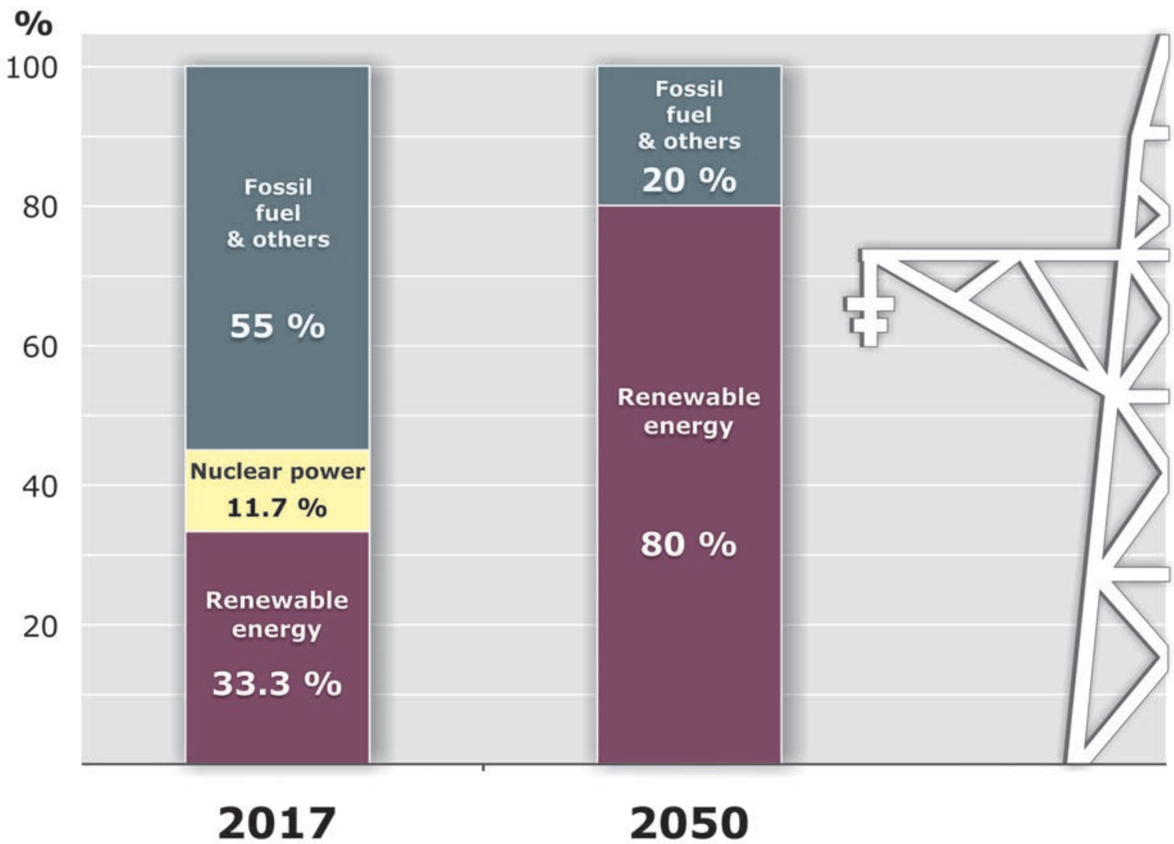

Figure 2-9: Share of gross power generation of specific energy resources (data sources: AGEB, BMWi).

The implementation of renewable energy has primarily focused to date on the power sector. Around 33 % of the power in Germany is currently generated by renewables (Fig. 2-9). Windpower and biomass are the most important renewable energy resources for power generation in Germany. Additional contributions are made by solar power, hydropower and geothermal energy, which all play their part in covering the energy consumption. The proportion of renewable energy in gross power consumption has risen from 7 % in 2001 to 36.2 % in 2017, and is therefore, however, only slightly higher than the level in 2016 (31.6 %). This is attributable to the strong expansion in power generation capacities, in particular in the case of windpower, as well as better wind conditions and the high number of sunshine hours compared to the previous year.

Power generation from windpower (onshore and offshore) in total came to 106.6 billion kWh (around one third more than 2016: 79.9 billion kWh), and stands with a proportion of 16.3 % of the German power mix in second position for power generation in Germany behind lignite (AGEB 2018a). The expansion of onshore windpower in particular in 2017 reached a new record. Onshore wind farms with a total capacity of 5,484 MW were commissioned (UBA 2018). The onshore wind farms generated 31 % more power than the previous year with a total of 88.7 billion kWh.

The offshore wind farms also generated 46 % more electricity than the previous year. The main reason in addition to the good wind conditions in 2017 is the continuous expansion of offshore wind farms in recent years. Whilst the offshore windpower generation in 2014 only stood at 1.4 billion kWh, this had already risen to 17.9 billion kWh in 2017. Germany has a total installed windpower capacity (onshore and offshore) of over 55,850 MW (Tab. A-44 in the Appendix).

The second most important renewable energy resource for power generation in Germany is biomass. 51.4 billion kWh of electricity are generated from biogenic fuels (solid, liquid and gaseous biomass) with almost 9,000 MW of installed capacity. In addition to biogas, this also includes landfill and sewage works gas, as well as sewage sludge, not to mention biogenic waste for the generation of power in waste power plants (AGEB 2018a). The share of biomass in the German power mix was 8 % as in the previous year. Although there was hardly a change in the installed capacity of solid and liquid biomass, investments are being made particularly in boosting the capacity of existing biogas plants, as well as in building new plants (UBA 2018). With a total of 313 MW, significantly more biogas capacities were added in 2017 compared to the previous year (addition in 2016: 192 MW).

Power generation from solar energy (photovoltaics) continues to be intensely expanded in Germany and has the highest installed capacities of all of the renewables with the exception of windpower. After a decline in the volume of expanded capacity in recent years, 2017 saw another slight increase in the growth rate. The installed capacities of photovoltaic plants in 2017 grew by around 1.6 GW. Nevertheless, 2017 was the fourth year running in which the addition of 2.5 GW in generation capacities per year stipulated in the EEG failed to be achieved (BMWi 2018e). One of the reasons for this is probably the reduction in the feed-in tariff paid for solar power in accordance with the EEG. The total installed photovoltaic capacity available in Germany is currently almost 42,400 MW

(Tab. A-44 in the Appendix). Compared to the previous year, this corresponds to a slight increase of 3 %. Power generation from this source has so far, however, remained relatively low. The contribution to the German power mix with 39.4 billion kWh was only around 6.6 %.

The share of renewables for heat generation declined slightly in 2017 to 12.9 %. Because of lower natural gas and heating oil prices and similar weather conditions, the consumption of wood in private households declined slightly to 66 billion kWh (UBA 2018). However, there was a rise in the consumption of wood pellets (2.1 Mt) as seen in recent years as well. With a share of around 87 %, solid biomass (including biogenic waste) accounts for the most significant proportion of renewables in heat generation. Renewables account for around 5.2 % of fuel consumption in the transport sector in Germany (UBA 2018). Biofuels such as bioethanol, biodiesel and biogas account for the lion's share of renewables in the transport sector. The electricity consumption in the transport sector from renewable sources (electric vehicles), however, only accounts for a very subordinate share of 0.6 %.

Analysis of the share of renewables in primary energy consumption (PEC) according to areas of application reveals that the dominant form is power generation with a share of 57 %. The second biggest application of renewables is thermal generation, whereby thermal generation from primarily privately used systems (stoves, solar thermal systems, heat pumps, etc.) with a share of 23 % easily dominates the applications, whilst the use of heat generation in industrial power plants only accounts for 5.5 %. Another 6 % is used in the transport sector as ad-mixtures to petrol and diesel fuels, and another 6 % is used by industry (AGEB 2018a). With a share of the renewables in PEC of over 54.1 %, biomass is the dominant energy form (Fig. 2-10), followed by windpower (21.6 %), solar power (9.7 %), waste (7.3 %), hydropower (4.1 %), and geothermal energy (3.3 %).

PEC in Germany rose slightly to 13,550 PJ in 2017, and was therefore up almost 1 % year-on-year. Nevertheless, a long-term analysis of the statistics reveals a reduction in the energy consumption in Germany, as well as a step-wise reduction in the use of fossil energy resources for the generation of energy. Compared to 2001, primary energy consumption in Germany has declined by 8 % from 14,679 PJ (2001) to 13,550 PJ (2017), whilst the proportion of renewables in PEC has quadrupled at the same time from 427 PJ (2001) to 1,780 PJ (2017). Each of the renewable energy resources made different contributions to this growth (Fig. 2-10). With the exception of hydropower, the proportion of all renewables in PEC has grown considerably in the last 15 years. The planned further expansion of renewables in Germany will lead to another increase in their share, and a lower demand for fossil fuels as a consequence. At the same time, there will be an increase in weather-related fluctuations in energy generation because of the variable character of most renewable energy resources in Germany.

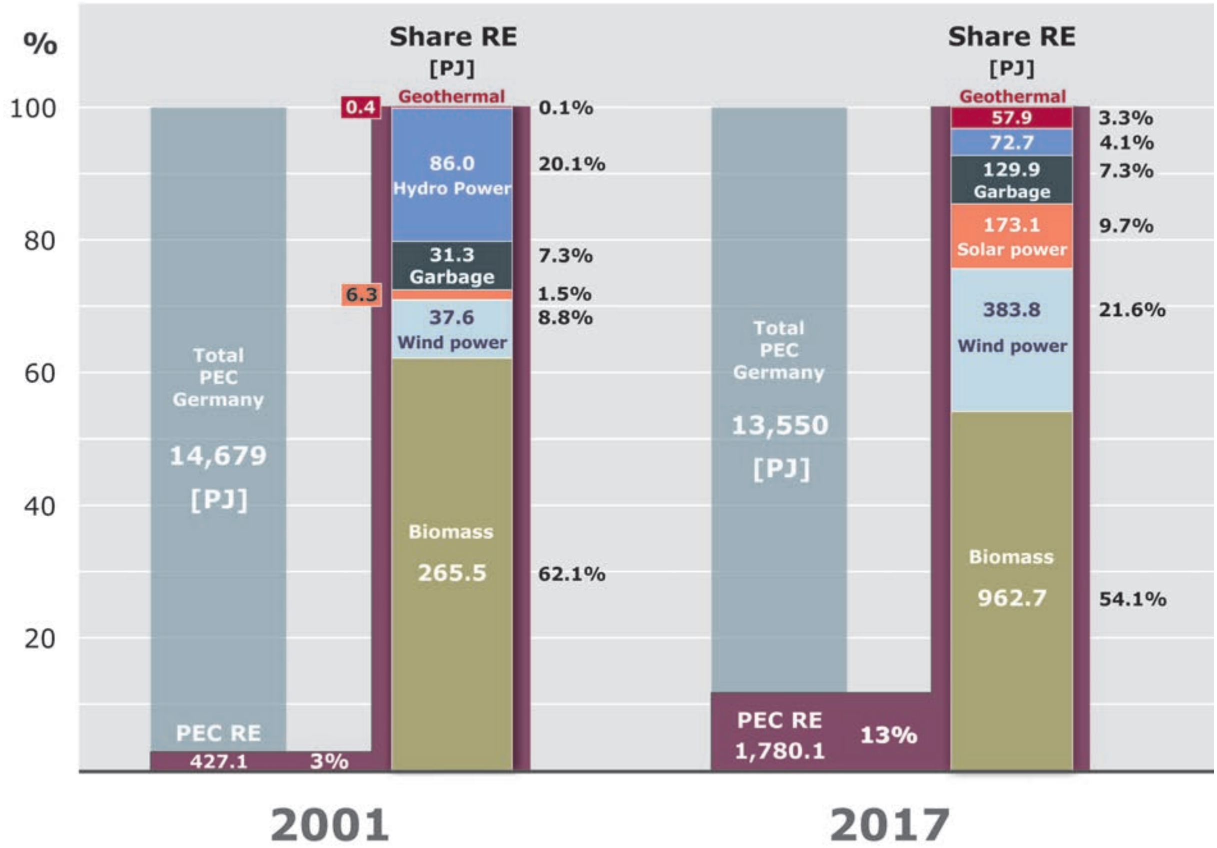

Figure 2-10: Primary energy consumption [PJ] in Germany 2001 and 2017, as well as the share [%] of individual renewables in comparison (data sources: AGEB, BMWi).

3 ENERGY RESOURCES WORLDWIDE

The global demand for energy has risen almost continuously for many decades, whilst the changes in the energy mix appear only marginal (Fig. 3-1). However, the dramatic change from biomass to coal, and the subsequent step-wise change to today's energy system based largely on fossil energy resources over the last 30 years and more is only revealed within a historical time frame. The latest development is the increasing establishment of „modern" renewables such as solar power and windpower since the start of the new millennium. However, every new energy source added to the mix, has so far only served to cover the additional demand rather than displace already established energy resources. As a consequence, the volumes of all energy resources consumed has grown in recent years, and reached new record levels in the case of crude oil and natural gas in 2017 to satisfy the world's energy demand.

The increase in human population numbers worldwide, combined with a rise in general living standards, will result in a growth in energy demand in the long term as well, despite the gains being made in improving energy efficiency. Notwithstanding the increasing shift in the global energy mix, a limited number of energy resources will continue to make the biggest contributions to satisfying energy supplies. Without a considerable boost to the modification of the global energy system, fossil fuels will continue to remain indispensable in the long term as well. To continue to adequately satisfy the growing global demand for energy, fossil fuels as well as nuclear power will continue to play a major role in the coming decades as well (Fig. 3-1).

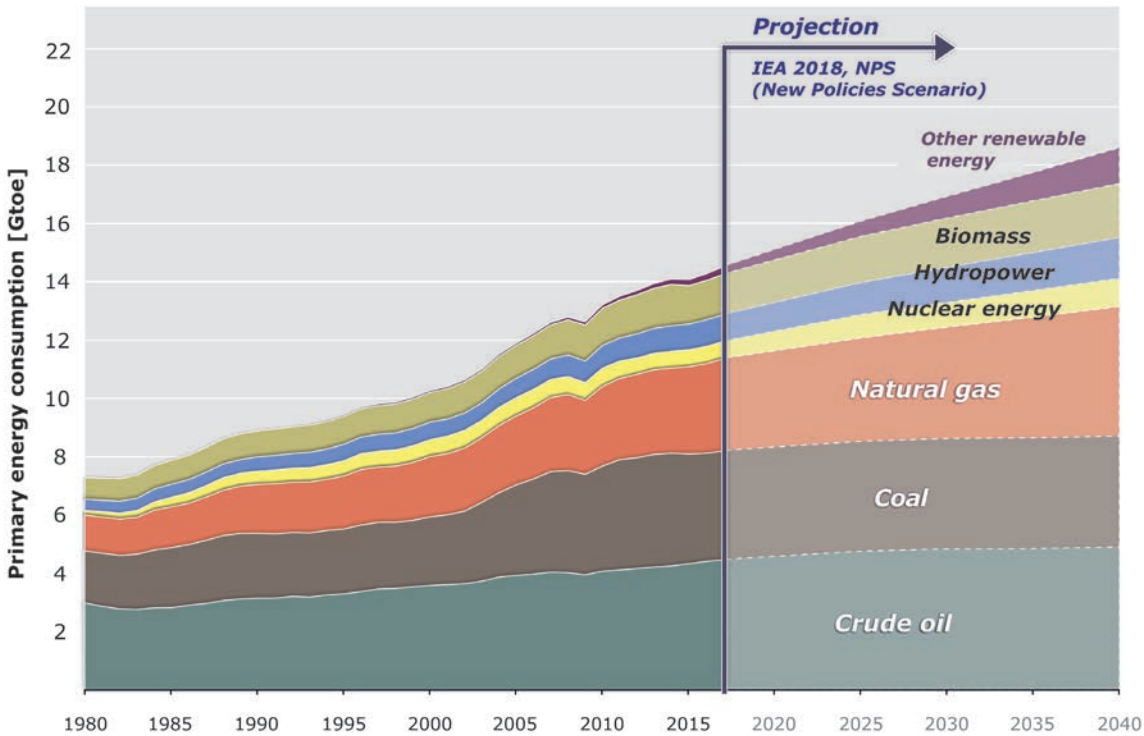

Figure 3-1: Development of global primary energy consumption according to energy resources and a possible scenario (IEA New Policies Scenario) for future development (after BP 2018, IEA 2018b).

Following the global review of the reserves situation, a more detailed look is undertaken at individual fossil fuels and energy resources in terms of reserves and potential, production, consumption and important developments. Deep geothermal energy is the only energy resource in the geological sphere, which counts as a renewable energy. It will therefore be looked at in its own special chapter.

3.1 Global reserves situation

Table 1 shows all known global potential for fossil energy resources including nuclear fuels. This is supplemented by a visualisation of the theoretical CO_2 emissions released by their use (calculated after IPCC 2006). Values are derived from the total of the country data as listed individually in Tables A-8 to A-44 in the Appendix. It also includes figures on the resources of oil shale, aquifer gas, natural gas and gas hydrates, as well as thorium, because their quantities cannot be broken down to individual countries. Despite other gaps in the data, unconventional potential is presented as far as possible. These include the resources and reserves from tight rocks (shale oil), bitumen (oil sand), ultra-heavy oil and oil shale, as well as tight gas, shale gas and coal bed methane. The study pursues a conservative approach overall, so one of the main criteria is the potentially economic production of energy resources. For this reason, the enormous in-place quantities, which are not considered to be producible even in the long term according to today's understanding and technology, are not listed as standard, or only after providing additional explanations. For this reason, the resources of aquifer gas and natural gas in gas hydrates in particular appear relatively low in this table.

The largest proportion of non-renewable global energy resources totalling 550,183 EJ is defined as resources and is many times higher than the reserves. This applies to all energy resources with the exception of conventional crude oil, where the resources are smaller than the reserves. In total, resources dropped slightly by 0.1 % compared to the previous year (BGR 2017). There was growth in the resources mainly in the case of uranium (plus 1.2 %) because of exploration and re-evaluations. Lower resources for conventional natural gas are attributable to re-evaluations and transfer to reserves. A comparison of all energy resources shows that coal continues to dominate (hard coal and lignite) with a share of 89.2 % (Fig. 3-2). Trailing well behind in second place are natural gas resources with 5.8 %, which are dominated by unconventional deposits. The remaining energy resources, including crude oil (3.4 %), only play a minor role with regard to the energy content of the resources. Overall, a comparison with the previous year reveals only minor changes which have no influence on the level of global resources.

The energy content of the reserves in 2017 corresponded to 40,237 EJ, and was therefore 1.8 % higher compared to the previous year's value. The largest absolute changes involve the hard coal deposits, especially because of the exploration activity and a re-evaluation of the reserves in Indonesia. Other much smaller changes involved most of the other energy resources. Noteworthy here are relatively large changes in shale oil (plus 31.9 %) and shale gas (plus 18.6 %) due to re-evaluations undertaken in the light of rising oil and gas prices, as well as because of exploration activities. The aforementioned changes primarily concern the deposits in the USA. In terms of energy content, coal remains the dominant energy resource accounting for 54.4 % of the reserves. Crude oil (conventional and unconventional) accounts for 25.3 % of total reserves, with natural gas accounting for 18.7 %, and uranium 1.5 %. The relative shares of all energy resources have therefore only changed slightly compared to the previous year. The volumes of crude oil which were produced were completely compensated for, and re-evaluations meant that there was also a pro-rata increase in reserves. The relatively high proportion of crude oil in the reserves highlights the intense exploration and production activities involving this energy resource which have been undertaken for many decades.

Table 1: Reserves and resources of non-renewable energy resources as well as theoretical CO_2 emissions (calculated after IPCC 2006).

Fuel	Unit	Reserves			Resources		
		(cf, 2nd column)	EJ	Gt CO_2	(cf, 2nd column)	EJ	Gt CO_2
Conventional crude oil	Gt	173	7,234	530	168	7,034	516
Shale oil	Gt	2,2	91	6,7	60	2,496	183
Oil sand	Gt	26	1,086	116	67	2,785	298
Extra heavy oil	Gt	42	1,752	187	42	1,767	189
Oil shale	Gt	< 0,5	7,2	0,77	111	4,653	498
Crude oil (total)	Gt	243	10,070	841	448	18,734	1,683
Conventional natural gas	Tcm	191	7,261	407	312	11,855	665
Shale gas	Tcm	6,1	230	13	203	7,713	433
Tight gas	Tcm	–[1]	–[1]	–[1]	61	2,332	131
Coal-bed methane	Tcm	1,8	69	3,9	51	1,950	109
Aquifer gas	Tcm	–	–	–	24	912	51
Gas hydrates	Tcm	–	–	–	184	6,992	392
Natural gas (total)	Tcm	199	7,560	424	836	31,754	1,338
Hard coal	Gtce	624	18,288	1,730	14,966	438,625	41,494
Lignite	Gtce	123	3,601	364	1,776	52,037	5,256
Fossil fuels [total]	–	–	39,619	3,359	–	541,150	49,771
Uranium [2]	Mt	1,2 [4]	618 [4]	–	12 [5]	5,855 [5]	–
Thorium [3]	Mt	–	–	–	6,4	3,178	–
Non-renewable fuels	–	–	40,237	3,359	–	550,183	49,771

– no reserves or resources

1 included in conventional natural gas reserves

2 1 t U = 14,000 bis 23,000 tce, lower value used or 1 t U = 0.5 x 10^{15} J

3 1 t Th assumed to have the same tce-value as for 1 t U

4 RAR recoverable up to 80 USD / kg U

5 Total from RAR exploitable from 80 to 260 USD / kg U and IR and undiscovered < 260 USD / kg U

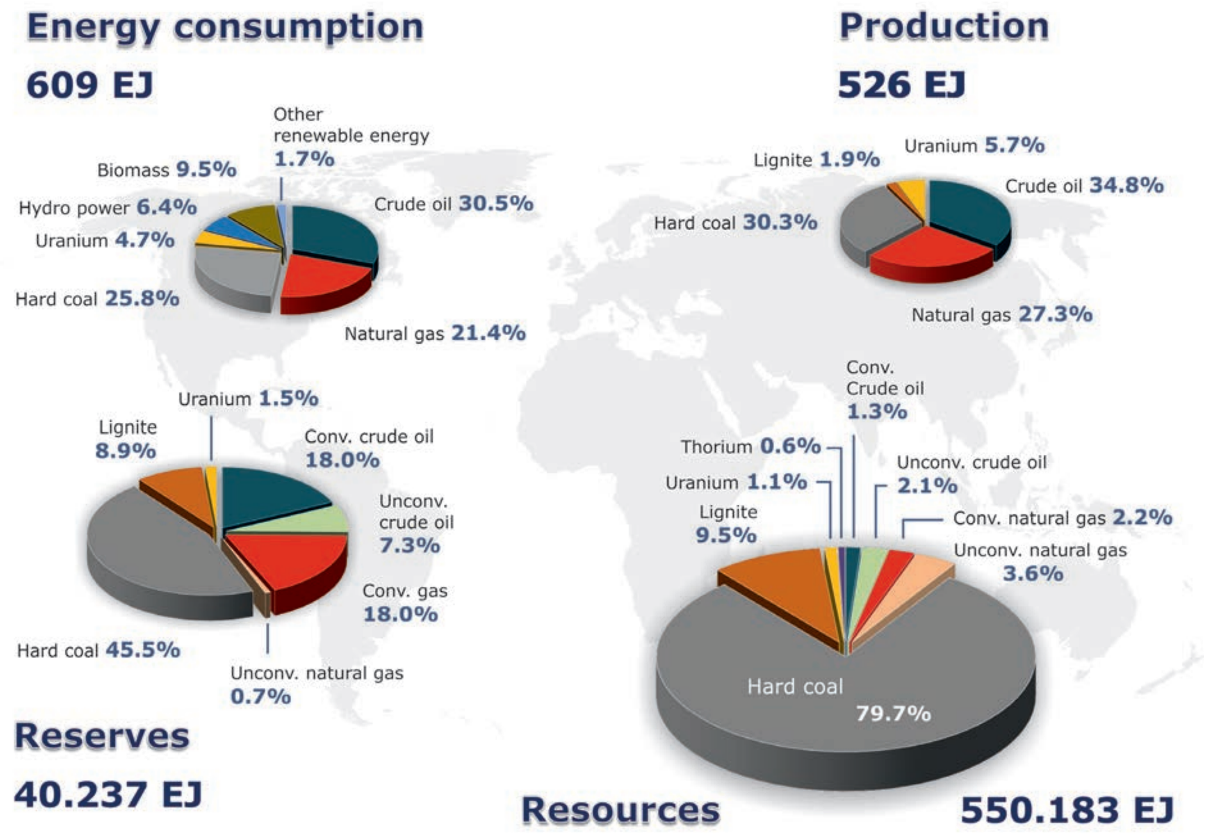

Figure 3-2: Global shares of all energy resources and fuels in consumption (IEA 2018b, hydroelectric power efficiency calculated after BP 2018), as well as non-renewable energy resources in production, reserves and resources for end 2017.

In 2017, non-renewable energy resources with an energy content of around 526 EJ were produced. This represents a production increase of 2.1 % compared to the previous year (2016: 515 EJ). With respect to energy content, the share of natural gas and hard coal rose in the production mix because of a rise in their production, as well as because of the decline in the production of uranium (Fig. 3-2). Crude oil (34.8 %) continues to be the most important resource ahead of hard coal (30.3 %), and followed by natural gas (27.3 %), uranium (5.7 %) and lignite (1.9 %).

Energy consumption worldwide in 2017 was 609 EJ which reflects the total amount of primary energy used globally. A look at the composition of the global energy mix reveals the huge dominance of fossil fuels, headed by crude oil with 30.5 %, coal (25.8 %) and natural gas (21.4 %). Nuclear power accounts globally for a 4.7 % share of PEC. Of the renewables, the dominant energy resources are biomass with 9.5 % and hydroelectric power with 6.4 %. The remaining renewables including solar power and windpower account for a global share of 1.7 % (BP 2018, IEA 2018b).

According to the information available today, there are still enormous quantities of fossil energy available which in geological terms can still cover rising energy demand for several decades. Impossible to answer here is the question of whether all energy resources can individually always be available in future in adequate quantities when required. This challenge affects crude oil in particular because of the low amount of investment in the crude oil sector in recent years and the advanced degree of depletion of many fields around the world. Whether and when, which energy resource can be used depends amongst other things on the geological understanding, the technical and economic extractability, and therefore means-centric availability. Thanks to the largely secure supplies of energy resources for many years, the relevant questions today are increasingly focused on sustainability and environmental compatibility, as well as public acceptance. In addition to the expansion of renewable energy, the further growth in global energy demand will have to be covered by the rising production of fossil energy resources in the foreseeable future. Given the current significant decline and further reduction in investments in this sector, one can again expect there to be temporary production shortages and price peaks for some natural resources in the medium term.

3.2 Crude oil

Crude oil continues to be the most important energy source worldwide. Its share of primary energy consumption was 30.5 %. Global crude oil production rose slightly by 0.1 % to 4,380 Mt (2016: 4,375 Mt).

No major changes compared to the previous year are reported for unconventional and conventional crude oil resources. Total crude oil resources (conventional and unconventional) increased only slightly to 448.2 Gt.

Global conventional crude oil reserves rose by around 1.1 % to 173 Gt. The unconventional crude oil reserves increased by around 70 Gt (plus 0.3 %). Shale oil reserves in the USA rose significantly during the reporting year by 33 % to 2.1 Gt. This is attributable to the much higher crude oil prices this year compared to last year, which made many shale oil projects profitable. In addition, technological advances have increased the recovery rates of shale oil fields further. However, this has only had a relatively minor impact so far on the size of total global reserves (conventional and unconventional). An improvement in the data increased the reserves estimate in Saudi Arabia by 3.3 Gt (plus 9 %). The figures for the Saudi crude oil reserves now also include NGL and condensate in addition to crude oil.

The largest proportion of total crude oil reserves with around 112 Gt (46 %) are located in the Middle East, followed by Latin America with 51 Gt (21 %) and North America with 34.6 Gt (14 %). Slightly under one per cent of total crude oil reserves are located in the European region (Fig. 3-3). Crude oil reserves are heterogeneously distributed around the world. The three countries with the highest crude oil reserves, Venezuela, Saudi Arabia and Canada, together account for more than 46 % of global crude oil reserves. Of the conventional crude oil reserves, which are particularly relevant for global liquid hydrocarbon supplies because of their relatively simple extraction, around two thirds are located in Middle Eastern countries.

The most significant event for crude oil production in the reporting year was the production regulation agreed between OPEC countries in December 2016 – which also involved other leading producing countries including the Russian Federation – with the aim of reducing the existing oversupply of crude oil on the world market (OPEC 2016).

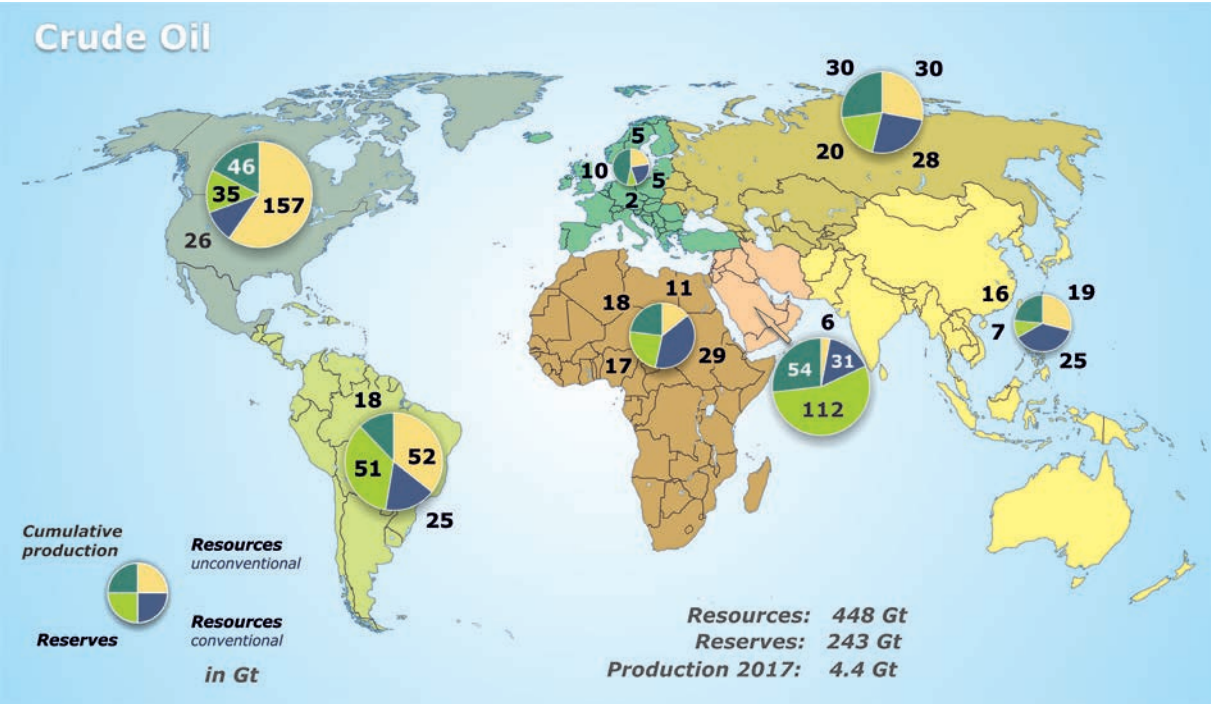

Figure 3-3: Total crude oil potential 2017: regional distribution.

The countries with the highest levels of production continue to be the USA, Saudi Arabia and the Russian Federation. Due to a significant increase in shale oil production, the USA boosted its crude oil production by 9.5 % and therefore became the leading crude oil producing country. The production was favoured by the continuous rise in the price of crude oil during the course of the year, the associated rise in drilling activity, and the more efficient recovery of the oil from the shale oil deposits. Shale oil reached a share of around 50 % of total US-American production. Iraq as well also again reported a considerable growth in production (plus 7 %). Canadian crude oil production from oil sand rose by around 10 % to 155 Mt, and thus reached a new all-time high. Together with conventional oil production and a minor amount of shale oil production, Canada produced 224 Mt crude oil (plus 2.6 %).

There was again a significant decline in production in Venezuela (minus 14 %). This drop in production is attributable to the lack of investment in E&P in recent years. The production and processing of the heavy oil and ultra-heavy oil from the Orinoco Heavy Oil Belt in particular, which accounts for a major share of total Venezuelan oil production, is relatively complex and associated with continuous investment in the production and processing facilities.

There was also a strong decline in production in Angola (minus 7 %) attributable to the increasing depletion of the fields and inadequate investment in E&P over a period of many years. The country produces almost exclusively from offshore oil fields, which because of their geological properties, are associated with must faster declines in production compared to the onshore fields

(Höök et al. 2009). The Angolan government has been attempting since 2017 to counteract the decline in production, which has been continuing for many years by granting oil companies tax relief if they extend their E&P activities to marginally economic fields as well (Eisenhammer 2018). Crude oil production also declined again in Mexico (minus 8.5 %) which occupies 12th position in the global crude oil production rankings. The People‘s Republic of China reported another decline in production to 191.5 Mt (minus 4.1 %). Given that China‘s petroleum consumption continues to rise, and that domestic production has declined further, it is likely that its dependence on imports will continue to increase. Back in the 1990s, national Chinese oil companies began to invest long term in crude oil projects worldwide to secure the country‘s supplies (Hayward 2009). China secures its crude oil and natural gas supplies by direct shareholdings in oil and gas fields, granting loans in exchange for oil supplies, as well as making long-term investments in the production and processing infrastructure of other countries. National Chinese oil companies are involved in upstream projects in 42 countries (EIA 2015).

The OPEC share of total production declined slightly from 43.1 % to 42.5 %. The strongest regional growth was in North America due to the significant increase in US-American shale oil and Canadian oil sand production. North America‘s share rose from 20.2 % to 21.2 %.

Whilst all the countries around the world use crude oil in the form of fuel or petrochemical products, only 102 countries produce crude oil. Moreover, oil production is very heterogeneously distributed to a few countries and regions. The ten largest oil producing countries alone account for around 70 % of total crude oil production. The most important production region with a share of 33.6 % continues to be the Middle East. Although global conventional crude oil production has stagnated since 2005, it still retains a share of around 79 % of total production, and will therefore continue to play a most significant role in the long term in supplying liquid hydrocarbons (Fig. 3-4). The rise in the production of natural gas leads to the production of increasing amounts of NGL and/or condensate which is added to the crude oil production figures. Their share of total production has risen within the last 30 years from 5 % to 9 %.

The production of unconventional crude oil is becoming increasingly important. The share of shale oil, oil sand and extra-heavy oil in total production was around 10 % in the reporting year, a threefold increase within one decade. The global significance of shale oil, which is primarily produced in the USA, and to a lesser extent in Canada and Argentina, has increased significantly in recent years. The share of shale oil in unconventional oil production now accounts for more than 50 %. Oil sand has so far only been produced in Canada because of the relatively favourable geological conditions in that country. The Canadian production of crude oil from oil sand which began in 1967 has risen continuously and now accounts for over 3 % of global oil production. The production of biofuels reached a new all-time high. Around 84 Mt of biofuels were produced during the reporting year (BP 2018). The USA (45 % global share) and Brazil (22 %) have easily been the most important producers of biofuels worldwide. The production of unconventional crude oil and the production of biofuels have so far largely been concentrated in North and South America (Fig. 3-4).

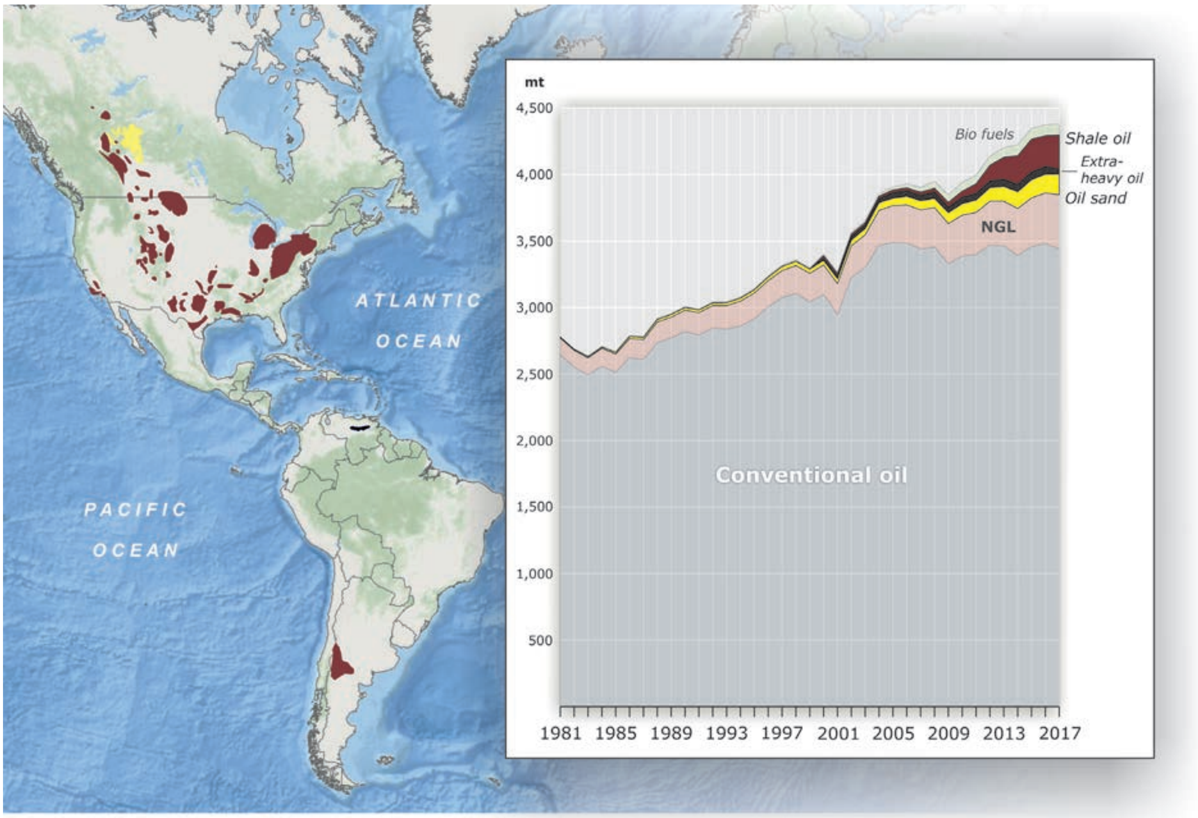

Figure 3-4: Oil sand, ultra-heavy oil and shale oil production areas in North and South America (left); compilation of global crude oil production (right).

The global consumption of petroleum products grew significantly year-on-year by around 4.2 % to 4,593 Mt. As the world's most important traded commodity, the most important energy resource and the most important raw material for the chemical industry, crude oil is a major indicator of economic development. Despite the significant rise in the price experienced by the crude oil reference types during the course of the reporting year, the price of crude oil still continues to be much lower than the average price over the last ten years. This and the relatively favourable development of the global economy led to higher consumption. The largest consumer continues to be the Austral-Asian supra region with 1,588 Mt (plus 2.5 %), followed by North America with 1,186 Mt (plus 1 %)[1]. Crude oil consumption in Europe also rose again to 686 Mt (plus 2.9 %). Latin America is the only supra region worldwide reporting a decline in petroleum consumption (minus 1.4 %), which reflects it`s weak economic development.

Although the petroleum consumption in Africa rose the most strongly in relative terms by around 6 % to 199.9 Mt, the per capita consumption is still at a very low level, particularly when compared to the highly industrialised supra regions in Europe, North America and East Asia.

1 The consumption data for the USA was revised. LPG (liquefied petroleum gas) was included in the consumption starting from the 2017 reporting year. The consumption figures for previous years were updated accordingly.

Over three quarters of the petroleum was used in the 20 leading consuming countries. However, of these countries, only five (Saudi Arabia, the Russian Federation, Canada, Mexico and Iran) are able to cover their demand from domestic production, and are also (net) crude oil exporters. The countries in the European Union only cover 12 % of their demand from domestic production.

Over half of the crude oil produced in 2017 was traded across borders. The oil was mainly transported by oil tankers or pipelines, and to a much smaller extent also by train or road tanker. 2,255 Mt of crude oil were exported worldwide, a rise of 1.2 % compared to the previous year. The two leading exporting countries are Saudi Arabia and the Russian Federation. The five largest exporting countries account for almost half of all of the exports. The global refinery capacity rose by 0.6 % to 4,873 Mt (BP 2018).

The leading importing region remains the Austral-Asia area with a share of 51 %. Africa imported the smallest amount of crude oil accounting for only 0.4 % of the total amount. China imported 420 Mt crude oil (plus 11 %) in the reporting year, and thus became the largest crude oil importer in the world. China thus replaced the USA (393 Mt) as the largest crude oil importer – a position it had held for several decades. The third largest crude oil importer was India whose crude oil imports rose to 217 Mt (plus 0.6 %).

The annual average price of the "Brent" (North Sea oil) crude oil reference type in 2017 was 54.13 USD/bbl. This means that the price rose by almost 25 % compared to the previous year (43.56 USD/bbl), to continue the trend of rising oil prices which began in January 2016. Oil reached its highest price over the year in December 2017 when it reached 64.37 USD/bbl. Crude oil prices fluctuated at a relatively constant level within the 50 and 55 USD/bbl band in the first quarter of 2017 after the production regulation measures agreed by OPEC at the end of 2016. The oil price was then very volatile until the middle of the year, driven by speculation on the size of the American strategic reserves of crude oil and petroleum products, and uncertainty about whether the OPEC production regulation mechanism would end or continue. The lowest price during the course of the year was reached at the end of June with 44.63 USD/bbl. Due to the robust demand for crude oil worldwide, as well as a devastating hurricane season which temporarily affected large parts of the US-American refinery capacity and offshore production, there was a continuous rise in the price of crude oil. In addition, OPEC announced in November, that it would continue to regulate production until December 2018. This gave rise to a further increase in prices towards the end of the year.

The US-American reference oil type "West Texas Intermediate" (WTI) roughly matched the change in prices of the "Brent" type. On average, the price of WTI crude oil rose from 43.77 USD/bbl the previous year to 50.88 USD/bbl in 2017. The price difference between the two crude oil types has been relatively low since 2014. However, this can fluctuate significantly due to differences in regional demand and supply. At the end of the reporting year, the price difference increased to over 6.49 USD/bbl at times. The third price indicator for crude oil is the OPEC basket price comprising 13 selected crude oil types from OPEC member countries. This rose to an annual average price of 52.43 USD/bbl (2016: 40.68 USD/bbl).

The storage capacities for crude oil and crude oil products in the OECD countries (strategic reserves and industrial reserves) stored in caverns or surface tank farms, totalled around 2.85 billion barrels at the end of 2017 (IEA 2018c). The free production capacity[2] amongst the OPEC countries at the end of September 2018 was around 1.4 million barrels per day (EIA 2018a).

Tables A-8 to A-14 in the Appendix list the country-specific resources, reserves, production and consumption of crude oil, as well as the exports and imports of crude oil (from the 20 most important countries in each case).

Supply security of liquid hydrocarbons

Although the geological reserves of crude oil are capable of covering even a rise in demand over a period of decades, and the crude oil oversupply on the market since the third quarter 2018 has led to a strong drop in crude oil prices, the overriding developments, in particular the investment activity, are crucial for supply security in the medium to long term.

Supply security for liquid hydrocarbons means that it is available at all times to satisfy demand. When considering individual countries or regions, this can be guaranteed via domestic production and processing of crude oil, or imports, or access to strategic reserves. But at a global scale, only via production and crude oil processing which satisfies demand, or access to strategic reserves.

In its New Policies Scenario (NPS), the IEA considers that the global demand for crude oil-based fuel and raw materials will increase by around 12 % by 2040. Petroleum consumption will initially rise by around 1 million barrels per day until 2025. The annual growth in the following 15 years is assumed to be 0.25 million barrels per day (IEA 2018b). The demand for petroleum-based fuels in developed countries in the next few years will tend to decline but will still remain at a much higher per capita consumption than in most countries around the world. Reasons for the decline are the predicted growing electrification of the transport sector, more fuel-efficient combustion technologies, as well as the use of alternative fuels. However, a strong rise in crude oil consumption is assumed in emerging economies and developing countries. The increase in petroleum-based transport in these countries in particular gives rise to an increase in consumption which overcompensates for the relatively moderate decline in the developed countries. Around half of the growth in the New Policies Scenario is attributed to China and India (IEA 2018b). Production will therefore need to grow accordingly to satisfy the demand for liquid hydrocarbons.

Future oil supplies are derived from the development of production in already producing oil fields, as well as the addition of new production capacities. Conventional oil fields which account for a share of around 80 % of global production reach a production peak, then transition to a period of plateau production, before entering a period of declining production. The size of this decline (Fig. 3-5) largely depends on the size of the field in particular, but also on whether a field is onshore or offshore – and in the case of offshore fields, also from the depth of the water (OGJ 2008). This

2 The additional volume of crude oil which can be boosted by production within 30 days and maintained for at least 90 days.

decline in production can be delayed or slowed down by implementing suitable technical measures which largely involve maintaining the pressure and the permeability in the reservoir, and the viscosity of the crude oil. So far, less than half of the crude oil produced worldwide comes from fields which have entered the production decline stage. However, this share will increase in future because an increasing number of fields are entering the post-plateau phase. The global average annual decline in production in these fields is around 6.1 % (IEA 2018b).

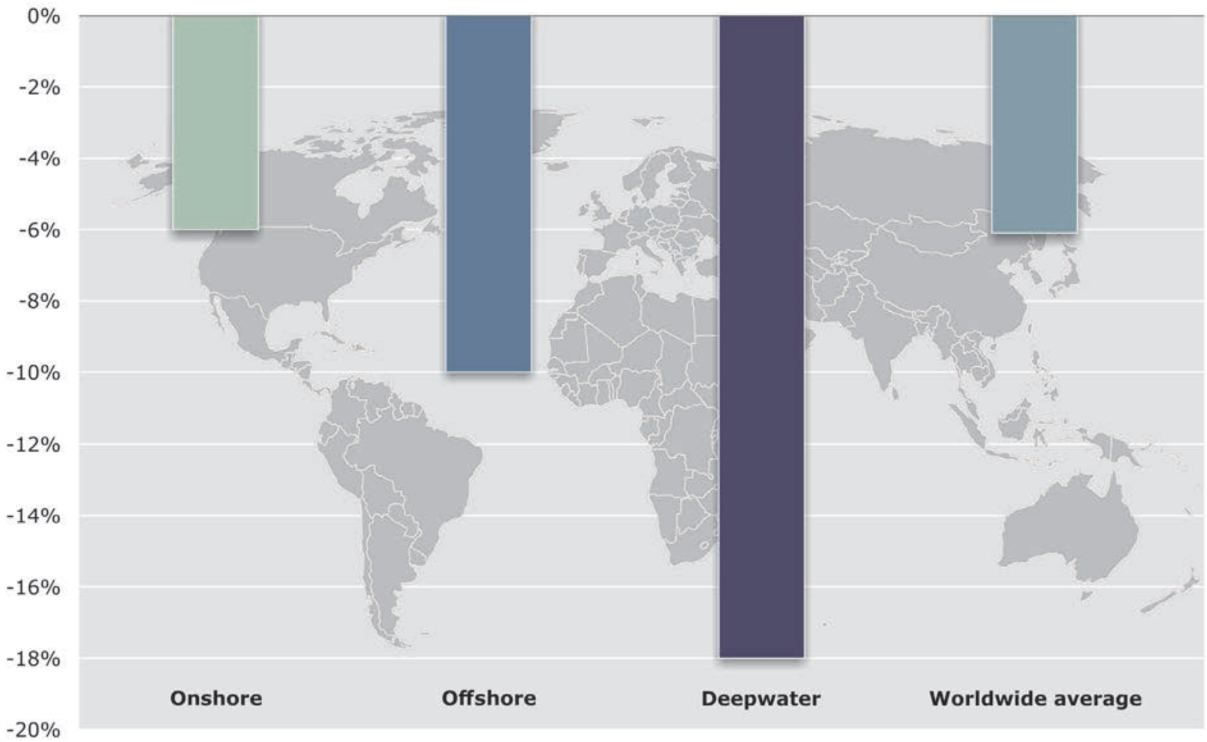

Figure 3-5: Annual production declines of conventional oil fields after the plateau phase (OGJ 2008, IEA 2018b).

Future crude oil production must therefore not only cover the rise in demand, but also compensate for the growing declining trend in the production from existing fields.

Because of the significant decline in crude oil prices since the third quarter 2014, there was a decline of around 50 % in investment in E&P projects up to 2016. Despite the significant increase in crude oil prices, investments have still only increased moderately since then and are mainly concentrated on US-American shale oil production (IEA 2018b). To cover the demand up to 2025 calculated in the New Policies Scenario, conventional oil fields with a volume of 16 billion barrels would need to be developed for production every year. The volume of developed fields averaged only 8 billion barrels per year between 2015 and 2017 (IEA 2018b). This potential discrepancy between supply and demand could lead to shortages in supplies in the medium term which would then probably also be reflected in price peaks.

From today‘s point of view, there are several options for avoiding these potential shortages in supplies: investments in E&P projects would need to be considerably increased over a relatively short period of time because the realisation of new conventional crude oil projects involves several years of work. Another option would be to implement measures to reduce consumption which go beyond those already included in the New Policies Scenario. The IEA also sees the option of expanding US-American shale oil production further by around 6 million barrels a day by 2025 (IEA 2018b). Unlike the development of conventional oil fields, shale oil projects can be realised within a relatively short period of time and with a relatively low amount of initial capital investment. However, the American Energy Information Authority (EIA) itself does not foresee such a high growth rate in shale oil production even in its most optimistic production scenario, which assumes high crude oil and natural gas prices, as well as further technical advances (EIA 2018b).

159 countries in total are (net) crude oil and/or petroleum product importers. Europe, as one of the largest consumers, can only cover around 12 % of its demand from domestic production, and is therefore dependent on imports. Norway is the only (net) crude oil exporting country in Europe (Fig. 3-6).

The dependence on crude oil imports − particularly against the background of the very high consumption − is particularly marked in the European supra region. Supply shortages in the highly industrialised countries of Europe could only be compensated by a relatively short time by opening

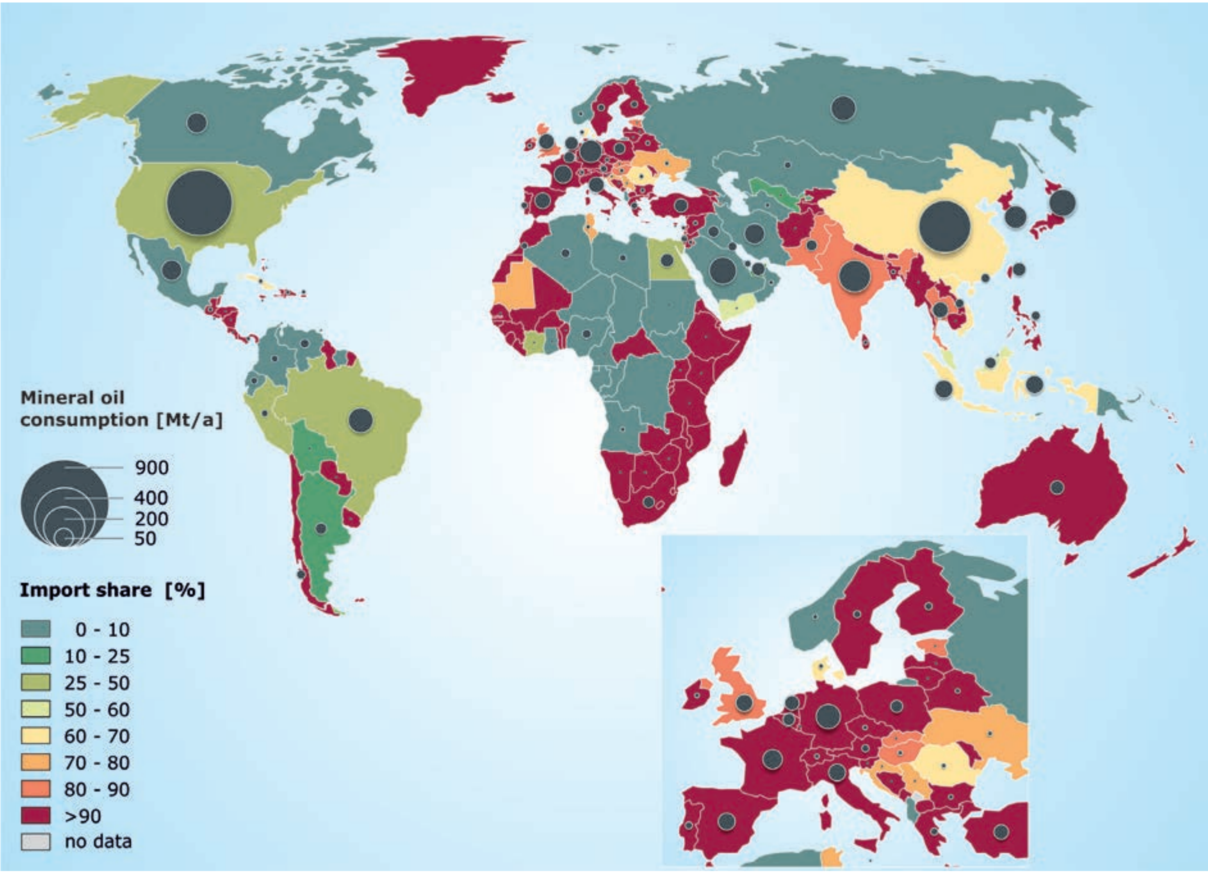

Figure 3-6: Import dependency and petroleum consumption of countries worldwide.

up the strategic crude oil and petroleum product reserves. Europe is therefore dependent on the smooth global trade in crude oil to cover its own demand. Despite a considerable boost to its domestic production in the last decade, the USA is still the second largest oil importer in the world. The USA is, however, located in a geographically favourable position because the neighbouring countries of Canada, Mexico and Venezuela are major oil exporting countries with significant crude oil resources. The third supra region with a particularly high level of dependence on imports is East Asia together with the Indian subcontinent. Especially economically strong and/or highly populated countries of Japan, South Korea, China, India and Pakistan have dad a growing demand for oil for several decades. The Middle East is already by far the most important supplier to these countries, and will play an ever more important role in supplying this region with liquid hydrocarbons in the years to come.

Countries with high levels of petroleum consumption and a high degree of dependence on imports would be particularly affected by supply shortages.

Liquid hydrocarbons can also be synthetically produced by natural gas- and coal liquefaction technologies. However, their share of the global production of liquid hydrocarbons is currently only around 1 % (IEA 2018b). Although the resources of coal in particular are much higher than those of crude oil, its share is not expected to rise significantly because of the debate about the challenges with associated CO_2 emissions, and the major investments required for liquefaction plants. The leading countries in the manufacture of synthetic liquid hydrocarbons from coal are South Africa and China, whilst Qatar and Malaysia are leading in synthesizing liquid hydrocarbons from natural gas.

3.3 Natural gas

With respect to its share of global primary energy consumption, natural gas remains the third most important energy resource behind crude oil and coal. Natural gas is the fossil fuel with the lowest specific CO_2 emissions. The use of natural gas is therefore seen as a flexible bridge technology during the transition to a renewable energy supply system. After a minor rise in global natural gas consumption in the previous year of almost 1.4 %, it rose again by around 3 % in 2017.

Global natural gas resources currently total around 628 trillion m³ (previous year: 643 tcm). This includes conventional natural gas resources as well as shale gas, tight gas and CBM (Tab. A-16 in the Appendix). Natural gas resources in conventional fields dominate the global situation accounting for around 312 tcm, followed by shale gas resources with 203 tcm, tight gas with 61 tcm, and CBM with 51 tcm.

The largest natural gas resources by far are located in the Russian Federation, followed by China, the USA, Canada and Australia (Tab. A-16 in the Appendix). Even if only the world‘s conventional natural gas resources are considered, the Russian Federation still has the most extensive deposits followed by the USA, China and Saudi Arabia (Fig. 3-7). There have been no major changes year-on-year in the ranking and size of the natural gas resources. The minor decline of around 15 tcm compared to the previous year is due to the re-evaluation of resources in particular in Australia and the Netherlands, as well as transferring resources to reserves.

In addition, there is also considerable natural gas potential in gas hydrate deposits. Gas hydrates are ice-like compounds formed by water and primarily methane, which are stable under certain pressure and temperature conditions. Estimates of the globally technically producible resources lie in the range of 180 trillion m³ to 300 trillion m³. These figures are not very reliable, however. Numerous countries have been doing research and tests on the development and use of gas hydrate deposits for many years now, and these are now pointing to the first applications. China for instance succeeded in producing more than 300,000 m³ of natural gas in the South China Sea over a 60-day test period in 2017. This gas from gas hydrates had a high degree of purity and was produced from a water depth of around 1230 m. NO commercial development and production of natural gas from gas hydrate deposits has been realised so far.

Global natural gas reserves rose slightly year-on-year and totalled 199 trillion m³ at the end of 2017 (previous year 197 tcm) (Fig. 3-7). When considering the annual production in 2017 of around 3,782 bcm, this reveals that production has been more than compensated for overall by additions to reserves.

At a global scale, the share of natural gas reserves in conventional fields lies at over 95 %; unconventional natural gas reserves in shale gas and CBM deposits only account for a very small proportion of global reserves (Tab. A-17 in the Appendix). Tight gas reserves are usually not treated separately but included in conventional reserves. They can account for a considerable share: in the USA for instance their share is assumed to be around 20 % of total natural gas reserves. Significant shale gas reserves are currently only reported for the USA, where they now account for over 65 % of the total reserves, and thus the largest proportion. Shale gas reserves in the USA at the end of 2016 totalled almost 6 trillion m³, a significant increase of almost 1 trillion m³ compared to the previous year.

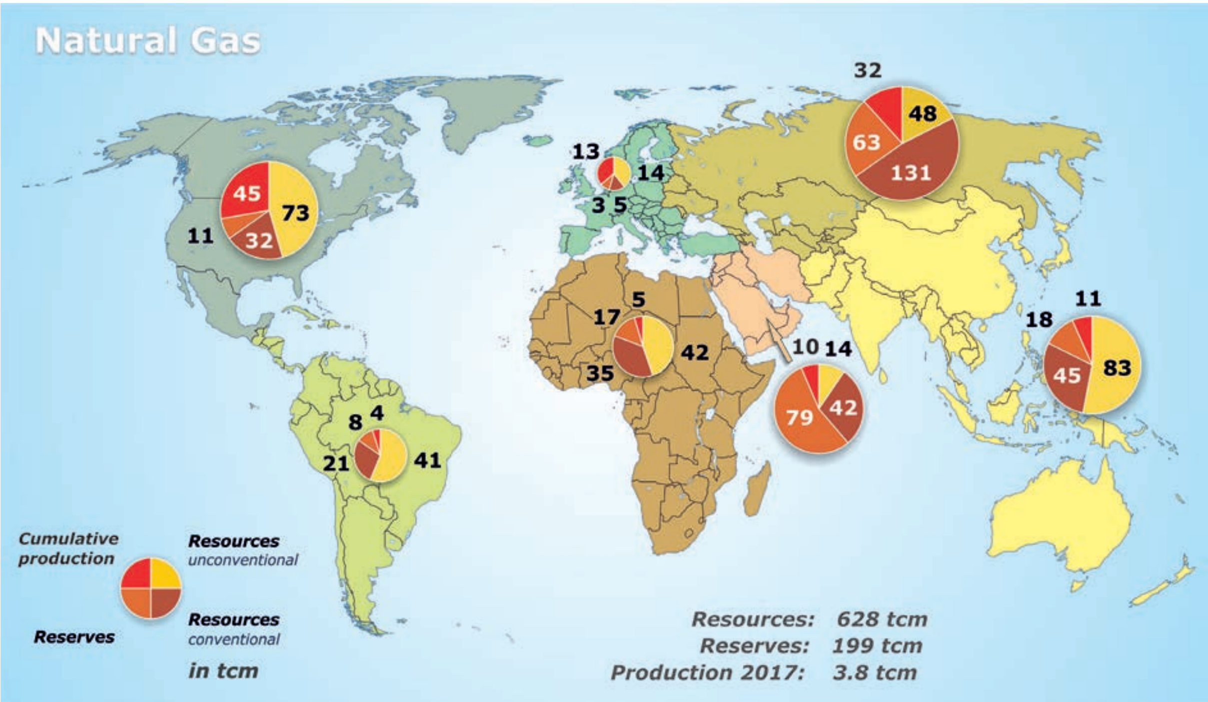

Figure 3-7: Total natural gas potential 2017 (excluding aquifer gas and gas hydrates): regional distribution.

Around half of global natural gas reserves (almost 53 %) are located in the Russian Federation, Iran and Qatar (Tab. A-17 in the Appendix), and are found almost exclusively in conventional fields. Almost 80 % of global reserves are located in OPEC and CIS countries. Most of the onshore reserves are located in the CIS, and in particular in the Russian Federation.

The Middle East has the highest volume of offshore reserves worldwide, and the dominant proportion of this is located in the largest natural gas field in the world at North Dome/South Pars (Qatar/Iran) in the Persian Gulf. This mega-giant is estimated to have originally contained almost twice as much producible natural gas as the world‘s second biggest natural gas field at Galkynysh in eastern Turkmenistan (Tab. 2). The remaining reserves in the North Dome/South Pars field are still over 50 times the reserves in the Zohr field discovered offshore Egypt in 2015, which is the largest natural gas field ever discovered in the Mediterranean (Tab. 2). Because of the current relatively moderate production and the remaining enormous reserves in North Dome/South Pars (Qatar/Iran) it will continue to be of major economic and geostrategic importance in future as well.

Global natural gas production in 2017 increased significantly by 4.8 % to around 3,782 bcm (previous year: 3,608 bcm. On a regional basis, the largest increases in production in percentage terms were in Africa (10 %), Austral-Asia (8 %), and the CIS (7 %). Increases in production in Africa came particularly from Egypt, as well as to a lesser extent from Nigeria and Algeria. In the Austral-Asian region and the CIS, production was primarily increased in Australia, Iran, China and the Russian Federation. Production in the European Union remained at the same level as the previous year.

The USA was the largest natural gas producer in the world, ahead of the Russian Federation and Iran (Tab. A-18 in the Appendix), and was able to cover almost the whole of its natural gas consumption from domestic production. The shale gas proportion of US-American total gas production rose again and accounted for 62 % in 2017 (EIA 2018c). Apart from the USA, commercial shale gas production is only found in Canada, China and Argentina, although at a very much lower level than in the USA.

The Russian Federation and the USA together produced around 1.4 tcm in 2017. This corresponds to around 38 % of global natural gas production.

Global natural gas consumption rose by around three per cent year-on-year. Most of the regions around the world reported increases of around 2 % to 6 %, and natural gas consumption only declined in North America by almost 3 %, and in particular in Canada. Nevertheless, the USA continued to be the largest consumer worldwide with 776 bcm natural gas, followed by the Russian Federation and China (Tab. A-19 in the Appendix).

The strong growth in natural gas consumption in the EU continued as in the previous year and grew further by 6 %. China and Iran also reported major increases of 13 %.

Table 2: The largest natural gas fields in the world (1 to 5) and selected examples from various countries

	Field name	Country	Location	Year of Discovery	Initial Reserves* [bcm]	Remaining Reserves* [bcm]	Annual Production** [bcm
1	North Dome South Pars	Qatar Islamic Republic of Iran	Persian Gulf – Offshore	1971 1990	38,000	35,800	255
2	Galkynysh	Turkmenistan	Onshore	1970 2006	21,000	20,500	40
3	Urengoy	Russian Federation	Western Siberia – Onshore	1966	9,500	2,500	77
4	Yamburg	Russian Federation	Western Siberia – onshore	1969	6,200	1,500	60
5	Shtokman	Russian Federation	Barents Sea - Offshore	1988	3,800	3,800	–
	Hassi R‘Mel	Algeria	Grand Erg – Onshore	1956	2,800	< 500	50
	Groningen	Netherlands	Onshore	1959	2,800	600	22
	Troll	Norway	North Sea – Offshore	1979	1,625	823	36
	Zohr	Egypt	Eastern Mediterra-nean – Offshore	2015	700	700	–
	Leviathan	Israel	Eastern Mediterra-nean – Offshore	2010	538	538	–
	Aphrodite	Cyprus	Eastern Mediterra-nean – Offshore	2011	125	125	–
	Calypso	Cyprus	Eastern Mediterra-nean – Offshore	2017	100	100	–
	Coral (Area 4)	Mozambique	Westl. Indian Ocean – Offshore	2011	2,123	2,123	–
	Snøhvit	Norway	Barents Sea – Offshore	1984	224	182	6
	Salzwedel	Germany	Saxony-Anhalt Onshore	1968	200	2	0.4

*valuations, partly including resources; **predominantly valuations

Around 1,205 bcm of natural gas, and therefore 30 % of the natural gas produced worldwide (3,782 bcm) were traded across borders in 2017. Natural gas imports rose worldwide by 10 %. Most of the world‘s regions imported much more natural gas than in the previous year, and only Latin America and the CIS reported significant declines, with minus 10 % and minus 16 % respectively. Europe was responsible for around 46 % of global natural gas imports. Germany‘s share rose again year-on-year and the 126 bcm imported accounted for almost one quarter of the total European imports. This made Germany again the biggest natural gas importer at a global scale in 2017. Of this, around 25.6 bcm of natural gas transited the country to other countries. With a consumption of around 106 bcm (previous year: around 102 bcm), Germany is one of the largest consumers in the world (Tab. A-19 in the Appendix).

At the same time, Germany has major natural gas storage capacities, even at a global scale. At the end of 2017, the maximum usable working gas volumes of these storages totalled around 24 bcm (LBEG 2017), which corresponds to around one quarter of its annual consumption.

Whilst Germany can import all of its natural gas via pipelines, Japan can only import its natural gas in liquefied form (LNG) even though it is the world‘s second largest natural gas importer. And although it increased its imports slightly year-on-year, the USA was displaced from third position in the biggest importer ranking by China. China underwent a significant increase in its imports of 23 % (by 23.5 bcm to 94.6 bcm). If this trend continues, China will rise to the biggest natural gas importer in the world within a few years.

Natural gas liquefied by cooling it down to minus 160 °C is known as LNG (liquefied natural gas), and can then be transported without pipelines.

The global trade in LNG increased by almost 10 % (compared to 6.5 % in 2016) (GIIGNL 2018), to again grow more than pipeline-transported gas, and accounted for around 33 % of natural gas trading in 2017 (IEA 2018d). There are now 40 LNG importing countries being supplied by 19 LNG exporting countries. Six new liquefaction plants were commissioned in 2017 with two each in Australia and the USA, one in the Russian Federation, and a floating plant in Malaysia.

The largest proportion of LNG was transported to Asia. In terms of LNG imports, China (54 bcm) has overtaken South Korea (52 bcm) and now lies in second place behind Japan (116 bcm) (GIIGNL 2018), even though China only began to import LNG in 2011

Qatar was again the world‘s largest LNG exporter in 2017 (26.7 % share), even though its export volume declined slightly to 107 bcm. Qatar is followed by Australia with 77 billion m³ and a share of 19.2 %. Malaysia in third place supplied around 37 bcm LNG (GIIGNL 2018). However, the largest increases in exports were reported by Australia (16 bcm; 27 % increase) and the USA (13 bcm; 330 % increase) (IEA 2018d).

With its expanding supply grid, Europe is connected to a large portion of global natural gas reserves via pipelines as well as by LNG receiving terminals. LNG was supplied to the European Union countries in 2017 primarily from Qatar (24 bcm, Algeria (14 billion m³), Nigeria (12 bcm) and Norway (5 bcm). Only relatively small quantities were derived from the USA (3 bcm) (GIIGNL 2018).

There are currently 24 large LNG receiving terminals in the EU, which are operational, and another 12 terminals which have been planned but for which no final investment decisions have been made. The construction of an LNG receiving terminal in Germany is under discussion. The map in Figure 3-8 shows the distribution of the existing terminals, their nominal capacity and the year they were commissioned.

The regasification capacity of the 24 EU terminals was 206 bcm in 2017. This corresponds to around 40 % of the natural gas consumption in the region. As was also the case in 2016, the average capacity utilisation of the European natural gas receiving terminals averages only around 25 % (King & Spalding 2018). This means that a doubling of imports could be handled without any problems.

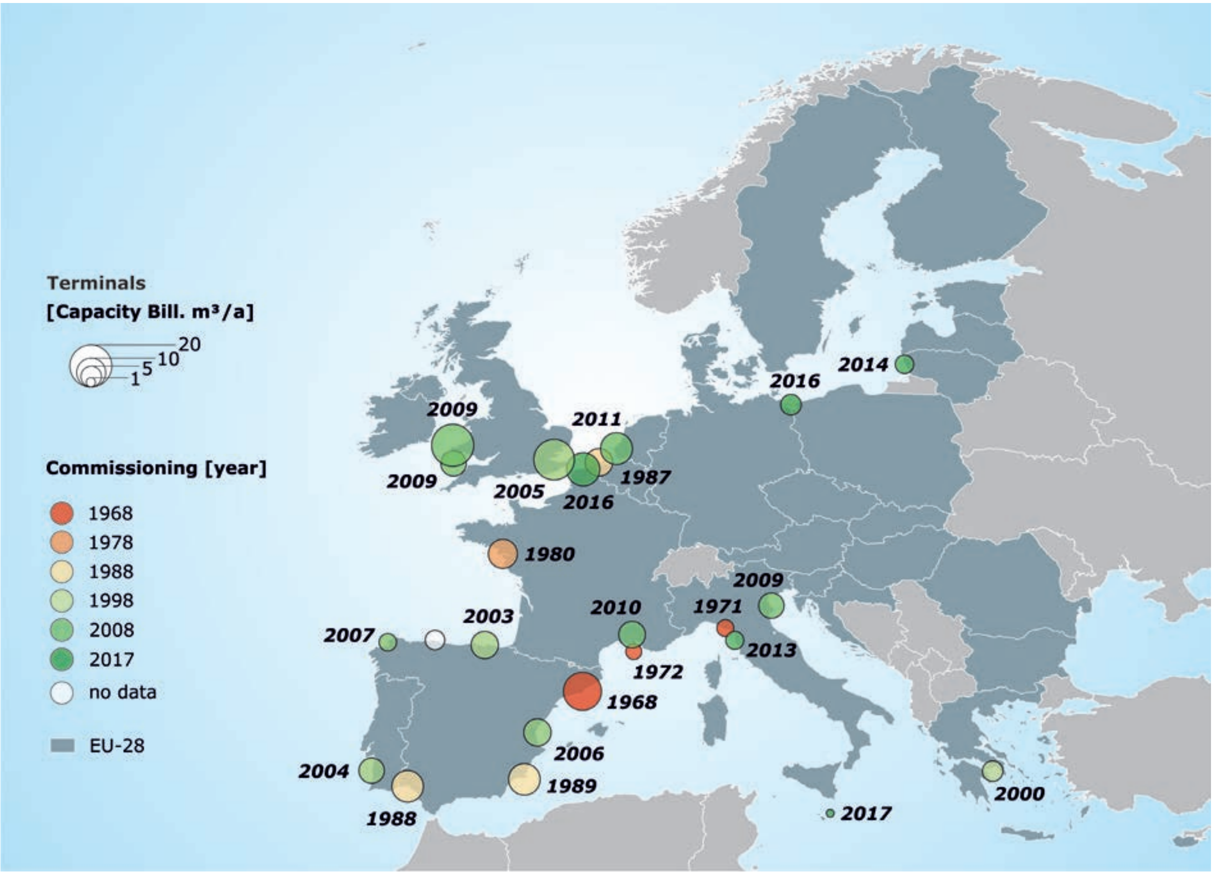

Figura 3-8: Large LNG receiving terminals in the EU.

Hand-in-hand with the rise in the price of crude oil, gas prices also picked up again in 2017. Because of the large volumes of natural gas available in the USA, it continued to be relatively cheap. The annual average price (Henry Hub spot price) in the USA was 2.96 USD/million Btu (previous year 2.46 USD/million Btu). The prices for LNG imports to Japan increased on average by 1.16 USD/million Btu to 8.10 USD/million Btu. Natural gas in Germany was imported on average for a price of 5.62 USD/million Btu, and was therefore around 14 % more expensive than the previous year (BP 2018).

Tables A-15 to A-21 in the Appendix provide an overview of country-specific production, consumption, imports and exports, as well as the reserves and resources of natural gas.

3.4 Coal

Despite all of the efforts being made to expand renewables and protect the climate, coal is still being used around the world in very large quantities. With a share of 27.6 % of global PEC, coal was the second most important energy resource in 2017 behind crude oil (BP 2018). Coal accounted for a 38.3 % share of global power generation in 2016, which is more than any other energy resource (IEA 2018e). Amongst the fossil energy resources, coal is not only the fossil fuel with the highest specific CO_2 emissions, but also the energy resource with easily the largest global reserves and resources.

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 either coking coal or steam coal. Because of its relatively high energy content, hard coal is economic to transport and therefore traded world-wide. Lignite on the other hand (energy content < 16,500 kJ/kg) is primarily used in the vicinity of the lignite deposit because of the lower energy and higher water content, and is mostly used to generate electricity

Total coal resources (total of reserves and resources) increased only slightly year-on-year. At the end of 2017, global coal reserves totalled 1,055 Gt, split between 734.9 Gt hard coal, and 319.9 Gt lignite. In terms of reserves, the main change compared to 2016 (BGR 2017) was in the hard coal reserves (plus 2.2 %), which was primarily attributable to exploration activity and the re-evaluation of reserves in Indonesia (ESDM 2018), as well as in Australia, India and China.

Global coal production increased slightly in 2017 and totalled around 7,566 Mt. This corresponds to a rise of 3.5 % compared to the previous year. Of this, 6,529 Mt (plus 3.9 %) involved hard coal, and the remaining 1,037 Mt (plus 1.4 %) involved lignite.

Unlike conventional crude oil and natural gas fields, coal deposits and their production are spread over a large number of companies and countries. Tables A-20 to A-31 in the Appendix provide an overview of the country-specific production, consumption, imports and exports, as well as the reserves and resources of coal and lignite.

Hard coal

The regional distribution of hard coal reserves, resources, and the estimated cumulative production since 1950 are shown in Figure 3-9. The largest remaining potential of hard coal is in the Austral-Asian region with 7,542 Gt, followed by North America with 6,872 Gt and the CIS with around 3,003 Gt. The USA has the world‘s largest hard coal reserves with 220 Gt (30 % global share). This is followed by the People‘s Republic of China with around 131 Gt (17.8 %), ahead of India with around 96 Gt (13.1 %). This is followed by Australia (9.7 %), the Russian Federation (9.5 %) and the Ukraine (4.4 %). The producible amounts (reserves) of subsidised hard coal in Germany until the end of 2018 totalled around 3 Mt. In terms of resources, the USA alone counts 6,459 Gt or 36.5 % of global hard coal resources, followed by China (30.1 %) and the Russian Federation (15 %).

The three largest hard coal producers in 2017 were China with a share of 49.6 % (3,236 Mt), India (10.4 %) and the USA (9.8 %). All three countries expanded their production in 2017, whereby the largest rise was in the USA with a growth of 7.5%, followed by China (plus 4.3 %) and India (plus 3.4 %). Production in the European Union (EU-28) was 80 Mt – and thus around 7 Mt less than the previous year – corresponding to a share of 1.2 % of global hard coal production.

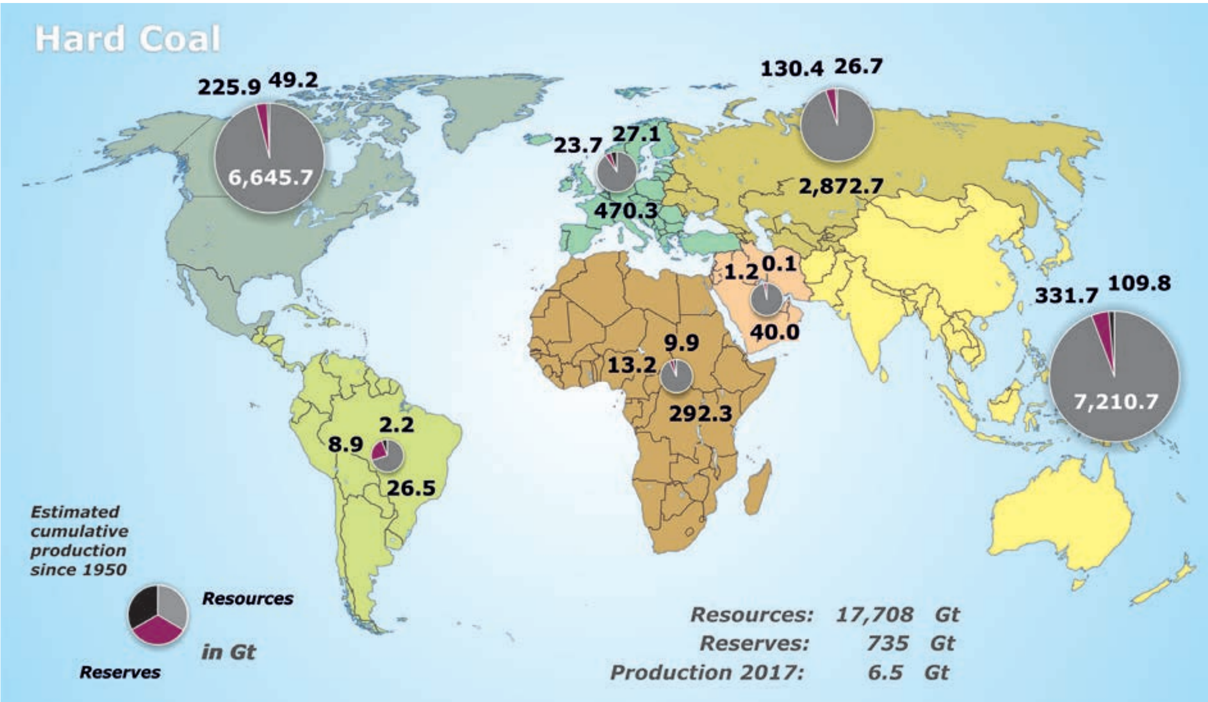

Figure 3-9: Regional distribution of total hard coal potential 2017 (18,443 Gt).

With around 1,350 Mt, around 21 % of the hard coal produced in 2017 was traded worldwide, of which 1,145 Mt was transported by sea (VdKi 2018a). This corresponds to a 4.7 % year-in-year rise in the amount of hard coal traded world-wide. Indonesia dominates the hard coal world market (Fig. 3-10) with exports totalling 389.5 Mt (28.9 %), followed by Australia (27.7 %) and the Russian Federation (13.8 %).

The highest hard coal imports are in China, India and Japan with a combined volume of around 672 Mt (49.2 %). China increased its imports in 2017 compared to the previous year (256 Mt) by around 6 % to 271 Mt. This means that China accounted for around one fifth of the global hard coal imports in 2017. India and Japan also increased their imports in 2017 to around 208 Mt (plus 9.1 %), and around 193 Mt (plus 1.6 %) respectively. As in previous years, Asia dominated the global hard coal import market with a current share of 74 %. With 171 Mt – and thus around 7 Mt or 4 % more than the previous year – the European Union (EU-28) only accounted for around one eighth of global hard coal imports, which thus covered around 70 % of its hard coal demand in 2017.

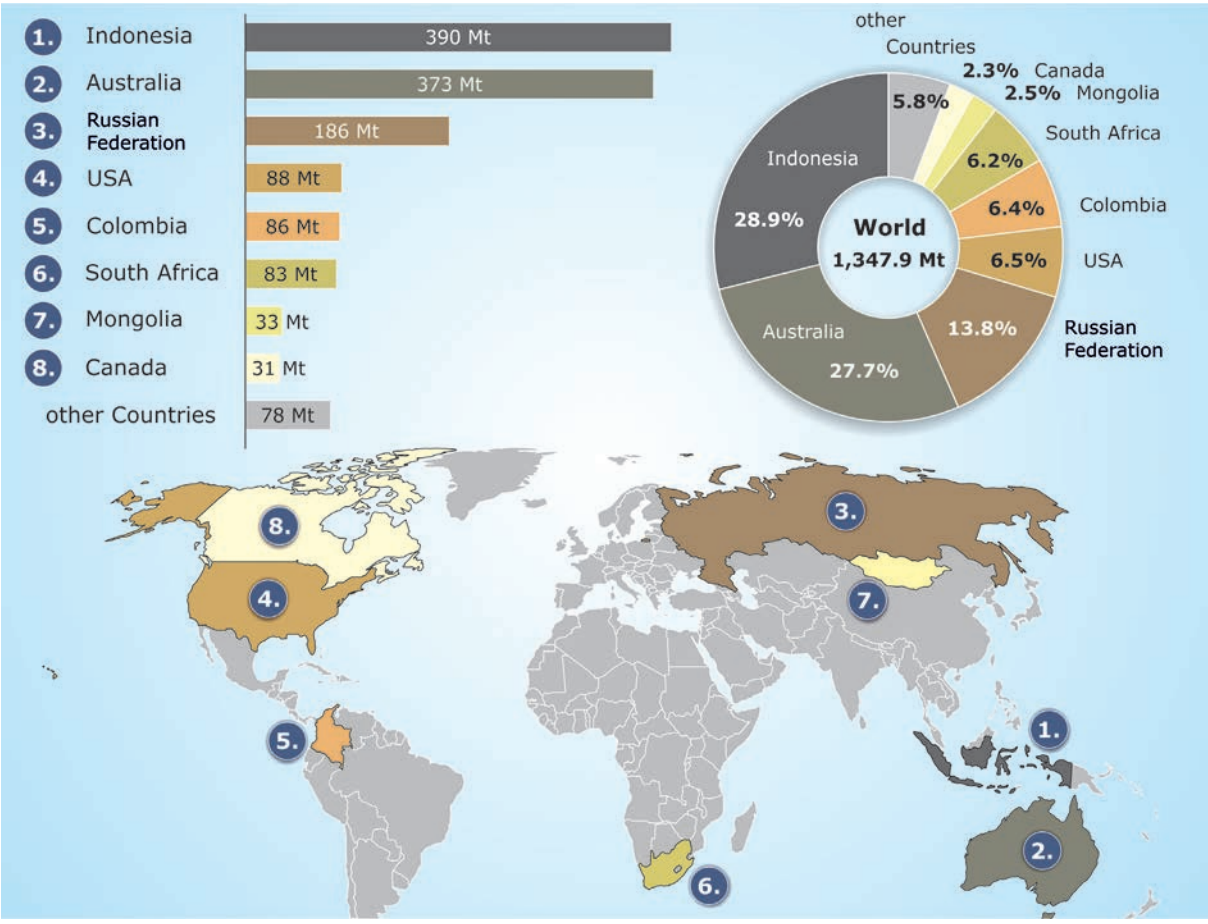

Figure 3-10: The largest hard coal exporters 2017 (> 30 Mt/a).

The Northwest European annual average spot price for steam coal (ports of Amsterdam, Rotterdam and Antwerp; cif ARA) rose significantly by around 30 USD/tce from 68.53 USD/tce in 2016 to 98.38 USD/tce in 2017 (plus 43.6 %). Primarily driven by the high prices in the Asian (Chinese) coal market, prices peaked at around 111 USD/tce in November 2017. And prices remained at a relatively high level until autumn 2018, even reaching a peak of around 118 USD/tce in October 2018 (Fig. 3-11) (VDKI 2018b). The last time prices reached similar levels was in February 2012.

Coking coal prices, which underwent a five-year decline until summer 2016, remained very volatile in 2017 and 2018 (Fig. 3-11). The annual average spot price for high quality Australian coking coal doubled from around 92 USD/t in 2015 to around 189 USD/t in 2017. At the beginning of 2017, the spot price for high quality Australian coking coal rose as high as 290 USD/t (day price mid-April 2017) because of production and transport disruptions caused by cyclone Debbie in Australia. By the beginning of summer 2017, the price had declined again to slightly below 150 USD/t. Because of a shortage in the supply of Australian coking coal, the price then rose almost continuously to around 240 USD/t by January 2018 before declining again until late summer 2018 to around 180 USD/t. The spot price for high quality Australian coking coal in autumn 2018 reached a level of 227 USD/t in response to demand (day price beginning of November 2018) (IHS Markit 2018a).

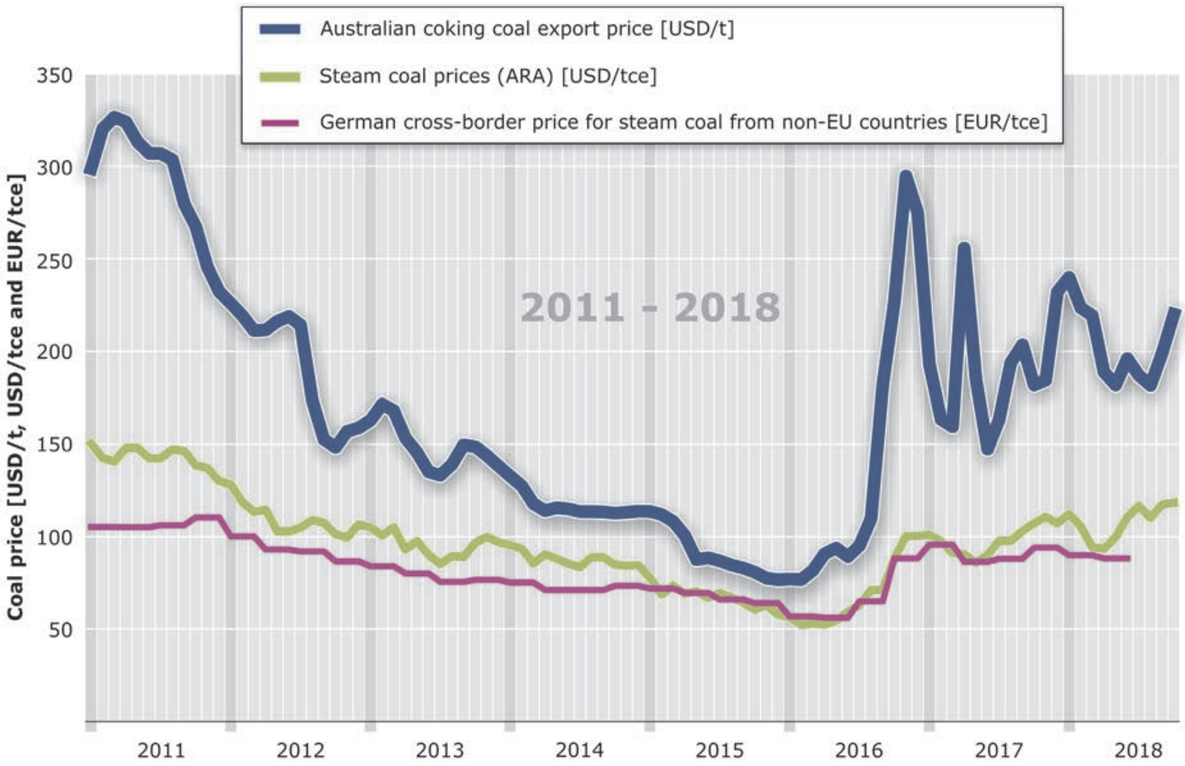

Figure 3-11: Development of Australian export prices for coking coal (prime hard coking coals) as well as Northwest European and German steam coal import prices from January 2011 to October 2018 (BAFA 2018c, IHS Markit 2018a, VDKI 2018b).

The price level and the higher price volatility will probably also be maintained in the short term without any significant changes given on the one hand, the rise in global demand which began again two years ago for steam and coking coal, and on the other hand, the relatively minor amount of investment in exploration and the development of new coal projects. The prices could be significantly influenced, however, by a further expansion in the trade conflict between USA and China, and a global recession, which may result as a consequence.

The global (export-orientated) coal sector experienced an upswing again from summer 2016 with the rise in the world market prices for coal. Because of the decline in demand between 2013 and 2016, global hard coal production reduced from 6.98 Gt to 6.28 Gt. This decrease of around 700 Mt corresponds almost exactly to three times the hard coal annual demand of all EU-28 countries (2017). Global hard coal production grew by 3.9 % in 2017 to around 6.53 Gt. This trend continued into 2018 and current estimates indicate a growth of around 3 % to 6.72 Gt. Whilst the Austral-Asian region, with the major coal producing countries of China, India, Indonesia and Australia, will probably account for more than three quarters of global hard coal production as in previous years, the European share is only around slightly more than one per cent (Fig. 3-12).

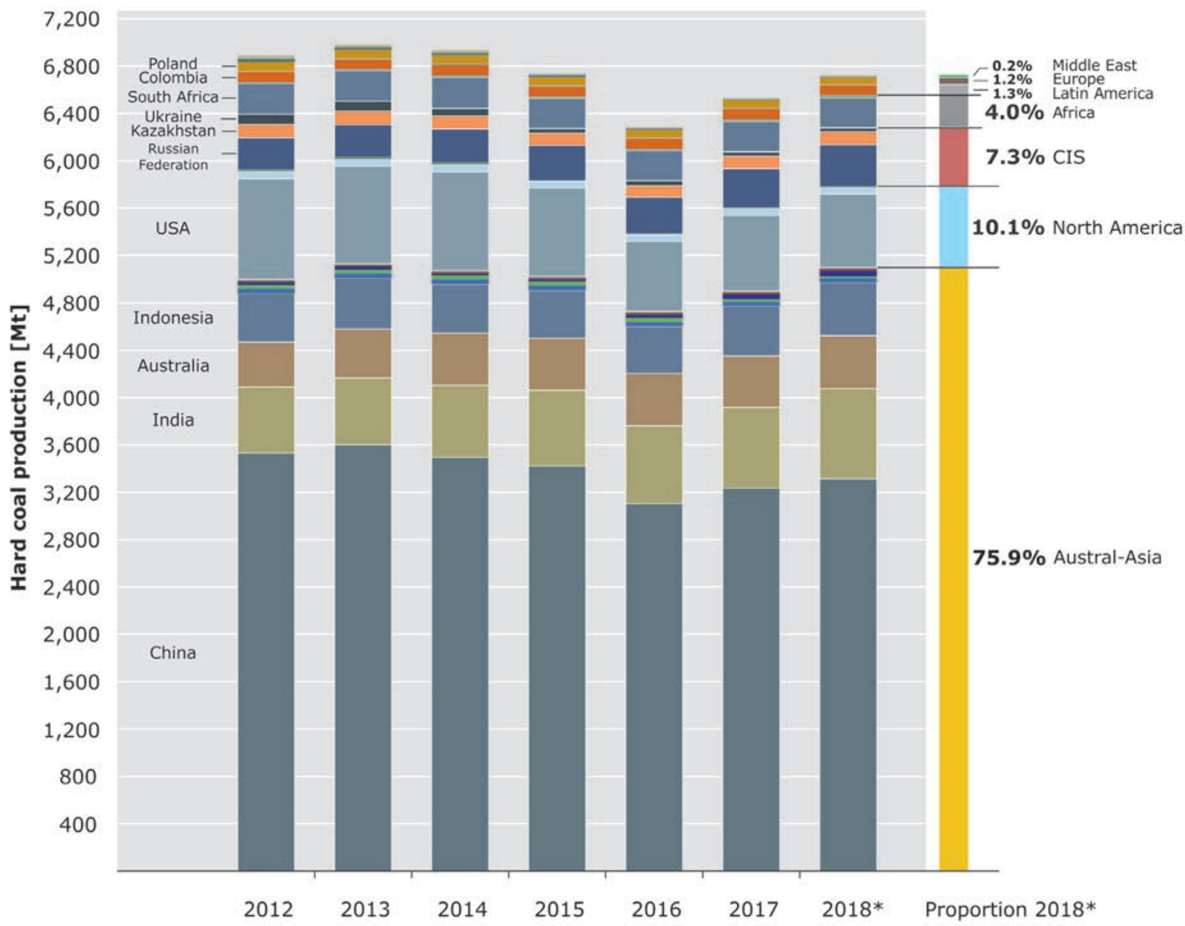

Figure 3-12: Development of global hard coal production since 2012 (estimate for 2018).

Whilst hard coal production in the USA declined by around 400 Mt from almost 1 Gt to around 593 Mt between 2008 and 2016, the country posted a growth of 7.5 % to 639 Mt in 2017. However, around three quarters of the year-on-year rise in production of around 45 Mt was exported, and therefore hardly any of the increase was attributable to higher coal consumption in the USA. This reveals the real picture of the US coal industry adopting its well-known role as a swing supplier to increase its coal exports year-on-year by 61 % to around 88 Mt in parallel to the rise in the coal world market prices (Fig. 3-11). The growth in production also gave rise to a slight increase again of 2.4 % in the workforce in the coal sector to around 53,000, even though the number of US-American coal mines decreased again from 710 (2016) to 680 (2017) (EIA 2018d). Preliminary estimates for 2018 indicate another decline in US-American coal production of probably around 3 % compared to 2017 (EIA 2018e). This is primarily attributable to the continuous decline in the use of coal for power generation where it has been increasingly displaced by natural gas and renewables (EIA 2018f). One of the reasons for this, in addition to the available supply of cheap natural gas, and a growing proportion of renewables, is the closure of a number of coal power plants in recent years (EIA 2018g). Between January 2015 and August 2018, coal power plants with a capacity of around 43.8 GW (EIA 2018h) were decommissioned primarily for economic reasons, and/or because of more stringent environmental regulations (EPA 2016). In this way, within only three and a half years, the coal-fired power plant fleet in the USA was reduced by almost the same capacity as all of the hard coal and lignite power plants supplying the grid in Germany in November 2018, which totalled 40.8 GW (of which 21.9 GW hard coal and 18.9 GW lignite power plant capacities, BNetzA 2018b).

Hard coal production in China rose again in 2017 for the first time in three years by around 4 % year-on-year. In addition, the country continues to push ahead with the restructuring of the coal sector which began several years ago, and particularly with the strategy to close small mines with low production capacities (< 90 kt/a), and a relatively high number of (fatal) accidents. This is accompanied by the removal of overcapacities, which after a decline of 290 Mt in 2016, led to a further decline in production capacities of 183 Mt in 2017. The decommissioning of another 150 Mt of production capacities is planned for 2018, so that by the end of 2020, a total of 800 Mt of obsolete and unproductive mines are scheduled to be closed in accordance with the Chinese government‘s five-year-plan formulated in 2016 (IHS Markit 2018b). In addition, overcapacities in the Chinese steel sector are also to be reduced by the end of 2020 with the closure of steel production capacities of 120 Mt to 150 Mt (Council of State of the People‘s Republic of China 2016). 120 Mt of this had already been decommissioned by early 2018 so that the aforementioned target of 150 Mt could already be achieved by end 2018, and thus two years earlier than originally planned (Reuters 2018a). The reduction in overcapacities in the coal and steel sector decreed by the state affected around 726,000 workers in 2016, and is estimated to affect around another 1 million workers by 2020. China set up a special fund totalling USD 15 billion for these workers. In 2017 alone, USD 3.43 billion of this special fund was provided for the reintegration of 377,000 workers in the job market (Fenwei Energy Information Services 2018a).

Despite the current phase of decommissioning, new modern coal mines are currently being planned or under construction. The existing mines are also being modernised and their production capacities expanded. According to the Chinese National Energy Administration (NEA), Chinese production capacities totalled 3.5 Gt/a at the end of June 2018. In addition, mines with almost 1 Gt in coal production capacities are still under construction or being modernised. The expansion by around 5 % in the first three quarters of 2018 compared to the same period the previous year is primarily attributable to the commissioning of ultra-modern coal mines, alongside the increased demand for coal by the power generation sector (Reuters 2018b, Fenwei Energy Information Services 2018b). Because of the mines currently under construction, the production capacity of the Chinese coal sector will probably increase again to a capacity of more than 4 Gt/a by 2020. Some market analysts therefore assume that China will reduce its imports of steam coal because of the higher domestic coal production. According to current estimates, Chinese coal imports in 2018 will probably be similar to those in the previous year (271 Mt) (S&P Global Platts 2018a, b, Fenwei Energy Information Services 2018c).

As in previous years, India increased its hard coal production again in 2017 to around 681 Mt (plus 3.4 %). Most of the total Indian hard coal production in the 2018 financial year (April 2017 to March 2018) was accounted for by the major state-owned coal producer Coal India Limited (CIL) which accounted for 567.4 Mt – although this means that CIL failed to reach its production target of 600 Mt. CIL production comes from 369 mines of which 177 are surface mines, 174 deep mines, and 18 surface/deep mine complexes, although most of the production comes from surface mines with a share of 536 Mt (CIL 2018b). In the first seven months of the 2019 financial year (April 2018 to October 2018), Indian hard coal production rose again significantly by 10.4 % to 370.3 Mt. During this period, CIL boosted its production by 10.1 %, and assumes that it will reach its production target of 652 Mt for the 2019 financial year (Fenwei Energy Information Services 2018d).

The plans presented by the Indian government in spring 2015 to increase Indian coal production to 1.5 Gt (total coal) by 2020 (IEA 2015), have been postponed. The time frame for achieving the CIL production target of 1 Gt (CIL 2015) – and thus also the total Indian production target – has been moved back to 2025/2026 (CIL 2018a) because of a combination of factors including lower growth, a change in energy mix, environmental challenges, and problems in acquiring the land needed.

Indian hard coal imports in 2017 totalled around 208 Mt, corresponding to a growth of around 9 % year-on-year. However, in an analogous way to China, expansion of Indian hard coal production in future could lead to a decline in the amount it needs to import (steam coal) (S&P Global Platts 2018a).

Lignite

With around 1,591 Gt, North America has the largest remaining potential for lignite, followed by Austral-Asia (1,416 Gt), and the CIS (1,389 Gt, including sub-bituminous coal) (Fig. 3-13). Of the 320 Gt global reserves of lignite identified in 2017, 90.7 Gt (including sub-bituminous coal) or more than a quarter, was located in the Russian Federation (28.4 % global share), followed by Australia (23.9 %), Germany (11.3 %), the USA (9.4 %) and Turkey (3.4 %). The USA has the largest share of lignite resources with around 1,368 Gt (30.9 % global share), followed by the Russian Federation (29.1 %, including sub-bituminous coal), and Australia (9.1 %). Around 80 % of global lignite production in 2017 totalling 1,037 Mt came from only 11 of the 37 producing countries. Global lignite production increased year-on-year by 1.4 %. The domestic production of lignite in Germany declined only slightly by 0.1 % year-on-year, making the country the largest lignite coal producer with a share of 16.5 % (171 Mt), followed by China (14 %) and the Russian Federation (7.2 %).

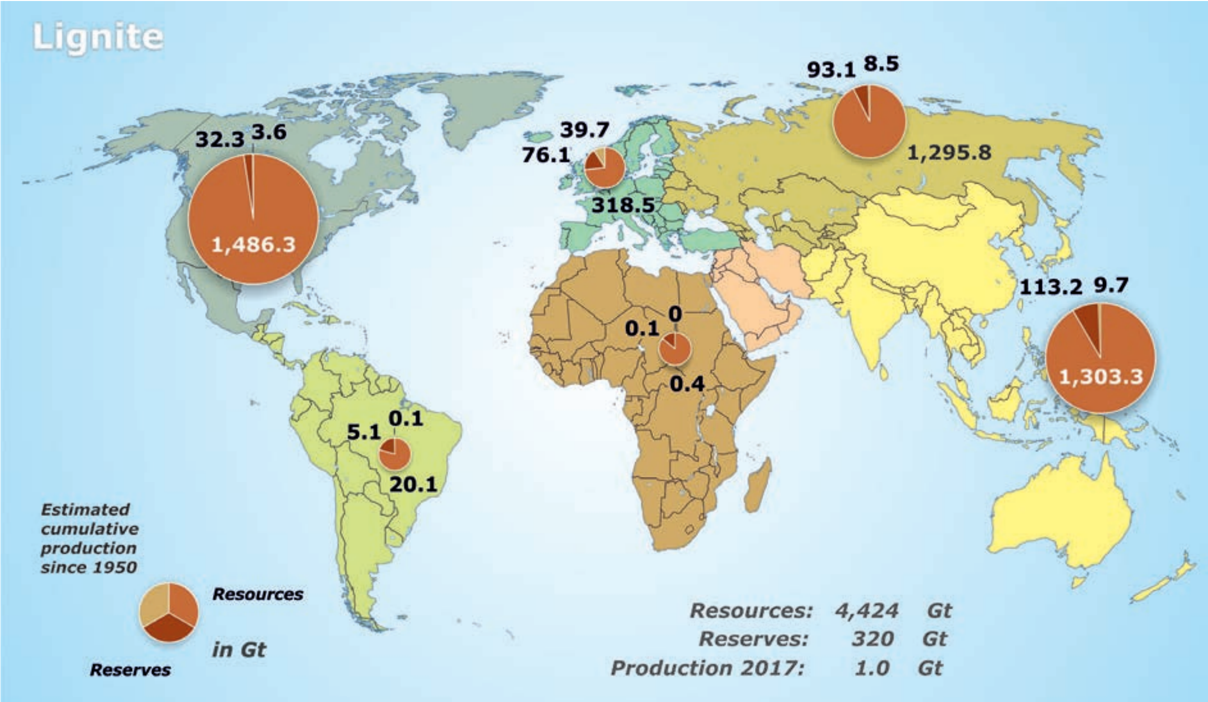

Figure 3-13: Regional distribution of total lignite potential 2017 (4,744 Gt).

3.5 Nuclear fuels

Uranium

After the German government‘s decision to withdraw from nuclear power, this energy resource continued to decline in significance in Germany, but from a global point of view, it is still an energy resource of high relevance and still in strong demand. The demand for uranium will probably sink further in Europe in future, but a rise in uranium consumption can be expected primarily in Asia and the Middle East. There are currently 128 reactors in operation, mainly in Asia, and another 40 under construction. Two nuclear reactors were again completed in China in 2017 and connected up to the national grid. Pakistan also began the operation of its fifth reactor. Two new countries have joined the nuclear energy club in the form of Bangladesh and Turkey. Both countries started the construction of their first nuclear power plants in 2017. A moderate rise in the demand for uranium in the coming decades is also expected in the Latin American and African regions (IAEA 2017a, OECD-NEA/IAEA 2016, WNA 2018a).

Global uranium resources[3] are very comprehensive at 11.7 Mt and have therefore remained almost unchanged compared to the previous year. As in previous years, the changes in uranium resources are mainly attributable to only a few countries. As a consequence of the continuing recession in the uranium market (BGR 2017), the growth in global uranium resources remained low in 2017. The uranium price has fallen rapidly worldwide in recent years because of the reactor accidents in Fukushima in 2011 and the associated shut-down of 48 reactors in Japan and 8 reactors in Germany. The uranium price on the spot market virtually halved in a very short period of time (Cameco 2018a). The price of uranium is crucial for the development of new exploration and extraction projects, and also has a direct influence on the economics of mines and projects. Investments were stopped or reduced in many exploration projects. The number of shelved or delayed projects has been growing for several years now and has a direct consequence on the re-evaluation of resources in many countries.

Notwithstanding the renewed reporting-associated reduction in US-American resources (BGR 2017), there were notable increases in Canada in 2017. Re-evaluations occurred here on the basis of exploration activity and re-evaluations over recent years. Reduction in the resources arose from the transfer of resources to reserves in Kazakhstan in particular. Kazakhstan, Canada and Australia are the three most important uranium-producing countries in the world (Tab. A-38 in the Appendix), and regularly re-evaluate their resources.

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

With respect to the reporting of uranium reserves, a purely statistical consideration of the economically extractable reserves in the cost category < 80 USD/kg U only partially reflects the real situation (BGR 2014). The production costs of many mines in 2017 continued to be higher than the market price. Australia (the third largest uranium producing country in the world) also extracts uranium at much higher costs, and only reports uranium reserves above 80 USD/kg U (Tab. A-37 in the Appendix). In the sense of the conservative approach of this Energy Study (cf. BGR 2014), only uranium deposits in the production class < 80 USD/kg U are counted as reserves. All other reserves with higher production costs are reported in this study as resources, even if they are already being mined.

As was the case for the uranium resources, there was almost no change in uranium reserves compared to the previous year (plus 1 %; Tab. A-36 in the Appendix). A significant rise in reserves was reported in Kazakhstan (plus 5 %), where resources were transferred to the assured reserves category after re-evaluations. Production-related declines and re-evaluations led to a reduction in reserves overall in Canada, even though reserves in the lowest cost category (< 40 USD/kg U) increased. This change is mainly attributable to evaluations of the main uranium extraction area in Canada. The Canadian McArthur River and Cigar Lake mines in the Athabasca-Basin in North Saskatchewan are the two mines with the highest production in the world. In a global comparison, they have very high uranium concentrations of up to 15 %, which means that a relatively high uranium yield can be achieved during extraction. In addition, extraction costs are reduced further by the use of a new mining technology in the Cigar Lake mine – which involves freezing the ground to

3 Unlike other energy resources, the stocks of uranium (reserves and resources) are divided up according to their extraction costs. The definition for uranium reserves limits extraction costs to < 80 USD/kg U (see definition in the Appendix).

mechanically stabilise the sediment around the ore body at a depth of around 400 m, so that the uranium can be extracted fully automatically in-situ (Cameco 2018b). Global uranium reserves in the < 80 USD/kg U cost category are 1.2 Mt (2016: 1.2 Mt). Around 93 % of the reserves are located in only 10 countries: led by Kazakhstan and followed by Canada and South Africa. According to the information currently available, these three countries account for more than half of the global reserves of uranium (Fig. 3-14).

Global uranium production has declined for the first time in several years. Production in 2017 dropped by around 2,800 t U to 59,566 t in total (minus 5 %). This was attributable to the reduction in production in some mines as a market regulation measure with the aim of counteracting the current oversupply of uranium on the world market. Numerous mines reduced their production or shut it down completely during the year. This also included market-dominating mines in Canada, Kazakhstan and Australia. The largest single production site in 2017 was the Canadian Cigar Lake mine for the first time with 6,924 t U, and a market share of 12 %. This knocked the McArthur River mine in Canada from the top spot it had occupied for many years (6,193 t U, 10 %) which had implemented production cuts in the face of the current pressure on the global uranium market. The mines at Tortkuduk and Myunkum in Kazakhstan (4,519 t U, 6 %), Olympic Dam, Australia (2,281 t U, 4 %) and Budenovskoye 2, Kazakhstan (2,381 t U, 4 %) also reduced their production in 2017.

Around 89 % of global production came from only six countries (Fig. 3-15). Kazakhstan was again the largest producing country. Although the country reduced its production significantly year-on-year because of the global market situation (2016: 24,574 t U) to 23,391 t U in 2017, it still

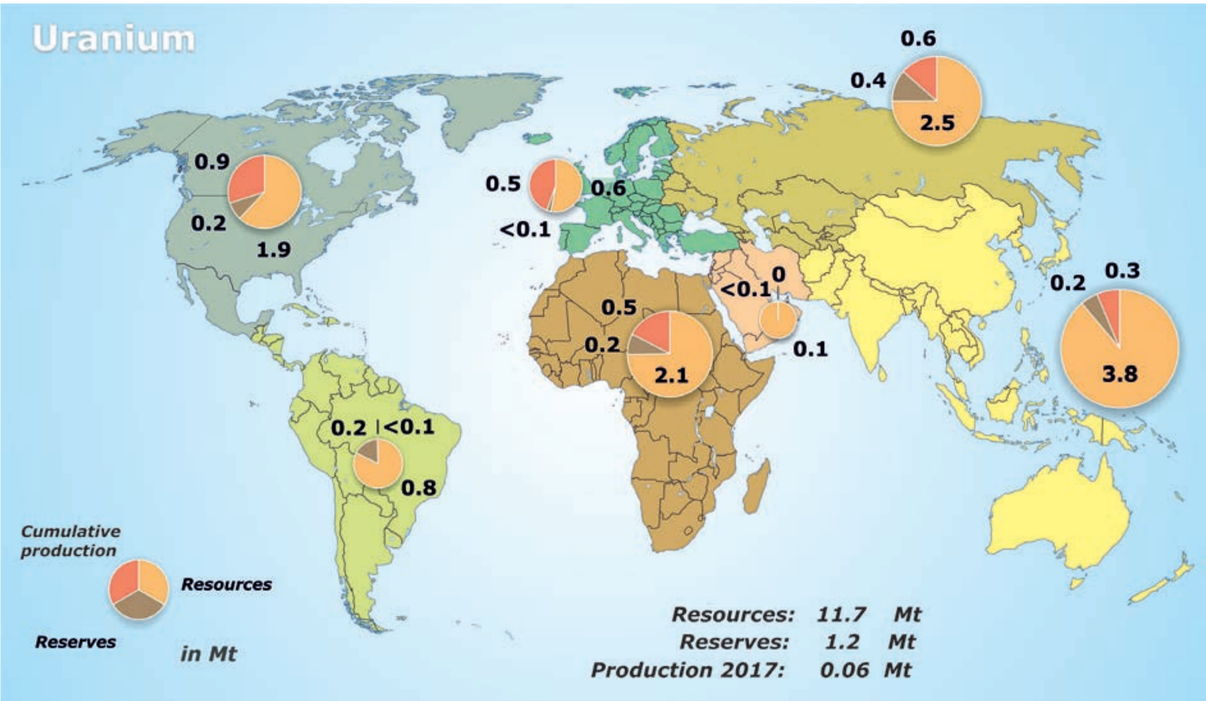

Figure 3-14: Total uranium potential: regional distribution.

dominates global uranium production with a share of 39 %. The annual production in Kazakhstan has increased by more than five times in the last ten years. Canada, Australia, Namibia, Niger and the Russian Federation together accounted for another 49 % of global production. Uranium production is concentrated on only a few major companies as in previous years. Around 88 % of global production came from only ten mining companies in 2017. Over half of the uranium produced worldwide comes from only three companies: Kazatomprom (Kazakhstan) with a 21 % market share, Cameco (Canada) with 15 %, and Orano (formerly Areva) (France) with 13 %.

Uranium consumption concentrated on only a few countries. Over half of global uranium demand comes from only three countries, namely the USA, France and China. The global demand for uranium in 2017 was 65,014 t U (2016: 63,404 t U), and thus rose by around 3 % compared to the previous year. There has been a higher uranium consumption in Asia and the Middle East in particular (Tab. A-39 in the Appendix), and this will probably grow further in coming years, primarily in China and India. The uranium demand in Germany has declined significantly since the shut-down of 10 nuclear power plants in the country since 2011 and was 1,480 t U in 2017 (cf. Chapter 2.2). The shut-down of the Gundremmingen B nuclear power plant in Bavaria in December 2017 has not yet had any statistical influence on the annual reactor demand.

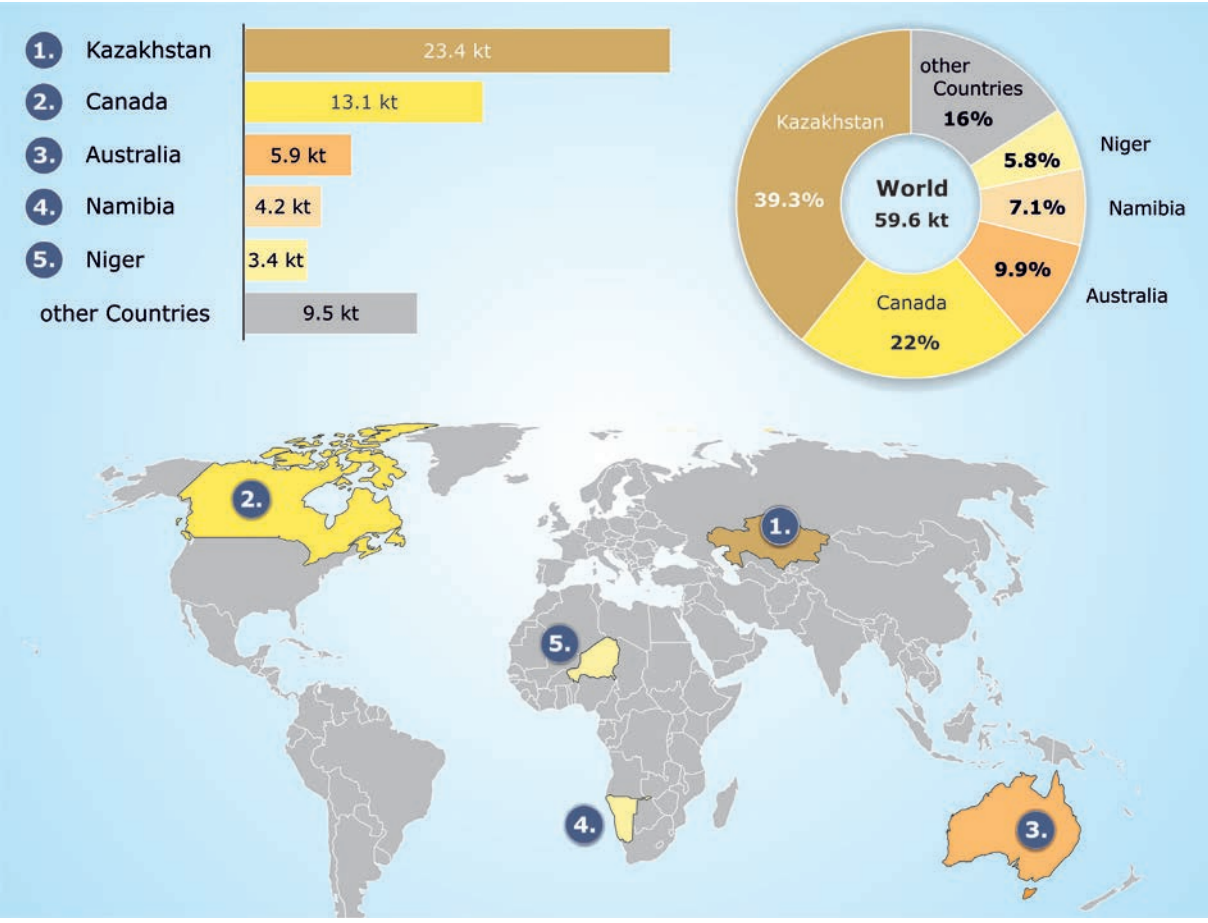

Figure 3-15: The largest uranium producing countries 2017.

Uranium is traded worldwide via long-term supply contracts in most cases. Uranium supplies to EU member countries in 2017 were 14,312 t U and thus very similar to the previous year‘s level (2016: 14,325 t U). As is usual in Europe, the share of supplies based on spot market contracts was only 4 % (European Union 2018). The uranium market continues to be affected by relatively low spot market prices which continue to jeopardise the profitability of various mines and exploration projects. The declining trend in uranium prices which has continued since 2011 (as at Jan. 2011: 188 USD/kg U) has now levelled off notably for the first time after a period of six years. The spot market prices declined only minimally during the course of 2017 from 63.70 USD/kg U to 58.03 USD/kg U. They remained almost constant during the course of the year at an average value of 56.46 USD/kg U. It is not yet possible to clearly foresee whether this represents a turnaround and thus a long-term change. An outlook for 2018, however, shows a stable level of spot market prices in the first half of the year. Many uranium producers also continue to benefit from their existing long-term contracts which mostly include higher price guarantees.

A growing demand for uranium is expected worldwide in the medium to long term. The growing demand for energy in Asia in particular will probably lead to a higher demand for uranium. Several Asian states have plans to begin the production of nuclear power. Bangladesh started the construction of its first nuclear reactor at the end of 2017, Rooppur-1 (followed by the construction start of the second reactor, Rooppur-2 in July 2018). Indonesia, the Philippines, Thailand and Vietnam also have plans to add nuclear power to their energy mixes.

In Europe as well, uranium will continue to be used as an energy resource in the long term, despite the expected decline in demand due to Germany‘s and Belgium‘s withdrawal from nuclear energy, and the moratoria on expansion plans in Italy and Switzerland. Other countries though, such as Finland, France, Rumania, Sweden, Slovakia, Slovenia, Spain, Czechia, Turkey and the United Kingdom, continue to see nuclear power as an important part of their national energy mixes. Poland plans to build its first nuclear power plant, and foresees the construction of up to five additional reactors. The first reactor is scheduled to be connected up to the grid in 2033.

At the end of 2017, 56 nuclear power plants were under construction in 16 countries, including China (18), the Russian Federation (7), India (7), the United Arab Emirates (4), South Korea (4), Japan (2), Pakistan (2), Slovakia (2), Taiwan (2), the USA (2), Belarus (2), Argentina (1), Bangladesh (1), Brazil (1), Finland (1) and France (1). Another 125 nuclear power plants are in the planning or approval stage worldwide. Shut-downs occurred in Germany (1), Japan (1), Sweden (1), Spain (1), and South Korea (1). 116 commercial reactors (plus 48 prototypes and 250 research reactors) have been decommissioned worldwidesince the use of nuclear reactors began (as at November 2018). Of these, 17 reactors (including research reactors and prototypes) have been completely dismantled (WNA 2018c). Four decommissioning projects have been completely finalised in Europe, of which three alone in Germany (BfS 2015). Two nuclear reactors in China and one in Pakistan were commissioned. After the immediate shut-down of all reactors in Japan as a reaction to the reactor accident in Fukushima in 2011, two reactors (Takahama 3 and 4) have been recommissioned. The 448 nuclear power plants operated around the world in 2017 with a total net capacity of 396 GW_e (DAtF 2018b), accounted for a consumption of around 65,014 t natural uranium. Most of this came from mine production (59,566 t).

The world mine production of uranium in the last five years lay at around 60,000 t U, compared to an annual consumption of around 65,000 t U. The gap between annual demand and primary production is covered by civil and military inventories, in particular in the Russian Federation and the USA. These inventories were derived from the overproduction of uranium in the period from 1945 to 1990 in the expectation of a growth in civilian demand, as well as for military reasons. The military inventories in particular were successively reduced. The basis for this reduction was the START treaties closed in 1992 between the USA and the Russian Federation, and which covered the conversion of highly enriched weapons uranium (HEU) to low enriched uranium (LEU). Over a period of 20 years, 500 t of Russian HEU – corresponding to around 20,000 warheads – were converted into 14,446 t LEU (WNA 2017c). This corresponds to around 150,000 t natural uranium (WNA 2018d). Both countries initiated a NEW-START treaty in 2010 to dismantle more nuclear weapons and to use the uranium they contain. This treaty was ratified in 2011 and is valid until 2020.

In addition to mine production, this means that uranium from inventories and the dismantling of atomic weapons is available to cover future demand. Another source of uranium is the reprocessing of fuel elements. The industry here is currently working on increasing the efficiency of reprocessed material. The lifetime of material (reusability), as well as material enhancement (reduction in resource use), are the main priorities of these activities. Reprocessing is controversial because the first fuel cycle (nuclear fission) generates by-products (including plutonium) which have much higher toxic and radioactive properties, and can make reprocessing difficult and more expensive. Around 8 % of the nuclear power plants operating worldwide currently use reprocessed material (so-called MOX fuel) (OECD-NEA/IAEA 2016).

From a geological point of view, there is adequate potential available to guarantee long-term global supplies of uranium. The current closure of several mines and the reduction of exploration projects is exclusively attributable to temporary economic conditions. However, the development of new mining projects will become increasingly time and cost intensive. Whilst the development of a new deposit in the 1970s took five to seven years on average, the time period required today is fifteen to twenty years (URAM 2014). Nevertheless, more cost-intensive conventional mining methods (open-pit mining, underground mining) are in decline. The so-called in-situ leaching method (ISL) is now the leading uranium production technique, and accounts for a share of 50 %. The average production costs using this method are below 80 USD/kg U (as at: 2018).

Tables 39 to 44 in the Appendix provide an overview of the country-specific production, consumption, reserves and resources of uranium.

Thorium

Thorium is considered by the scientific community to be a potential alternative to uranium. However, it is currently not used for power generation. There are no commercial reactors operating anywhere in the world using thorium as a fuel. Nevertheless, thorium deposits have been discovered and evaluated in recent years as a by-product of the increasing exploration for other elements (uranium, rare earths, phosphate). Thorium is generally three to four times more common in the earth's crust than uranium (approx. 6–10 g/t). More than 6.35 Mt are reported for 2017.

3.6 Deep geothermal energy

Deep geothermal energy is the only geological energy resource which counts as a renewable because the decrease in the geothermal energy available below the earth‘s surface is negligible in relation to human time scales. It is therefore covered separately from the other renewables (Chapter 3.7).

In the year 2017, geothermal power production made a small step forward again: The newly installed electrical capacity worldwideof 644 MW_e (IRENA 2018a) was similar to the amount added in 2016. As in previous years, the additional capacity was largely contributed by Indonesia (306 MW_e) and Turkey (243 MW_e). Leading countries in terms of installed electrical capacity continue to be the USA (2.5 GW_e), followed by Indonesia (1.9 GW_e) and the Philippines (1.9 GW_e). The next countries in the ranking are Turkey, New Zealand, Mexico and Italy, each with approximately 1 GW_e installed capacity. The number of countries generating electricity in geothermal projects has increased for the first time in five years with the addition of Hungary, Honduras, and Chile, bringing it to a total of 27 countries.

The total global installed electrical capacity amounts to 12.9 GW_e[4] (Fig. 3-16). The electrical energy generated with this capacity reached 85 TWh_e, i.e. only a small contribution to total power production, and therefore remains at a low level. The largest part of power supplies, with a share of almost three quarters, continues to be provided by non-renewable energy resources (REN21 2018). As a consequence, CO_2 emissions have grown again by 1.4 % for the first time after stagnating for three years. The increase is attributable amongst other reasons to stable global economic growth (3.7 %) and lower prices for some fossil fuels (REN21 2018).

Unfortunately, no complete data set for 2017 is currently available on all of the countries around the world producing geothermal power. Figure 3-16 provides an overview of the data currently available a table provides an overview in the Appendix (Tab. A-40). The data used is primarily based on information provided by EGEC (2018), IRENA (2018b), REN21 (2018), and Weber (2019, unpublished). In addition to the incomplete data situation, a consistent compilation is made difficult by the fact that some relevant data sources (e.g. REN21 2018) have revised their databases in 2017. Moreover, some data sets were also modified retrospectively.

Geothermal power production accounts for a share of 0.2 % of total power generation within the EU-28, corresponding to 6.5 TWh_e. The installed electrical capacity is slightly higher than 1 GW_e (WEC 2018). As already mentioned previously, Hungary is now among the countries generating power from geothermal sources in 2017. This means that the number of countries in the European Union with geothermal power production has now risen from five (Germany, France, Italy, Austria, Portugal) to six. The power plant in Hungary is a combined power plant, generating power (3 MW_e) as well as heat (7 MW_{th}). Two other combined power plants are also being developed here with capacities in each case of 18 MW_e and 34 MW_{th}. Italy with 916 MW_e continues to be the largest

4 A direct comparison with past years‘ figures is not possible for all countries because of delays in reporting data and/or data publications. Total figures can differ from the sum of the individual figures because of rounding errors. Note in REN21 report: the latest data cannot be compared with those of previous years without further analysis because revisions had to be made in the face of improved and/or modified data and/or technologies (REN21 2018).

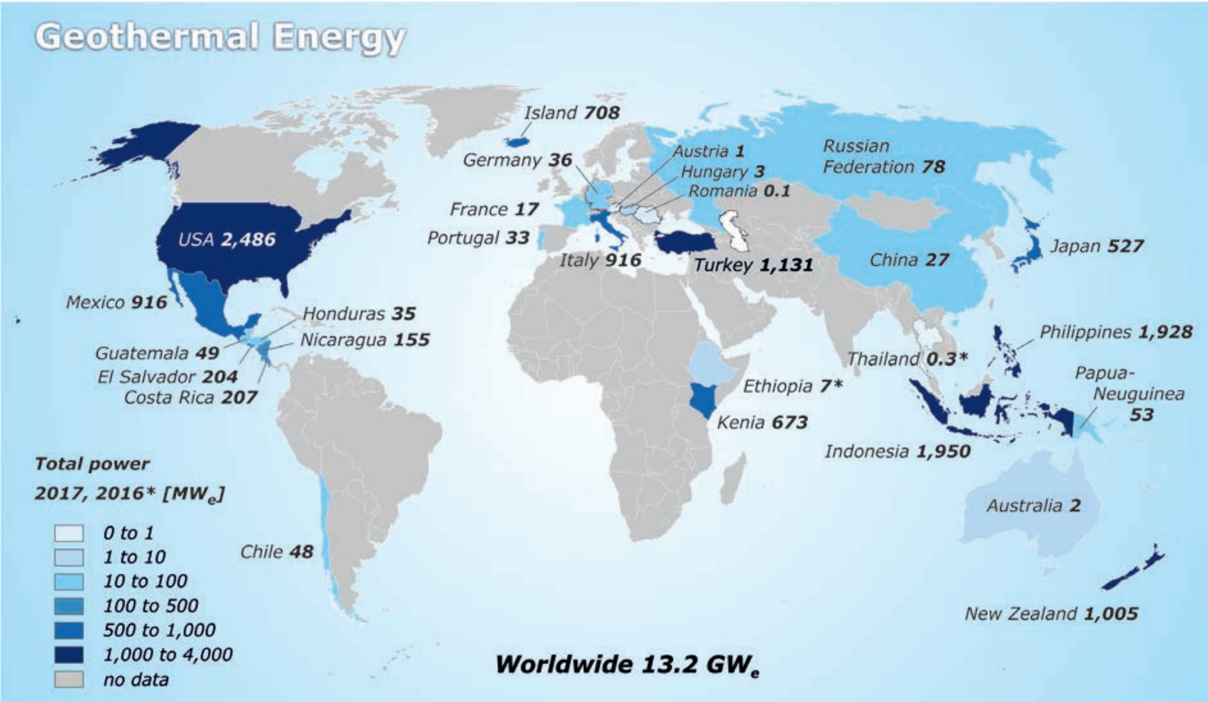

Figure 3-16: Countries using deep geothermal energy for electricity production. Because of the limited data situation for 2017, data from 2016 was used in some cases.

producer of geothermal electricity in the EU-28. Regarding at Europel, – including Turkey and Iceland, the resulting picture is slightly. Because of their favourable geological conditions, both countries, as well as Italy, can use their underground heat more advantageously: Iceland with 708 MW_e, Turkey with 1,131 MW_e. This means that the current installed electrical capacity for Europe as amounts to 2.8 GW_e.

There has been worldwide growth in the use of geothermal heat worldwide. The increase in recent years continued and remained stable at approximately. 6 %. The installed thermal capacity added in 2017 of 1.4 GW_{th} (value excluding heat pumps), resulted a total installed thermal capacity of 25 GW_{th} (REN21 2018). The geothermal heat generated in 2017 totalled 85 TWh_{th}. In addition to the direct use of heat in swimming pools and greenhouses, the heating (and cooling) of buildings is becoming more and more attractive, and has now developed into the largest and fastest growing sector in the geothermal heat utilisation market. Globally, China is the largest user of geothermal heat with 17.9 GW_{th}, including shallow geothermal energy (figures from 2016, WEC 2018). China has also set itself ambitious expansion targets as geothermal energy is considered a potential important contribution to reducing air pollution and protecting water resources (REN21 2018).

In Europe, nine new plants directly utilising heat were commissioned with a capacity of 75 MW_{th} in total. This means that the growth trend seen in recent years in the EU-28 is also continuing in terms of geothermal energy (ThinkGeoEnergy 2018 after EGEC 2018), and has now reached a value of around 3.6 GWh_{th} after a growth in the installed thermal capacity of 2 %. In 2017, the 288 European geothermal plants generated a total heat of 11.7 GWh_{th}, this includes the 198 plants in the EU-28 with direct thermal use of 4.6 GWh_{th} (EGEC 2018).

With respect to an analysis of the overall development, it has to be noted that no comprehensive country data is available worldwide for 2017, neither for heat use nor power generation. A compilation of the available country-specific data on deep geothermal energy is provided in Tables A-40 to A-42 in the Appendix. These tables provide information for each of these countries on the installed capacity (electrical and thermal), consumption (electrical), and theoretical and technical potential[5]. Despite the positive growth reported above, the expansion of geothermal energy can be considered only minor in comparison to its possibilities. The reasons for this include high drilling costs and exploration risks, inhibiting potential investors.

The geothermal sector suffered a setback, not least due to the earthquake in Pohang, South Korea, which occurred at a depth of around 4.5 km in the vicinity of the Pohang EGS location on November 15th, 2018 (Kim et al. 2018a; blue box). There is an ongoing scientific debate on whether the earthquake is the world‘s strongest induced seismicity event involving geothermal energy (e.g. Grigoli et al. 2018, Hainzl et al. 2018; Kim et al. 2018a, Porter et al. 2018). Moreover, with a magnitude of Mw 5.4, it is the second strongest earthquake occurring in South Korea since the beginning of seismic recording four decades ago, and the largest in terms of the damage caused within the last 100 years (Kim et al. 2018b, Porter et al. 2018). Almost 60 geothermally caused earthquakes are currently listed worldwide, corresponding to 8 % of all anthropogenically induced earthquakes (The Human Induced Earthquake Database). The topic of induced seismicity has a strong influence on public acceptance, which is a crucial factor for the successful implementation of new technologies or potential uses of the subsurface. Studies evidence that some of the main reasons for the lack of acceptance of geothermal utilisation include (a) limited understanding of the technology among the general population, the feeling of not being adequately involved in decision making processes, (b) adverse reporting in the media, (c) concerns about the impact on water and induced seismicity (Payera 2018).

Despite these difficulties, the IEA (2018b) promotes the expansion of geothermal energy in the "New Policies Scenario" of its World Energy Outlook. The expansion of installed electrical capacities by around four times by 2040 is required for electrical energy alone. Nevertheless, research and development support for the geothermal energy sector remains low within the EU, even when compared to other renewables (ETIP-DG 2018). This despite the fact that according to IRENA (2017), geothermal energy could make an important contribution, particularly in the district heating sector, to achieve the climate protection objectives.

5 Theoretical potential in the geothermal energy sector is understood to mean the heat of a geothermal reservoir available in a physical sense, and is also referred to as "heat in place". The technical potential refers to the proportion which could be extracted using current technologies.

Experts from three countries were asked to fill in a questionnaire for this Energy Study:

(1) Characteristic figures for geothermal energy as well as geological and geophysical characteristics of the geothermal reservoirs

(2) How would you define perspective and chances of geothermal energy in your country?

(3) What specifical challenges do you perceive for the geothermal energy sector in your country?

(4) How would you describe public acceptance of geothermal energy in your country?

REPUBLIC DJIBOUTI

Dr. Kayad Moussa

Directeur Général
Djiboutian Office for the Development of Geothermal Energy (ODDEG)

zu (1) The République de Djibouti is located in a particularly favourable geological environment for geothermal energy as the Oceanic spreading ridge of the Gulf of Aden penetrates the African continent through the Gulf of Tadjourah. As a consequence rather high heat-flows are encountered all along the Gulf and at Asal-Ghoubbet, where the spreading segment emerges. The regional geodynamics extends in the western half of the République, where the Afar tectonic and volcanic activity allows for several hydrothermal sites (steam leaking) to develop. Geothermal reservoirs are favoured by the distensive tectonics (open fissures and normal faults), and block rotation in this contex, also influences by the junction with the two other rifts: East African Rift Valley (EARV) to the south-west and Red Sea to the North.

zu (2) Geothermal perspectives are very high, particularly along the Gulf of Tadjourah and its western extension inland as temperatures of 180°C are found at less than 1,000 m depth, and 350 °C at 2,000 m depth, allowing for economic electric production, also due to the fractured-stimulated permeability of the reservoirs. The geothermal potential could cover the local needs of the population and developing services (as port for Ethiopia and regional hub), but also attract energy-intensive industry that could benefit here from an affordable renewable energy source, serving the base load with a climate friendly option.

zu (3) We still lack training of the local staff, equipment and software for exploration and data processing, transfer of know-how from experts with solid geothermal background and knowledge of the specific geological characteristics of the region. We also need to improve the legal and administrative environment in order to attract foreign investors and industries.

zu (4) Public acceptance is really high. The problem is not the acceptance of the public but the capacity of the producer to demonstrate its capability, as for 50 years geothermal energy as searched for, but not yet produced. The expectation is high!

Level of exploittation in Djibouti:

Djibouti is a relatively small country with a population of less than one Million people, but located in a key position in eastern Africa, in a close vicinity with Arabia, well deserved by marine routes of the Red Sea and Gulf of Aden, ensuring the link between the Mediterranean and the Indian Ocean parts of the world. It acts as the major port for its neighbour Ethiopia worth 100 Million inhabitants.

In terms of energy, for long, it has relied upon imported fuels. However, considering the global climate issue – hitting the region with increasing draughts – and despite its moderate contribution to Greenhouse Gas Emissions, the Government of Djibouti defined a "Vision 2035" in which an objective of 100 % renewable energy production was defined. This implies to rely upon the various natural resources available including Wind, Solar and Geothermal.

This is the reason why the President of the Republic of Djibouti decided in 2014 to establish a specialized public entity called ODDEG (for Djiboutian Office for the Development of Geothermal Energy), which is hosting the present meeting.

Since ODDEG was created, it was staffed, provided with large office facilities and a significant budget. ODDEG developed a strategy, a pluri-annual work plan and a procedure manual. A data bank was also established with a description of more than 20 identified geothermal sites in Djibouti. With the different project ongoing, (below) in Djibouti we expect to connect the first MWe from geothermal the next three years.

It is on feasibility stage on four at four sites:

- *Asal Fiale (high enthalpy), Financement of three explorations and productions wells is secured and drilling should start and June 2018;*
- *Asal Galla le Koma (medium enthalpy), Financement of eight explorations and productions wells and two injections wells are secured and drilling should start September 2018;*
- *Hanlé (medium enthalpy) Financement of three explorations and productions wells are secured and drilling will start September 2020;*
- *PK20 Ambado(medium enthalpy). Financement of one exploration and production well is secured and drilling will start September 2018.*

It is on prefeasibility stage on five sites:
Arta, North Ghoubbet, Abhe, Sakalol, Dimbir Dirir, Assal West.

There are altogether 22 sites identified (16 others at reconnaissance stage)

MEXICO

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zu (1) Geothermal systems in Mexico are of convective type. The heat sources are extrusive magmatic bodies arising from the subduction of tectonic plates in the central part of the country (Faja Volcánica Transmexicana) and the extensional domains (pull-apart-basin) around the Baja California peninsula.

zu (2) Changes are currently taking place in the Mexican energy sector (Reforma Energética) associated with the government's aims for environmentally-friendly energy production. A number of incentives are offered by a special law (Ley de Energía Geotérmica), which provide investors with legal assurance, and give rise to a boost to research by the Mexican Geothermal Energy Innovation Centre (CeMIEGeo). In addition, a financing and risk transfer programme is offered with the aim of reducing the exploration risk. This financing mechanism contains steps, which go all the way to the elaboration of a technical road map detailing the challenges and difficulties presented by the sustainable use of geothermal energy. The aforementioned activities as a whole, favour the conditions for creating new investment opportunities in terms of sustainability in the country's energy sector, and for increasing the currently installed power generation capacities from geothermal resources in the medium term

zu (3) The relatively low electricity prices for solar and wind technology projects, which are the winners in the electricity auctions in the Mexican electricity trading market, hinder the competitiveness of geothermal projects because of the cost-intensive early phases. This barrier represents a market risk, which is considered to be higher than the technical risk. Hence, there is a large challenge in creating the ideal mechanisms to establish a market for geothermal energy). However, with the implementation of the Mexican Geothermal Financing Programme, an extremely competitive level of generation costs can be achieved, which may provide the possibility to compete at the current reference costs for combined heat and power plants. This opens up theopportunity for a stronger integration of geothermal projects in the country.

zu (4) Public awareness and acceptance of projects of this kind is high in the vicinity of projects, in which the developers have integrated the surrounding communities. However, acceptance is currently low for exploration projects in areas with geothermal potential]; mainly due to the lack of publicness of geothermal energy. However, it is expected that community acceptance can be easily increased in the future through specific information campaigns and implementing further projects on direct use of geothermal energy.

REPUBLIC KOREA

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zu (1) Located far away from any active plate boundary and lack of modern active volcanoes, high-temperature geothermal resources at shallow subsurface are not available in Korea. This led developers to consider drilling deep wells to depths of about 4 km to 5 km to explore geothermal potentials. Thus, areas for potential geothermal exploitations in Korea are distributed over larger areas including a few offshore islands.

zu (2) The Pohang enhanced geothermal site (EGS) was the only development for large-scale commercial usage of geothermal energy in Korea. In the early stage of the development, it was favoured by the public as an alternative renewable energy resource. After the most damaging earthquake in modern Korean history, i.e. the magnitude 5.4 earthquake in Pohang, local residents expressed their concerns on the potential relationship between the EGS activity and the high rate of induced seismicity. Apparently, the Pohang EGS example will setup a high standard in technology and environmental concerns for future geothermal development in Korea

zu (3) Due to lack of active tectonics and active volcanic activities in the vicinity areas, geothermal energy development in Korea will most likely focus on "non-conventional" approaches. Specific challenges for the geothermal energy development in Korea will mainly be, but are not limited to (1) the establishment of bridges between scientific community and general for modern energy related issues through education, newspapers, and TVs, (2) the identification of ideal sites with a close system to provide a completed cycle of water circulation while minimizing hazard and environmental impacts, (3) the lack of well-trained high level professionals in geothermal exploration, drilling, and management, (4) the lack of experience to establish guidance from government level to regulate geothermal development, and (5) the high cost of drilling and continuous maintenance. Therefore, the geothermal development for energy in Korea is still in its beginning stage. So far, the biggest setback in the geothermal energy sector in Korea is the potential of induced earthquakes and their implications on seismic hazard and environmental impacts from the EGS activity. Lessons we have learned from the Pohang geothermal development program will shed a light to establish better guidance and regulations for future geothermal development in Korea.

zu (4) Although Korean government has not officially acknowledged the Pohang earthquake sequence as induced activities potentially by the EGS activity, most local residents have a lot of speculations from news reports in newspapers and on TVs. Since the Pohang earthquake is the most damaging earthquake in modern Korean history, public support for geothermal development has been dramatically declined and most local governments have withdrawn their support for local geothermal development. The failure of the Pohang EGS for commercial development and lack of interactions among the public, local- and central-governments and EGS developers made it extremely difficult for future EGS development in Korea.

Level of exploitation of the Republic of Korea

Before the 2017 November 15 earthquake (local magnitude 5.4) in the Pohang area of southeastern Korea, there was an extensive research and development in the region for geothermal energy, although most people were not aware of its pros and cons. A few local governments have also examined the business potential for exploring and using geothermal energy. After the damaging earthquakes with magnitude 5.4 and its aftershocks, most plans are abandoned.

3.7 Renewables

At the end of 2015, the international community initiated an internationally binding climate treaty at the UN Climate Conference in Paris, with the intention of restricting global warming to a level well below 2 °C (UNFCCC 2015). This treaty only comes into force if ratified by at least 55 countries which are responsible in total for at least 55 % of total global greenhouse gas emissions. After ratification by the USA[6] and China on 3 September 2016, as well as the European Union (including Germany), Canada and Nepal on 5 October 2016 (UNFCCC 2018), the conditions were satisfied for the treaty to come into force on 4 November 2016. The treaty has currently been ratified by 169 countries (as at: November 2018). The energy transition with an expansion of renewable energy as the central energy resource, and other accompanying measures, is indispensable to achieve the targets formulated in the Paris Treaty.

Around 18 % of global primary energy consumption in 2017 was covered by renewable energy (Fig. 3-2 PEC WORLD). Over half is provided by biogenic energy resources of which the main proportion accounting for around 60 % is solid biomass, and particularly firewood. In developing countries in particular, the production of energy still primarily involves the use of wood and charcoal. However, in industrial countries as well, there is a rise in the number of privately used systems such as wood stoves and pellet heating systems for the generation of heat. After biomass, hydroelectric power is another "classic" renewable energy resource, and accounts for a share of around 6.4 % of global primary energy consumption, and is therefore the second most important renewable. "Modern" renewables such as solar power and windpower still only cover around 1.7 % of global primary energy consumption. However, their expansion has enjoyed the highest growth rates in recent years.

As in the previous year, the newly installed power generation capacities around the world were primarily associated with additional renewable power capacities. Their share in 2017 was around 70 % (2016: 63 %). This means that the annual increase in renewables was higher than the increase in fossil fuels for power generation. One reason is the political frameworks in many countries which favour the expansion of renewables. Another reason is that the technology costs − for solar power and windpower in particular − have sunk significantly in recent years, to improve the competitiveness of renewables. Photovoltaics in particular dominated the installation of new power generation capacities in 2017. Around 55 % of the new capacities for renewables came from the addition of 98 GW in photovoltaic plant capacity. This corresponds roughly to the net nominal capacity of conventional power plants in Germany of 103 GW (BNetzA 2018b). Half of the photovoltaic installations were installed in China alone. With the addition of 53 GW installed capacity in China in 2017, they added more photovoltaic capacity than was added around the world in total in 2015. In terms of windpower and hydroelectric power, additional capacities of 52 GW and 19 GW respectively were added in 2017.

6 President Donald Trump in the USA announced in June 2017 that the country would withdraw from the Paris ClimateTreaty. However, the withdrawal of the USA from the Treaty cannot come into force until 2020.

Investments in new projects have also grown year-on-year, rising to USD 279.8 billion in total (USD 274 billion in 2016) (REN21 2018). Investments in emerging economies and developing countries with a share of 67 % of total investment greatly exceeded that in early industrialised countries. The dominant factor here is investment in the Chinese market which accounts for around 45 % of global capital investment in renewables. Chinese investment in new projects, primarily photovoltaics and windpower, rose from around USD 97 billion in 2016 to USD 126 billion in 2017. Investments in early industrialised countries, however, such as the USA, Japan and EU countries declined by 18 % despite the enormous addition of capacities. This is attributable on the one hand to a decline in the growth of demand for power in some countries, significant already existing potential, or prioritising the integration of existing renewable capacities within the grid (REN 21 2018). Another reason for the slump in the investment figures is a consequence of the globally growing market for renewables. The lower development costs and ever more effective production processes lead to generally declining technology costs, and therefore ultimately also to lower costs for the investment in capital goods.

The global capacity for power generation from renewables is around 2,179 GW (Fig. 3-17). Compared to this, around 420 GW (gross) was available globally from nuclear power in 2017. The dominant renewable for power generation with around 1,270 GW of installed capacity (around 58 %) is hydroelectric power, followed by windpower (513 GW, 23 %), and photovoltaics (385 GW; 17 %). China leads the world with over one quarter of the globally installed capacity for renewables (619 GW). 341 GW of this are accounted for in China by hydroelectric power alone and another 164 GW by windpower. Another 471 GW renewables capacity are installed in the USA (230 GW), Brazil (128 GW) and Germany (113 GW). These four countries account for almost half the globally installed capacity for renewable energy (Tab. A-44 in the Appendix).

With over 48 GW of installed photovoltaic power generation capacity, Germany is one of the three market dominating countries worldwide. New capacities totalling 1.7 GW were installed in 2017. The market leader is still China, however, with over 130 GW installed capacity. Additional capacities of 53 GW were installed there in 2017. Japan follows China with the highest installed capacity totalling 49 GW. These four countries account for over 57 % of the globally available capacities for solar power. The globally installed capacity for photovoltaic power generation rose by 32 % year-on-year to 386 GW (2016: 292 GW).

The expansion of windpower and photovoltaics is powering ahead. Nevertheless, power generation from these sources is still relatively low. Although the total share of renewables in global power generation is already 26.5 % (2016: 24.5 %), hydropower is the dominant renewable accounting for around 16.4 % of this figure (around 60 % of power generation from renewables). Windpower (5.6 %), biomass (2.2 %) and photovoltaics (1.9 %) together accounted for 10 % of power generation in 2016 (REN21 2018). Unlike the global power generation from renewables which is dominated by hydropower, over half of the electricity generated by renewables in Germany came from windpower (106.6 billion kWh; 16.3 % of the German power mix) and biomass (51.4 billion kWh; 8 % of the German power mix) (Chapter 2.2.).

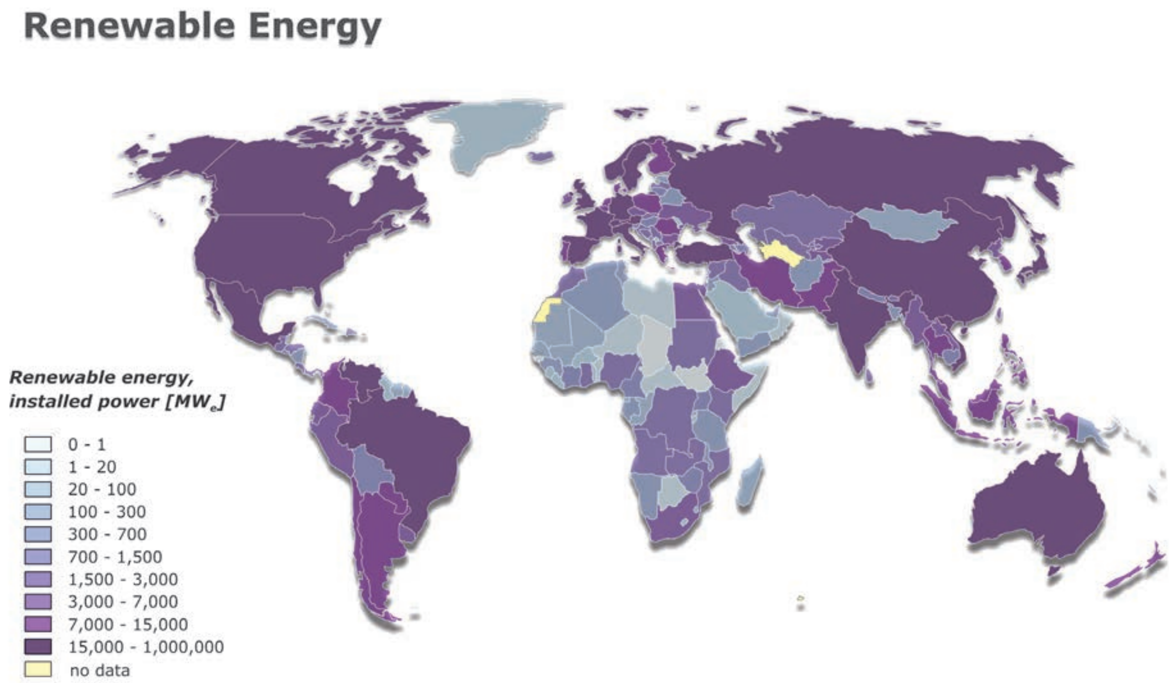

Figure 3-17: Total potential of the installed capacity of renewables for power generation (2,008 GW): regional distribution (IRENA 2018b).

The energy generated by renewables globally is primarily used for the generation of electricity, which is also where the highest capacities were installed (Tab. A-44 in the Appendix). An international comparison (Tab. A-43 in the Appendix) reveals the dominance of China (368 Mtoe), the USA (162 Mtoe), Brazil (106 Mtoe), and Canada (100 Mtoe). Over half of the power production generated by renewables worldwide took place in these four countries (Fig. 3-18).

The expected further expansion of capacities will enable the share of renewables in power generation capacities to grow further in future. In addition to geographical factors, the strategies and targets of countries in particular will be crucial in determining in which direction the expansion of renewables heads in future. Even today, over 20 % of the electricity demand in Denmark, Germany, Ireland, Portugal, Spain and Uruguay is covered by windpower (REN21 2018). 100 % of Iceland‘s electricity needs are covered by renewables (73.1 % hydropower; 26.9 % geothermal energy; 0.4 % windpower) (IEA 2018f). Around 33 % of the demand for electricity in Germany in 2017 was covered by renewables (2016: 29 %) (Chapter 2.2).

Renewable energy resources are also gaining in importance in the mobility and transport sectors in the form of biofuels (ethanol and biodiesel), although at a much slower rate than in the electricity

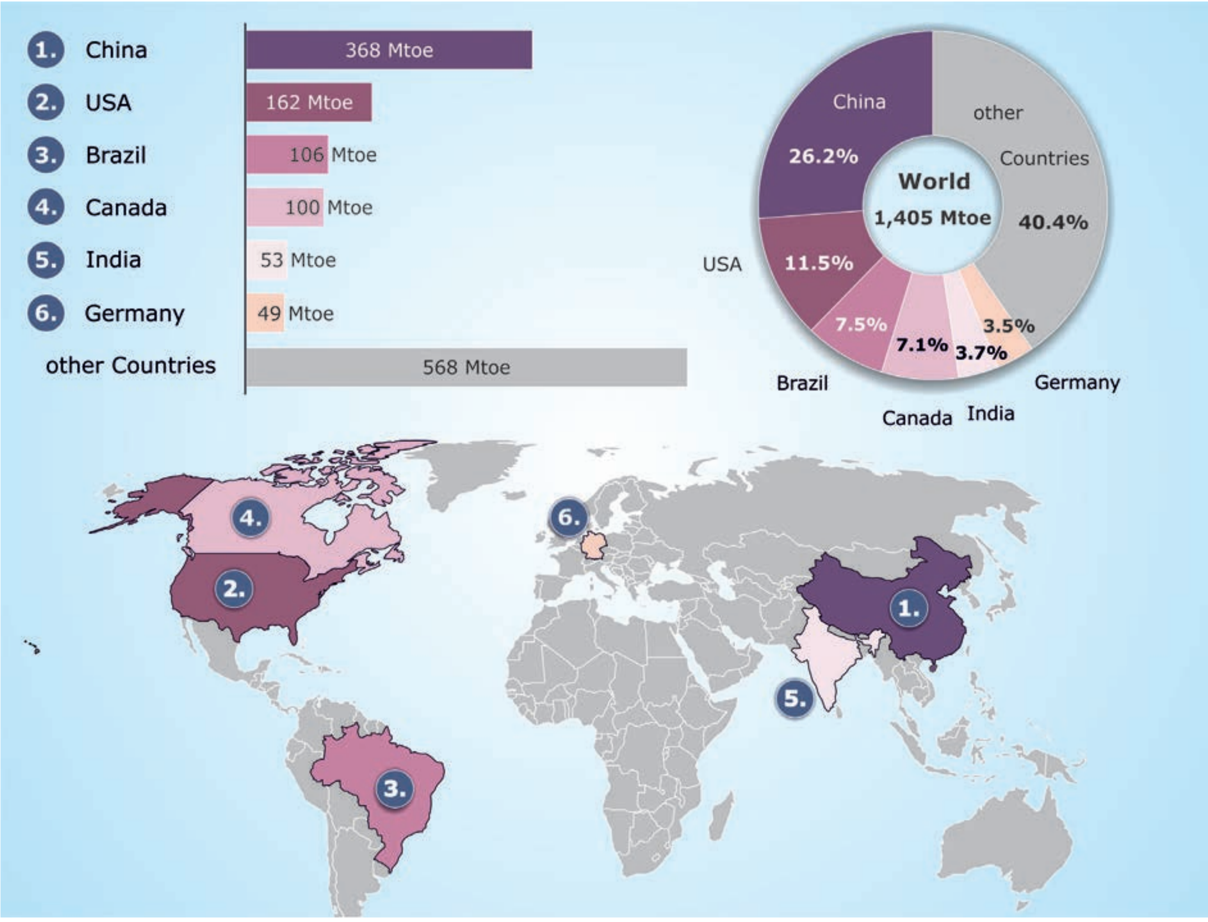

Figure 3-18: The largest users of renewables for electricity generation 2017.

generation sector. Biofuels currently account for 0.9 % of global end energy consumption. Global production in the last 13 years has increased several times over from around 30 billion litres (2004) to around 143 billion litres (2016) (REN21 2018), and a further rise is expected. The leading producers are the USA and Brazil. Over 80 % of ethanol fuels and biodiesel are sourced from these two countries. The integration of e-mobility in the mobility and transport sector including the already globally existing use of rail transport is being further expanded. Norway and China are today's leading countries in the use of e-mobility. Around 3 million electric cars and over 200 million two-wheeled electric vehicles are currently being used worldwide – and the trend is increasing (REN21 2018). Its use in heavy goods vehicles on the roads as well as in ships is also being developed and/or expanded. The share of renewables in transport sector consumption currently accounts for around 3 %.

The production of wood pellets for generating heat rose from around 4 Mt in 2004 to around 28.9 Mt (2016). The main producer regions here are Europe and North America. Whilst only around 2 Mt wood pellets were produced in Europe (EU 28) in 2004, this had already grown to around 14 Mt in

2016 (AEBIOM 2017). Demand in Europe as well as in Asia has grown considerably in recent years (IEA 2015) and can no longer be covered by domestic production. Today‘s biggest exporter is North America. The domestic demand in Germany alone is estimated to be 2.2 Mt/a (2006: 470 kt) (DEPL 2017), although this is increasingly being covered by domestic production.

Tables A-43 to A-44 in the Appendix list the country-specific installed electrical capacities as well as the power consumption from renewables.

4 ENERGY RESOURCES IN FOCUS (SPECIAL TOPIC)

Venezuela's heavy and extra-heavy oilfields in the Orinoco

Venezuela has the largest crude oil reserves in the world. These are primarily located north of the Orinoco, in the so-called Orinoco Heavy Oil Belt, as heavy and extra-heavy crude oil, which is difficult to produce and process. Production in this area has increased continuously since the middle of the 1990s by technical advances in exploration and production technology. This oil currently accounts for around 40 % of total Venezuelan oil production. The development of these fields is driven by joint ventures (so-called Empresa mixtas) with foreign oil companies. The state oil company PdVSA holds a majority share in these Empresa mixtas. The crude oil industry is easily the most important part of the country's economy, accounting for a share of around 25 % of the gross domestic product (OPEC 2018a). Over 82 % of total export revenues in 2016 were generated by the sale of crude oil and crude oil products (Observatory of Economic Complexity 2018). Despite the boost in heavy and ultra-heavy oil production from the Orinoco heavy oil sector, the productivity of the Venezuelan oil industry has declined considerably in the last 20 years. Declines in production and export of crude oil are accelerating rapidly and beginning to have an impact on the production of heavy and ultra-heavy oil..

Petroleum geology of the Orinoco Heavy Oil Belt

The Orinoco Heavy Oil Belt is located in the southern part of the Eastern Venezuelan Basin and covers an area of 55,000 km² (Fig. 4-1). It extends around 600 km east-west and around 90 km north of the Orinoco river (Villarroel 2008).It is the largest contiguous oil accumalation in the world, in addition to the Canadian oil sands. The Orinoco Heavy Oil Belt contains in place reserves of around 1,300 Gt crude oil, primarily in the form of heavy and extra-heavy oil (Villarroel 2008). The Eastern Venezuelan Basin is a foreland basin located south of a fold and thrust belt. It was formed through the west-east collision of the Caribbean Plate with the passive margin of the northern South American Plate which began at the end of the Palaeogene (Schenk et al. 2009).

The most important source rocks of the Orinoco Heavy Oil Belt are Cretaceous marine black shales of the Quarequal and San Antonio formations (Talwani 2002). These were deposited in the northern and central parts of today's Eastern Venezuelan Basin in front of the passive continental margin. The source rocks around Serrania del Interior have a thickness of up to 1,000 m, but wedge out towards the south. The hydrocarbon generation potential continues to be very high with a very high HI index[7] (up to 700 mg hydrocarbon/TOC) and a total organic carbon content (TOC) of up to 8 % (Summa et al. 2003). The source rocks have a complex maturation history. Hydrocarbons began to gernerate in the early Miocene in the area of today's Serrania del Interior as a result of the eastward movement of the Caribbean Plate, and is still active today. Rapid subsidence favoured by orogenic processes enabled an efficient maturation of the source rocks. Because of the absence of traps,

7 HI: Hydrogen index: S2 with respect to grams organic carbon (mg HC/g C_{org}).

large volumes of the hydrocarbons generated were initially lost. By the middle Miocene, however, when the source rock began to mature in the foredeep of the foreland basin, reservoir rocks, seals and migration paths were all present.

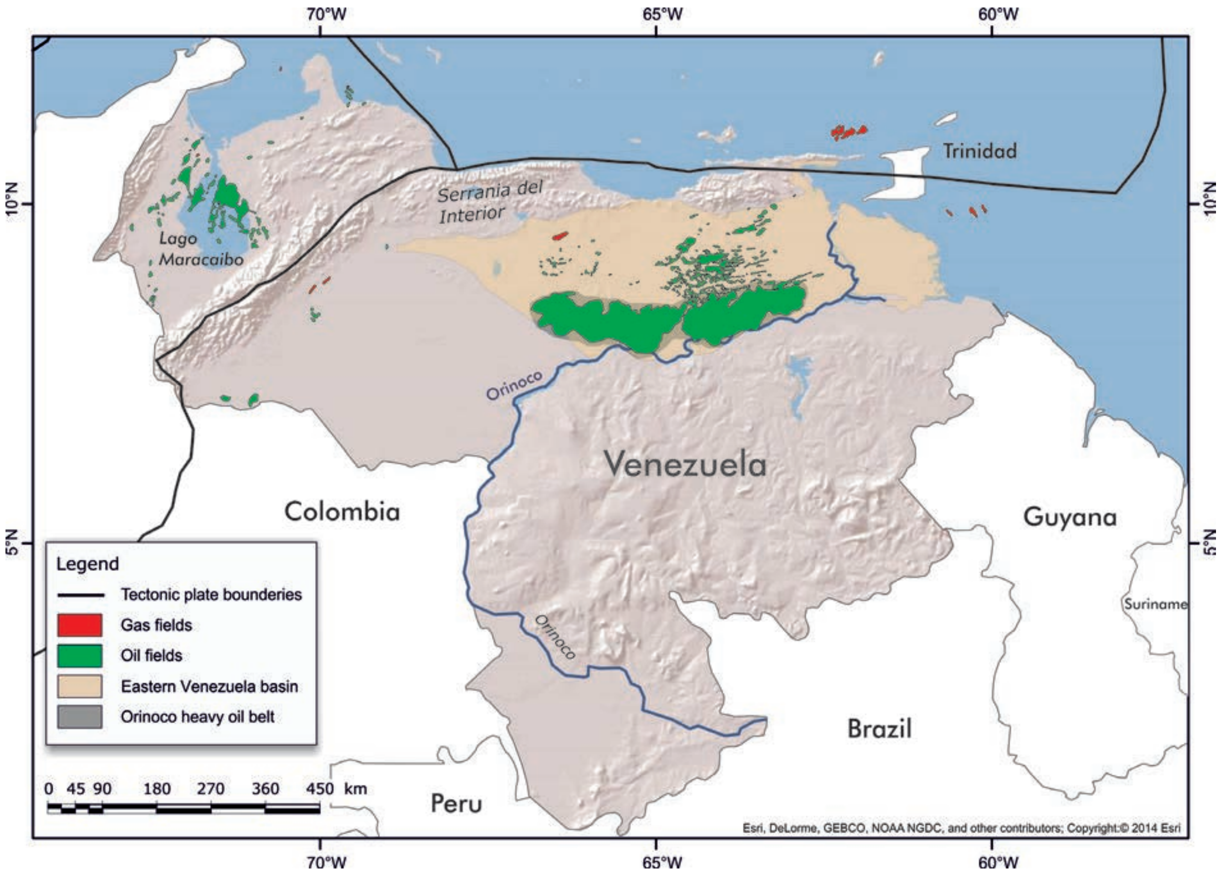

Figure 4-1: Oil and gas fields in Venezuela (modified after Petroleum Economist 2013).

The crude oil generated by the source rocks migrated hundreds of kilometres to the south (Villarroel & Hernández 2013) and accumulated in the southern part of the foreland basin (Schenk et al. 2009; today's Orinoco Heavy Oil Belt (Fig. 4-2). During migration, the crude oil changed as a result of the loss of the volatile hydrocarbons and biodegradation (Villarroel & Hernández 2013), so that its geochemical composition altered. The biodegradation of the crude oil was favoured by the influx of meteoric water into the relatively shallow reservoir rocks. The density and viscosity of the crude oil increases to the south in the direction of the Orinoco river. The heavy and extra-heavy oil has very high concentrations of sulphur and metals because of the loss of the short-chain hydrocarbons (up to four percent respectively more than 500 ppm) (Fiorillo 1987). Fault tectonics beginning 12 million years ago cut the long lateral migration paths (Talawi 2002).

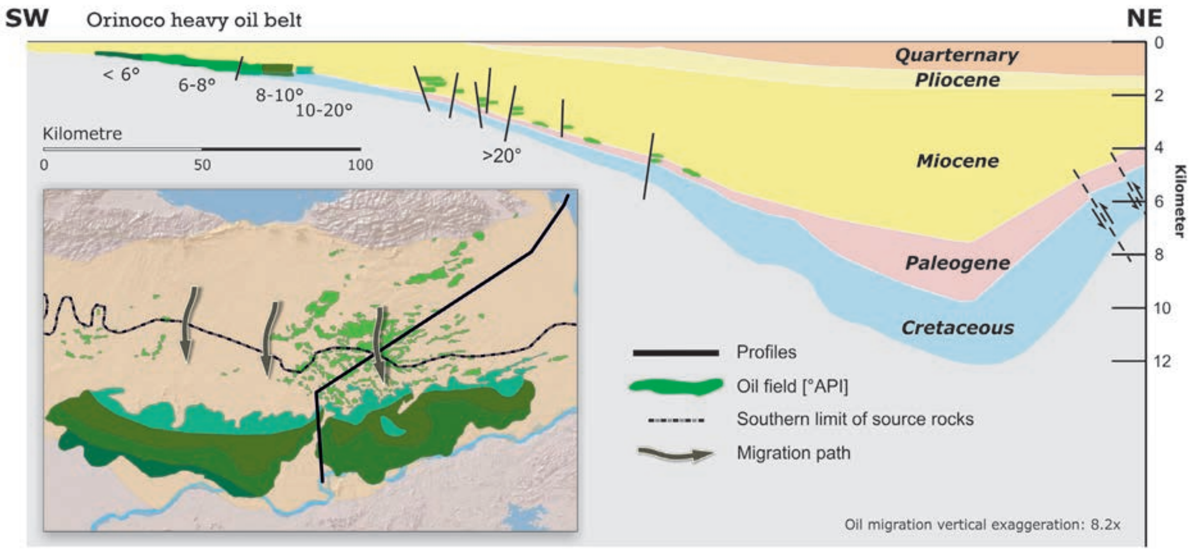

Figure 4-2: Geological cross-section through the East Venezuelan Basin (summarised after Talwani 2002, Petroleum Economist 2013).

The main reservoir rocks of the Orinoco Heavy Oil Belt are fluviatile and marginally-marine sandstones of the Oligocene Merecure Formation and the Miocene Oficina Formation (Fig. 4-3). These consist of a sequence of stacked estuarine and deltaic sedimentary complexes formed by rivers which drained the Guayana shield south of the Orinoco (Talawi 2002). The lower part of the Oficina Formation primarily consists of unconsolidated sand. The main reservoirs are sealed by the claystones of the overlying Carapita Formation (Villarroel & Hernández 2013). The crude oil is trapped in relatively shallow reservoirs with depths of around 250 m in the south and around 1,200 m in the north of the heavy oil belt. Reservoir temperatures rise with increasing depth from 37 °C to 60 °C. Individual reservoir sands are between 6 m to 90 m thick. They have a porosity between 28 % to 34 %, and a permeability of 1 Darcy to over 20 Darcy (Villarroel & Hernández 2013). The API grade of the crude oil[8] in the Orinoco Heavy Oil Belt increases from south to north from less than 6 to over 20, and grades successively from ultra-heavy to heavy oil. The area to the north of the Orinoco Heavy Oil Belt primarily contains heavy oil and medium-heavy crude oil. Crude oil is less biodegraded in the northern part of the Orinoco Heavy Oil Belt and flows betterdue of the higher temperature in the reservoir. Crude production is therefore concentrated in this area.

Despite the high density and relatively high viscosity, the crude oil is largely mobile within the reservoir rocks and can be produced without any additional thermal stimulation (cold production), although the recovery rates are relatively low at between 8 % and 12 %. Higher recovery rates can be achieved using advanced thermal production methods.

8 Classification of crude oil according to °API: light oil (>31.1), medium heavy oil (22.3–31.1), heavy oil (10–22.3), ultra-heavy oil (<10).

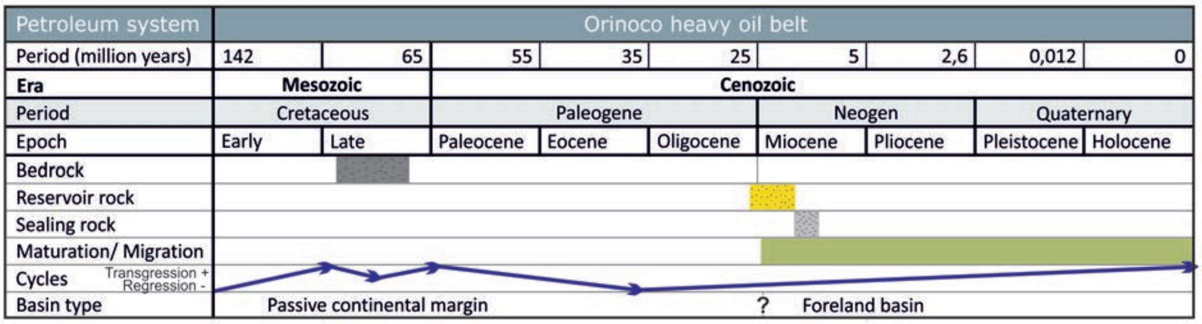

Figure 4-3: Petroleum system of the Orinoco Heavy Oil Belt (generalised after Parnaud et al. 1995).

The largest crude oil reserves in the world

The total crude oil reserves in Venezuela are currently 302 billion barrels or 47.7 Gt (PdVSA 2017a) (Fig. 4-4). Around 90 % or 272 billion barrels of this (around 43.7 Gt) are in the form of heavy and extra-heavy oil from the Orinoco Heavy Oil Belt (PdVSA 2017). Venezuela therefore has the largest crude oil reserves in the world ahead of Saudi Arabia (35.4 Gt) and Canada (26.8 Gt).

The results of an analysis of the Orinoco Heavy Oil Belt from 1978 to 1983 led to the economically producible part of the heavy and ultra-heavy oil being added to the Venezuelan crude oil reserves in the middle of the 1980s. The recovery rates defined for this purpose lay between 8 % and 12 % according to the drilling and production technology (cold production) available at the time (Dusseault 2001, Safinya 2008, PdVSA 2017). The reserves increased significantly between 2007 and 2010 on the basis of a re-evaluation of the belt as part of the Magna Reserva project initiated in 2005. The recovery rate with respect to the in-place reserves is currently at around 21 % (PdVSA 2017, Villarroel 2008). The increase in reserves was justified on the basis of advancements in drilling and production technology, and is considered to be viable in the opinion of BGR. However, only a very small proportion of the extra-heavy oil reserves (0.65 Gt or 1.5 %) have actually been developed for production (PdVSA 2017). So, although the size of the heavy oil and extra-heavy oil reserves in Venezuela (43.7 Gt) are comparable with the conventional crude oil reserves of Saudi Arabia (35.4 Gt), production today is still at a very much lower level because of the much more complex production and processing involved.

From a geological point of view, Venezuela‘s crude oil reserves will rise even higher in future because of the considerable additional hydrocarbon potential in the crude oil province around Lake Maracaibo (Schenk et al. 2017), as well as in the Eastern Venezuelan Basin (Schenk et al. 2009). Moreover, technological advances could further increase the oil recovery in the Orinoco Heavy Oil Belt and therefore could lead to a further transfer of resources into. Venezuela also has significant reserves of natural gas either in the form of associated gas within the oil fields, as well as in the country‘s offshore gas fields.

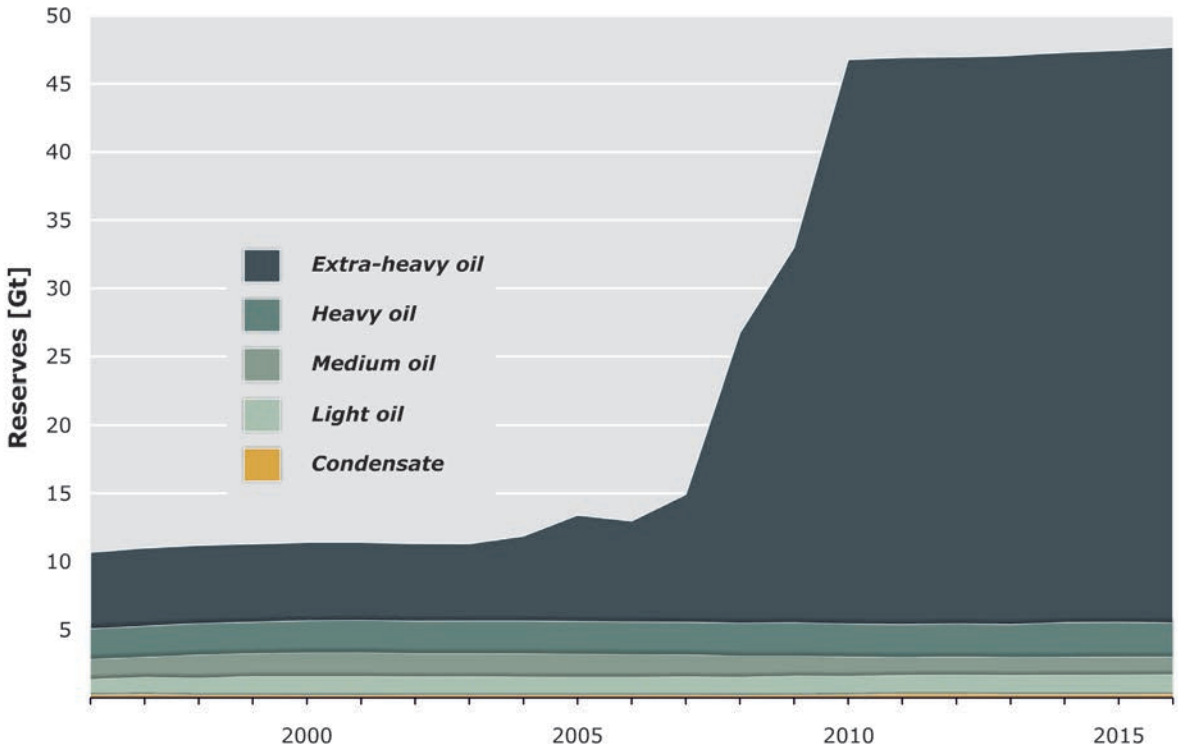

Figure 4-4: Venezuelan crude oil reserves classified after oil types (data: PdVSA 2017).

History of crude oil production

The production history in the country is marked by major downturns and upswings (Fig. 4-8). A production peak was reached in 1970. Crude oil production halved within the following ten years as a result of major declines in production in the traditional oil production areas around Lake Maracaibo in the north-western part of the country, a phase of inadequate investment in exploration lasting many years. The disruptions were caused by the nationalisation of the Venezuelan oil industry from the beginning to the middle of the 1970s. The strong expansion in exploration after the completion of the nationalisation process in 1976 led to numerous new discoveries which enabled production to increase from 1983 to the end of the 1990s. A continuing decline in production in the most important production area around Lake Maracaibo has so far been successfully compensated for to an increasing degree by growth in production of heavy and extra-heavy oil in the Orinoco Heavy Oil Belt. In 2016, the production of heavy and extra-heavy oil in the Orinoco Heavy Oil Belt already accounted for 40 per cent of total production in the country (Fig. 4-5). Around one quarter of the total production comes from the production area around Lake Maracaibo, and more than 30 % from the fields in the northern Orinoco Heavy Oil Belt. The remainder comes from other regions within the country. Crude oil production has declined significantly in Venezuela since 2015. Whilst more than 2.3 million barrels a day were produced on average in 2016, this sank to 1.2 million barrels per day in September 2018 (OPEC 2018b). This major decline in production is a consequence of the failure to invest adequately in the oil sector over a period of many years.

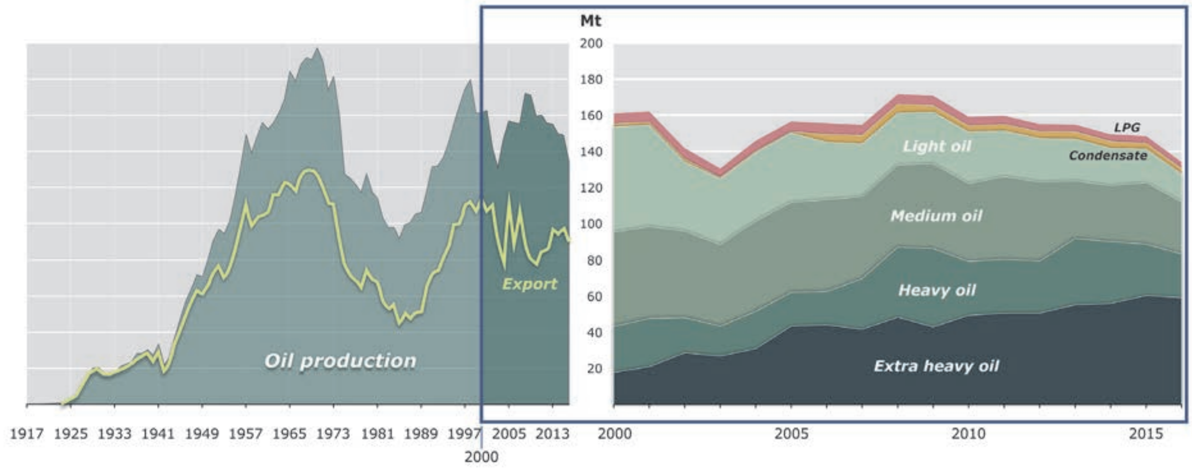

Figure 4-5: Venezuelan crude oil production to 2016 (BGR database, PdVSA 2017).

Outlook

Maintaining and expanding oil production is primarily dependent on future investment in the oil sector. In the past, co-operation with foreign oil companies and service providers led to a boost in oil production and processing, and particularly the production of heavy and extra-heavy oil in the Orinoco Heavy Oil Belt. The expansion of oil production in the Orinoco Heavy Oil Belt and the processing of the heavy and extra-heavy oil to high-quality syncrude, is vital for Venezuela because the income from petroleum exports in the years to come will probably continue to be the most important source of the country‘s revenue by far. It is difficult to estimate which measures will actually be implemented in the oil sector in the future, and what influence the implementation of the El Petro cryptocurrency will have against the background of the overall critical situation in the country. History has shown that for instance a complete nationalisation of the Empresa mixtas, all the way to the successive take-over of parts of the oil industry by foreign companies, is possible.

Extra-heavy oil is unconventional crude oil which has lost the light hydrocarbon fractions as a result of biodegradation. This oil therefore has a high concentration of heavy residues such as asphalt and wax. It has a high density (< 10° API) and viscosity (between 1,000–5,000 cP), as well as a high proportion of sulphur and metals compared to conventional crude oil. Extra-heavy oil differs from natural bitumen by lower viscosity, which makes the crude oil mobile in the reservoir. Extra-heavy oil is technically much more complex to produce than conventional crude oil, and the refinery products have a relatively low proportion of high-value distillates, as well as a higher proportion of residues, because of the composition of the crude oil. Nevertheless, the use of upstream processing (upgrading) makes it possible to produce high quality syncrude and refinery products.

5 FUTURE AVAILABILITY OF FOSSIL ENERGY RESOURCES AND DEEP GEOTHERMAL ENERGY

5.1 Supply situation and future demand

The reliable and uninterrupted provision of energy is essential for the proper functioning of our modern societies today. Global energy supplies are characterised by continuous change, and renewable energy is an integral part of energy supplies. There are even countries today which can already cover most of their energy requirements from renewables. From a global point of view, however, these are still only special cases which enjoy special geological or climatic conditions for instance. Making the almost inexhaustible potential of renewable energy available when it is needed and where it is needed in accordance with demand, is therefore one of the key challenges facing future energy supplies. Many industrial countries, and particularly developing countries and emerging economies, with their foreseeable rising energy needs, therefore primarily continue to include crude oil, natural gas, coal and nuclear power in their future energy mixes, in addition to solar power, windpower and geothermal energy.

This study analyses the global capacities and potential for energy and energy resources. The main focus continues to be the provision of information on non-renewable energy resources. The quantities in which they can be extracted and consumed in future are dependent on many factors, and only foreseeable to a limited extent. The projected consumption of these energy resources until 2040 according to the IEA's New Policies Scenario (2018b) can be used as the basis for the long-term comparison of supply and demand (Fig. 5-1). This reveals a comfortable situation from a geological point of view for the energy resources uranium, coal and natural gas, because the projected

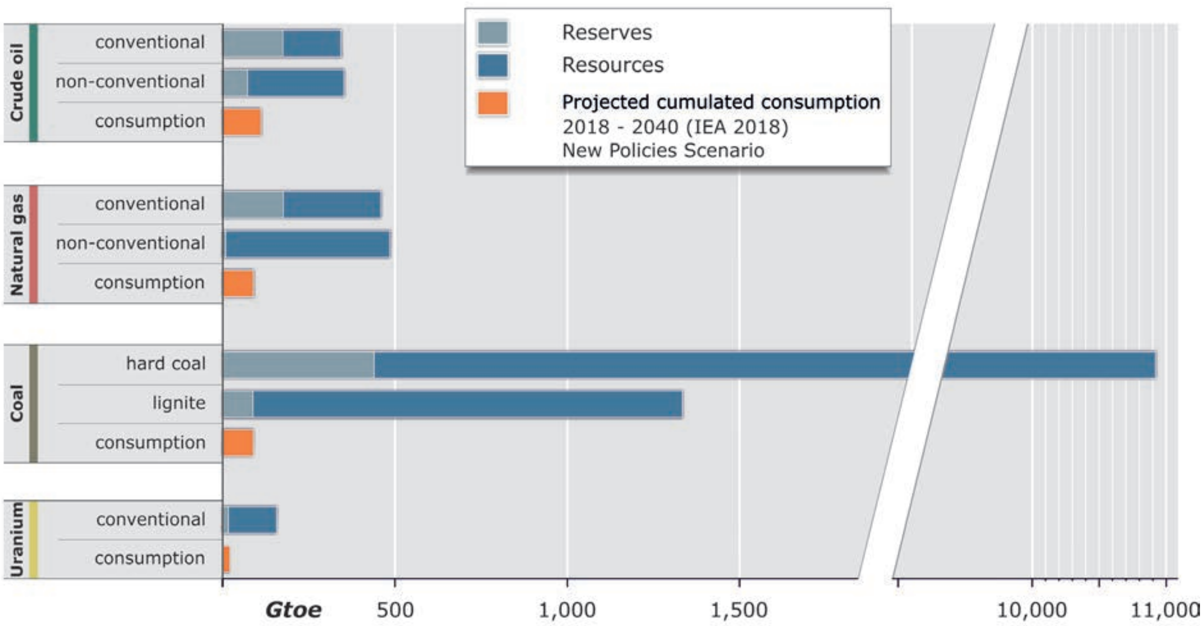

Figure 5-1: Supply situation for non-renewable energy resources end 2017.

demand only encompasses a small proportion of the currently known natural resource inventories, and can even be covered solely from today's known reserves. Coal in particular stands out with reserves which far exceed the demand. And the comprehensive level of resources (compared to the reserves) indicates that large and so far unexploited potential exists which could be reclassified as economically extractable reserves. Unconventional hydrocarbon deposits in particular underpin the relatively comfortable supply situation. However, the resource figures also include numbers on energy resources which cannot yet be exploited economically, such as the production of crude oil from oil shales, natural gas in aquifers and from gas hydrates. Their potential is also incorporated in the analysis independent of whether and to what extent they can be economically exploited in the foreseeable future. According to the information currently available, the only energy resource with restricted future availability from a geological point of view is crude oil. According to the IEA scenario, around half of the crude oil reserves identified today will have been consumed by 2040.

This study cannot answer the question of which natural resources will be used in which quantities and under which conditions in future. Answers to these questions need to be sought elsewhere, particularly against the background of the targets involved in the German energy transition and the agreed international climate treaty.

5.2 Summary and outlook

Crude oil

Crude oil continues to be the most important primary energy resource around the world. Both the production of crude oil as well as its consumption rose to a new all-time high. The global reserves situation remains largely unchanged. The global demand for petroleum products will probably also continue to rise in the next decades as well. China overtook the USA for the first time as the biggest crude oil importer in the reporting year. The USA still remains dependent on crude oil imports despite the fact that shale oil production in the USA reached a new record high during the past year, and will probably rise further in the medium term. Although all countries require petroleum products, a high market concentration exists in terms of production as well as exports. The ten largest oil producing countries alone cover around 70 % of the production, whilst the five biggest exporters account for around one half of all exports. The price of crude oil rose by around 25 % year-on-year. From a geological point of view, supplies of crude oil can be maintained even in the face of a continued moderate rise in consumption. Nevertheless, supply shortages cannot be excluded in the medium term because investments in the crude oil sector have stuck at a relatively low level for several years now, and there are indications that a demand-supply deficit could occur as a result of the inadequate development of new fields and the continuing low number of new discoveries. As one of the largest petroleum consumers in the future as well, Europe, and Germany in particular, are confronted with a declining trend in their own domestic production. Crude oil still lacks any replacement for its leading role as an energy and basic resource. The high dependence on crude oil imports could become critical against the background of a possible demand-supply deficit occurring in the medium term.

Natural gas

Natural gas continued to be the world‘s third largest energy resource behind crude oil and coal in 2017 with respect to primary energy demand. After a minor increase in the previous year of around 1.4 %, global natural gas demand rose by around 3 % in 2017. A tangible rise in the global natural gas consumption is expected in the medium to long term as well. Because of the high remaining natural gas potential, this resource will be able to supply global needs for many decades to come. Global natural gas reserves have risen slightly compared to the previous year. As in previous years, this enabled the natural gas produced in 2017 to be completely compensated for by additions to the reserves. Global natural gas trading increased further in 2017. Despite the price difference to pipeline natural gas, the global natural gas markets are growing closer together because of the generous supply of LNG. 40 importing countries are now supplied by 19 exporting countries. As in the previous year, the largest increase in LNG exports is reported by the USA (plus 13 billion m^3), and Australia (plus 16 billion m^3). Germany and Europe are connected to a significant proportion of global natural gas reserves via their integrated and growing supply grids involving pipelines as well as LNG receiving terminals, and are therefore relatively secure. This means that geopolitical risks in particular continue to be a key factor for natural gas supplies. There are currently 24 large LNG receiving terminals in the EU which are under operation, and another 12 terminals are in the planning phase. The construction of a terminal in Germany is also under discussion. The total regasification capacity of the 24 EU facilities in 2017 was 206 billion m^3, which corresponds to around 40 % of the natural gas consumption in the EU. However, the average capacity utilisation of the European LNG terminals was only around 25 %. This means that Europe could already satisfy a much larger proportion of its natural gas needs via LNG imports.

Coal

Coal production around the world grew again in 2017 for the first time in three years. It rose year-on-year by around 3.5 % to total around 7,566 Mt in 2017. Global coal reserves rose slightly compared to the previous year. The global reserves of hard coal and lignite will be able to cover demand for many decades to come from a geological point of view. Global trading in hard coal experienced a major upswing compared to the previous year with a growth of almost 5 %. As in previous years, the significance of the Pacific market remains high in terms of its share of global coal imports (Asia: 74 %). China is easily the largest hard coal producer and consumer, not to mention being the world‘s largest hard coal importer since 2011, closely followed by India and Japan. In 2016, and therefore much earlier than previously forecast, India had already overtaken the USA as the second largest coal producer worldwide. Despite a strong growth in US-American coal production in 2017, India retained its number two position in the ranking. The ranking is unlikely to change much in the years to come given the large production growth in India in 2018, and the Indian government‘s production target of 1.5 Gt (hard coal and lignite) set for the middle of the 2020s.

As in previous years, the development of global and therefore also European coal prices is largely determined by the current situation in Asia, and primarily in China. The foreseeable expansion of Chinese and Indian coal production, accompanied by a slight decline in imports to both countries, could well lead to a decrease in pressure on prices on the world coal market in the medium term. A decline in hard coal demand in the coming decades is expected in Europe in particular. However, global hard coal demand will most likely hardly shrink at all because a significant rise in demand is expected in Southeast Asia in particular (IEA 2018b). Against the background of the stable global hard coal demand, as well as lower investments in new coal projects (export mines), and the increasing depletion of producing mines, there will probably not be any change in the trend of volatile coal prices in the short term − subject to the reservation of a possible global recession occurring as a consequence of the expanding trade conflict between the USA and China.

Nuclear fuels

The global reserves for uranium are very comprehensive. From a geological point of view, no shortage in supplies of nuclear fuels is expected in the foreseeable future. However, the uranium market continues to be dominated by relatively low spot market prices which jeopardise the economic viability of various mines and exploration projects. The current reduction in uranium production compared to the previous year is primarily attributable to the current recession in the uranium market. Regulatory measures, such as the reduction or shut-down of production in market-dominating production sites as well, could increase further in the near future. In this context, Kazakhstan − easily the largest uranium-producing country − will throttle its production further. The production in some mines in Canada and Namibia is to be shut down completely for a temporary period. The aim of the cutback in production is to boost uranium prices on the world market.

However, growth in production is expected again in the medium term against the background of a foreseeable rise in the global demand. Whilst the demand in Europe and North America will probably decrease in future because a significant number of reactors will reach the end of their operating periods by 2030, a rise in uranium consumption is expected in emerging economies and developing countries in the Asia and Middle Eastern regions in particular. 56 reactors are currently under construction worldwide, 40 of them in Asia alone. The growing energy demand in Asia has already led to an expansion in nuclear power in the past, particularly in China, Japan, India and South Korea. This will also spread to other Asian countries in the future. Nuclear power will also play a larger role in the Middle East in future. In addition to Iran and the United Arab Emirates, Saudi Arabia and Jordan will probably integrate nuclear power within their national energy mixes within the next few years.

Deep geothermal energy

Despite the major potential, the use of geothermal energy in Germany, Europe, and the rest of the world is only developing slowly. Deep geothermal energy faces many challenges, including uncertainties in predicting the main underground parameters required for successful geothermal energy projects, exploration risks, and significant maintenance costs. Nevertheless, EGEC (2017) is confident that the installed capacity in Europe will rise from the current level of around 2.5 GW_e to 3 GW_e by 2020. However, this will involve a much more intense effort in the short term than has been the case in the past few years. After the almost exponential growth in the utilisation of direct heat in Germany in the past ten years, the installed thermal capacity declined slightly compared to the previous year by 3 MW_{th} to around 374 MW_{th} in 2017. The installed electrical capacity also cecreased slightly by 2 MW_e over the same time period to its current level of 36.2 MW_e. The amount of electrical energy produced sank slightly by almost 15 GWh_e to around 160 GWh_e whilst the thermal production grew by 24 GWh_{th} to 1377 GWh_{th}. It is not possible to determine whether this represents a changing trend or merely a temporary pause. The development of deep geothermal energy worldwide is also less than dynamic. The USA continues to lead the world in the production of electricity from deep geothermal energy, followed by the Philippines and Indonesia. Year-on-year growth of 6 % occurred in 2017 in the global use of deep geothermal energy for heat. The largest user is China, followed by Turkey, Japan and Iceland. If deep geothermal energy is to occupy a more prominent position in the energy mix in the future, this will not only require more intense research at a national and international level, but also the continuous further building of mutual trust amongst the general public, operators, and politics.

Renewables

The proportion of renewables rose further in 2017 especially for power generation. Photovoltaics in particular again boasted the largest growth rates worldwide for the first time in terms of the expansion of renewable energy resources. The global installed capacity for power generation today totals 2,179 GW_e. Increased investment has been made here in developing countries and emerging economies in particular. The global volume of financial investments in renewables has risen in the past ten years from 113 billion USD/a to over 265 billion USD/a, whereby almost half (47 %) of all investments in renewables is accounted for by China. Here, capital expenditure is particularly directed at photovoltaics and windpower, which also reflects the global trend. Further expansion here is expected around the world as well in future, not to mention in all other areas of energy supply, associated with the development of significant new markets in Africa, Asia and Latin America. 179 countries have now formulated targets for the expansion of renewables. Technological advances, investments and the expansion of capacity will further increase the global influence of renewables, particularly in the electricity sector, as well as their influence in the thermal and transport sectors in the medium term. The major challenge is the discrepancy between the available potential and the actual output generated by renewables, so that only around 18 % of global primary energy consumption has so far been covered by renewable energy to date. The limiting factors continue to be the restricted technical effectiveness (efficiency), availability (storage technology) as well as the integration of renewables into existing global energy markets (infrastructure, investment, economic efficiency, and acceptance).

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APPENDIX

- Tables
- Sources
- Glossary / List of abbreviations
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- Ecconomic country groupings of the BGR energy study
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Table A-1: Reserves of non-renewable fuels 2017: Regional distribution [EJ]

Region	Crude oil		Natural gas		Coal		Uranium	Total	Share [%]
	conven-tional	non-conven-tional	conven-tional [1)]	non-conven-tional	Hard coal	Lignite			
Europe	84	7	117	< 0.5	632	681	13	1,535	3.8
CIS	825	–	2,406	2	3,282	1,354	183	8,053	20.0
Africa	719	–	635	–	309	1	112	1,776	4.4
Middle East	4,680	–	2,988	–	30	–	–	7,698	19.1
Austral-Asia	275	–	635	59	8,126	1,139	102	10,336	25.7
North America	268	1,177	191	239	5,676	383	120	8,054	20.0
Latin America	383	1,751	289	–	232	43	88	2,786	6.9
World	**7,234**	**2,936**	**7,261**	**300**	**18,288**	**3,601**	**618**	**40,237**	**100.0**
OECD	371	1,184	403	277	8,227	1,747	133	12,342	30.7
EU-28	35	7	49	< 0.5	605	481	10	1,187	2.9
OPEC	5,523	1,751	3,575	–	59	1	–	10,908	27.1

[1] including tight gas

Table A-2: Ressources of non-renewable fuels 2017: Regional distribution [EJ]

Region	Crude oil		Natural gas		Coal		Uranium	Thorium	Total	Share [%]
	conven-tional	non-conven-tional	conven-tional	non-conven-tional[1]	Hard coal	Lignite				
Europe	217	209	220	530	12,570	2,972	280	286	17,283	3.2
CIS	1,155	1,245	4,974	1,833	70,292	18,958	1,233	103	99,792	18.4
Africa	1,211	443	1,317	1,611	6,864	4	1,063	264	12,777	2.4
Middle East	1,276	254	1,602	521	1,008	–	57	–	4,719	0.9
Austral-Asia	1,058	813	1,722	3,141	176,472	12,383	1,890	771	198,249	36.6
North America	1,082	6,576	1,206	2,790	166,908	17,548	932	427	197,469	36.4
Latin America	1,034	2,159	814	1,570	686	173	398	466	7,300	1.3
World	**7,034**	**11,700**	**11,855**	**11,995**	**438,625** [2]	**52,037**	**5,855**	**3,178** [3]	**542,279**	**100.0**
OECD	1,375	6,917	1,767	4,295	220,593	24,028	2,089	1,010	262,075	48.3
EU-28	107	162	117	494	12,531	2,687	280	55	16,432	3.0
OPEC	1,900	2,157	1,787	1,717	1,220	3	21	150	8,954	1.7

[1] without natural gas in gas hydrates and aquifer gas (7,904 EJ)
[2] including hard coal in the Antarctic (3,825 EJ)
[3] including Thorium resources without country allocation (863 EJ)

Table A-3: Production of non-renewable fuels 2017: Regional distribution [EJ]

Region	Crude oil	Natural gas	Hard coal	Lignite	Uranium	Total	Share [%]
Europe	7.4	9.6	2.2	4.7	< 0.05	23.9	4.5
CIS	28.9	33.6	11.8	1.2	14.6	90.1	17.1
Africa	15.9	8.7	6.4	< 0.05	4.0	35.0	6.7
Middle East	61.6	24.9	< 0.05	–	–	86.5	16.5
Austral-Asia	15.3	23.1	118.6	3.4	4.1	164.6	31.3
North America	38.9	37.2	17.5	0.9	7.0	101.4	19.3
Latin America	15.2	6.6	2.6	< 0.05	–	24.4	4.6
World	**183.1**	**143.7**	**159.1**	**10.2**	**29.8**	**525.9**	**100.0**
OECD	46.6	51.4	31.3	4.9	10.0	144.3	27.4
EU-28	3.1	4.9	2.1	3.5	< 0.05	13.6	2.6
OPEC	77.7	29.9	0.1	–	–	107.7	20.5

Table A-4: Consumption of non-renewable fuels 2017: Regional distribution [EJ]

Region	Crude oil	Natural gas	Hard coal	Lignite	Uranium	Total	Share [%]
Europe	28.7	21.1	7.5	4.7	9.8	71.7	13.4
CIS	8.3	23.6	7.8	1.2	3.7	44.6	8.3
Africa	8.4	5.1	4.5	< 0.05	0.1	18.1	3.4
Middle East	17.3	20.6	0.3	–	0.4	38.7	7.2
Austral-Asia	66.4	28.8	122.9	3.4	7.9	229.5	42.9
North America	49.6	35.8	15.2	0.9	10.3	111.7	20.9
Latin America	13.3	6.4	1.2	< 0.05	0.3	21.1	3.9
World	**192.0**	**141.5**	**159.3**	**10.2**	**32.5**	**535.5**	**100.0**
OECD	93.2	64.7	33.4	4.9	22.5	218.8	40.9
EU-28	25.4	18.6	6.4	3.5	9.5	63.4	11.8
OPEC	19.5	21.7	0.1	–	0.4	41.7	7.8

– no reserves, resources, production or consumption

Table A-5: Germany: Supply of crude oil 2016/2017 [kt]

Country / Region	2016	2017	[%]	Changes 2016 / 2017	[%]
Russian Federation	36,048	33,517	36.9	-2,531	-7.0
Norway	11,190	10,303	11.4	-887	-7.9
United Kingdom	9,210	8,555	9.4	-655	-7.1
Kazakhstan	8,375	8,114	8.9	-261	-3.1
Libya	1,779	6,915	7.6	5,136	288.7
Nigeria	3,810	4,916	5.4	1,106	29.0
Iraq	3,146	4,675	5.2	1,529	48.6
Azerbaijan	5,131	2,451	2.7	-2,680	-52.2
Algeria	3,266	1,958	2.2	-1,308	-40.0
Egypt	1,740	1,737	1.9	-3	-0.2
Saudi Arabia	812	1,021	1.1	209	25.7
USA	608	868	1.0	260	42.8
Iran, Islamic Republic,	0	794	0.9	794	
Ghana	202	662	0.7	460	227.7
Venezuela, Bolivarian Rep.	407	654	0.7	247	60.7
Denmark	503	612	0.7	109	21.7
Côte d'Ivoire	492	460	0.5	-32	-6.5
Netherlands	327	440	0.5	113	34.6
Mexico	854	345	0.4	-509	-59.6
Italy	235	316	0.3	81	34.5
Poland	223	219	0.2	-4	-1.8
Angola	675	205	0.2	-470	-69.6
Equatorial Guinea	304	180	0.2	-124	-40.8
Kuwait	190	176	0.2	-14	-7.4
Tunisia	284	160	0.2	-124	-43.7
Colombia	228	138	0.2	-90	-39.5
Brazil	208	97	0.1	-111	-53.4
South Africa	0	87	0.1	87	
other countries	680	82	0.1	-598	-87.9
Congo, Rep.	0	39	0.0	39	
Sweden	16	30	0.0	14	87.5
Guatemala	0	14	0.0	14	
France	18	3	0.0	-15	-83.3

continuation of table A-5
[kt]

Country / Region	2016	2017	[%]	Changes 2016 / 2017	[%]
Turkmenistan	159	0	0.0	-159	-100.0
Canada	32	0	0.0	-32	-100.0
Total imports	**91,245**	**90,743**	**100.0**	**-502**	**-0.6**
OPEC		21,494	23.7		
Middle East	4,148	6,666	7.3	2,518	60.7
Africa	12,586	17,319	19.1	4,733	37.6
CIS	49,713	44,082	48.6	-5,631	-11.3
Europe	21,781	20,478	22.6	-1,303	-6.0

Data for 2017 are partly preliminary

Table A-6: Germany: Origin of consumed natural gas [bcm]

Country of origin	2016	[%]	2017	[%]	Changes 2016 / 2017	[%]
import	112.0	92.9	122.6	93.9	10.6	9.4
domestic production*	8.6	7.1	7.9	6.1	-0.7	-7.9
Total	**120.6**	**100.0**	**130.5**	**100.0**	**9.9**	**8.2**
re-export	19.3	16.0	24.9	19.1	5.6	29.3
storage change	0.2	0.1	0.4	0.3	0.2	155.0
total consumption	**101.5**	**84.1**	**105.9**	**81.2**	**4.5**	**4.4**
domestic production‘s share in total consumption		8.5		7.5		

* Crude gas excluding petroleum gas and mine gas

Data are partly preliminary
Translating energy units into volume units is based on conversion factors by IEA 2018

Annotation: An umambiguous conversion into volume units (m^3) is not possible owing to the varying energy contents of natural gas from different producing regions.

Sources: BAFA 2018b (original numbers in TJ), LBEG 2018

Table A-7: Germany: Imports of hard coal and coke by supplying countries [kt]

Country / Region	2013	2014	2015	2016	2017	Changes 2016 / 2017	[%]
EU	8,364	11,024	8,248	7,209	6,010	-1,199	-16.6
hard coal	5,891	8,817	6,651	5,502	4,113	-1,389	-25.2
coke	2,473	2,207	1,597	1,707	1,897	190	11.1
Non-EU	44,502	45,182	49,262	49,835	45,213	-4,622	-9.3
hard coal	44,228	44,854	48,894	49,584	44,849	-4,735	-9.5
coke	274	328	368	251	364	113	45.0
Australia	4,739	5,673	5,737	6,608	5,635	-973	-14.7
hard coal	4,739	5,673	5,737	6,608	5,635	-973	-14.7
coke	0	0	0	0	0	0	
Indonesia	0	0	53	180	0	-180	-100.0
hard coal	0	0	53	180	0	-180	-100.0
coke	0	0	0	0	0	0	
Canada	1,214	1,462	1,316	1,487	1,524	37	2.5
hard coal	1,214	1,462	1,316	1,487	1,481	-6	-0.4
coke	0	0	0	0	43	43	
Colombia	9,999	7,381	9,948	10,745	6,503	-4,242	-39.5
hard coal	9,974	7,381	9,948	10,711	6,461	-4,250	-39.7
coke	25	0	0	34	42	8	23.5
Norway	680	435	561	636	171	-465	-73.1
hard coal	680	435	561	636	171	-465	-73.1
coke	0	0	0	0	0	0	
Poland	4,325	4,389	4,096	3,705	2,673	-1,032	-27.9
hard coal	3,008	2,931	3,098	2,421	1,248	-1,173	-48.5
coke	1,317	1,458	998	1,284	1,425	141	11.0
CIS	13,091	13,722	16,724	17,943	19,710	1,767	9.8
hard coal	12,842	13,495	16,528	17,854	19,612	1,758	9.8
coke	249	227	196	89	98	9	10.1
South Africa	2,533	5,082	3,400	2,003	1,630	-373	-18.6
hard coal	2,533	5,082	3,400	2,003	1,630	-373	-18.6
coke	0	0	0	0	0	0	
Czechia	690	659	832	539	441	-98	-18.2
hard coal	365	362	566	393	160	-233	-59.3
coke	325	297	266	146	281	135	92.5

continuation of table A-7
[kt]

Country / Region	2013	2014	2015	2016	2017	Changes 2016 / 2017	[%]
United States	12,044	11,099	10,913	9,547	9,141	-406	-4.3
hard coal	12,044	11,099	10,913	9,547	9,141	-406	-4.3
coke	0	0	0	0	0	0	
Venezuela, Bolivarian Rep.	59	0	0	0	0	0	
hard coal	59	0	0	0	0	0	
coke	0	0	0	0	0	0	
China	8	124	91	140	184	44	31.4
hard coal	8	23	16	12	12	0	0.0
coke	0	101	75	128	172	44	34.4
other Non-EU	135	204	519	546	717	171	31.3
hard coal	135	204	422	546	707	161	29.5
coke	0	0	97	0	10	10	
total	**52,866**	**56,206**	**57,510**	**57,044**	**51,224**	**-5,820**	**-10.2**
hard coal	50,119	53,671	55,545	55,086	48,963	-6,123	-11.1
coke	2,747	2,535	1,965	1,958	2,261	303	15.5

Table A-8: Crude oil 2017 [Mt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
EUROPE	Albania	1.0	60	28	56	144	84
	Austria	0.7	126	6	10	142	16
	Bosnia & Herzegovina	–	–	–	10	10	10
	Bulgaria	0.2	10	2	34	46	36
	Croatia	0.8	106	10	16	131	26
	Cyprus	–	–	–	35	35	35
	Czechia	0.6	14	2	27	43	29
	Denmark	6.7	369	60	187	615	247
	Estonia	1.0	9	172	455	636	627
	Finland	0.7	6	–	–	6	–
	France	0.8	129	9	801	939	810
	Germany	2.2	309	28	240	577	268
	Greece	0.1	17	1	35	53	36
	Hungary	1.2	104	3	16	123	19
	Ireland	–	–	–	245	245	245
	Italy	4.1	205	78	1,540	1,823	1,618
	Lithuania	0.2	5	2	60	67	62
	Malta	–	–	–	5	5	5
	Netherlands	2.1	153	11	455	619	466
	Norway	97.7	3,924	1,089	2,482	7,495	3,571
	Poland	0.9	67	14	259	340	273
	Romania	3.6	784	82	200	1,065	282
	Serbia	0.9	49	11	220	280	231
	Slovakia	0.7	4	1	5	10	6
	Slovenia	< 0.05	n. s.	n. s.	n. s.	n. s.	n. s.
	Spain	0.1	39	20	43	102	63
	Sweden	–	–	–	112	112	112
	Turkey	3.2	154	53	980	1,186	1,033
	United Kingdom	47.0	3,761	501	1,643	5,905	2,144
CIS	Armenia	–	–	–	6	6	6
	Azerbaijan	38.7	1,968	952	1,245	4,165	2,197
	Belarus	1.7	143	27	158	328	185
	Georgia	< 0.05	24	5	51	79	55
	Kazakhstan	86.2	1,949	4,082	12,933	18,964	17,015
	Kyrgyzstan	< 0.05	12	5	10	27	15
	Moldova, Republic	–	–	–	10	10	10
	Russian Federation	546.7	24,373	14,449	40,078	78,900	54,527
	Tajikistan	0.1	8	2	60	69	62
	Turkmenistan	12.4	587	82	1,700	2,369	1,782
	Ukraine	2.2	373	54	377	804	431
	Uzbekistan	2.4	207	81	800	1,088	881

continuation of table A-8
[Mt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
AFRICA	Algeria	66.6	3,230	1,660	2,375	7,265	4,035
	Angola	81.8	1,816	1,296	5,095	8,207	6,391
	Benin	–	4	1	70	75	71
	Cameroon	3.9	200	27	350	577	377
	Chad	5.4	87	204	2,365	2,656	2,569
	Congo, DR	0.9	49	24	1,980	2,053	2,004
	Congo, Rep.	14.7	410	218	519	1,147	737
	Côte d'Ivoire	1.2	35	14	300	348	314
	Egypt	32.0	1,723	599	2,340	4,661	2,939
	Equatorial Guinea	9.5	258	150	250	657	400
	Eritrea	–	–	–	15	15	15
	Ethiopia	–	–	–	60	60	60
	Gabon	11.5	582	272	1,400	2,254	1,672
	Gambia	–	–	–	20	20	20
	Ghana	4.9	38	90	210	338	300
	Guinea	–	–	–	150	150	150
	Guinea-Bissau	–	–	–	40	40	40
	Kenya	–	–	–	300	300	300
	Liberia	–	–	–	160	160	160
	Libya	40.6	3,890	6,580	4,750	15,220	11,330
	Madagascar	–	n. s.	n. s.	2,131	2,131	2,131
	Mali	–	–	–	128	128	128
	Mauritania	0.2	8	3	184	195	187
	Morocco	< 0.05	2	< 0,5	2,607	2,609	2,607
	Mozambique	n. s.	n. s.	2	2,300	2,302	2,302
	Namibia	–	–	–	300	300	300
	Niger	0.8	n. s.	20	30	50	50
	Nigeria	95.3	4,770	5,096	5,378	15,244	10,474
	São Tomé and Príncipe	–	–	–	180	180	180
	Senegal	–	–	–	136	136	136
	Seychelles	–	–	–	470	470	470
	Sierra Leone	–	–	60	260	320	320
	Somalia	–	–	–	300	300	300
	South Africa	0.1	16	2	502	520	504
	South Sudan	5.4	–	476	365	841	841
	Sudan	4.2	–	204	365	569	569
	Sudan & South Sudan	9.6	210	680	730	1,621	1,410
	Tanzania	–	–	–	500	500	500
	Togo	–	–	–	70	70	70
	Tunisia	2.4	215	58	300	573	358
	Uganda	–	–	137	300	437	437
	Zimbabwe	–	–	–	10	10	10

continuation of table A-8
[Mt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
MIDDLE EAST	Bahrain	9.8	282	17	200	498	217
	Iran, Islamic Republic	221.5	10,353	21,170	7,200	38,723	28,370
	Iraq	234.2	5,783	20,030	6,320	32,134	26,350
	Israel	0.1	3	2	970	974	972
	Jordan	< 0.05	–	< 0.5	1,912	1,912	1,912
	Kuwait	146.0	6,655	13,810	700	21,164	14,510
	Lebanon	–	–	–	150	150	150
	Oman	47.6	1,586	731	1,540	3,857	2,271
	Palestinian territories	–	–	–	60	60	60
	Qatar	79.9	1,909	3,435	700	6,044	4,135
	Saudi Arabia	555.1	21,481	38,701	11,800	71,982	50,501
	Syrian	0.4	747	340	400	1,487	740
	U. Arab Emirates	176.3	5,196	13,306	4,160	22,663	17,466
	Yemen	1.6	403	408	500	1,311	908
AUSTRAL-ASIA	Afghanistan	–	–	12	80	92	92
	Australia	13.7	1,079	544	4,055	5,677	4,599
	Bangladesh	0.3	5	4	30	38	34
	Brunei	5.5	538	150	160	848	310
	Cambodia	–	–	–	25	25	25
	China	191.5	6,899	3,496	29,001	39,396	32,497
	India	37.4	1,407	604	1,840	3,851	2,444
	Indonesia	46.4	3,521	431	3,572	7,524	4,003
	Japan	0.6	53	6	24	83	30
	Korea, DPR	–	–	–	50	50	50
	Korea, Rep.	< 0.05	n. s.	< 0.5	n. s.	< 0.5	< 0.5
	Laos	–	–	–	< 0.5	< 0.5	< 0.5
	Malaysia	32.2	1,192	490	850	2,532	1,340
	Mongolia	1.0	7	35	1,015	1,058	1,050
	Myanmar	0.6	59	19	595	672	614
	New Zealand	1.4	65	10	250	325	260
	Pakistan	4.4	117	45	1,342	1,505	1,387
	Papua New Guinea	2.5	76	25	290	391	315
	Philippines	1.0	20	14	270	304	284
	Sri Lanka	–	–	–	90	90	90
	Taiwan	< 0.05	5	< 0.5	5	10	5
	Thailand	11.9	229	44	452	725	496
	Timor-Leste	2.0	54	51	175	280	226
	Viet Nam	14.1	384	599	600	1,583	1,199
NORTH AMERICA	Canada	224.0	6,330	26,613	57,170	90,113	83,783
	Greenland	–	–	–	3,500	3,500	3,500
	Mexico	110.6	6,780	1,170	4,760	12,710	5,930
	USA	595.0	33,585	6,799	117,768	158,153	124,568

continuation of table A-8
[Mt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
LATIN AMERICA	Argentina	27.4	1,653	294	4,183	6,130	4,477
	Barbados	< 0.05	2	< 0.5	30	33	30
	Belize	0.1	1	1	15	17	16
	Bolivia	3.6	94	29	280	403	309
	Brazil	130.2	2,531	1,741	15,206	19,478	16,947
	Chile	0.2	63	20	330	414	351
	Colombia	44.7	1,383	226	1,790	3,399	2,016
	Cuba	2.8	76	17	1,145	1,237	1,162
	Dominican Rep.	–	–	–	150	150	150
	Ecuador	26.4	853	1,126	107	2,085	1,232
	Falkland Islands	–	–	–	800	800	800
	(French) Guiana	–	–	–	800	800	800
	Guatemala	0.5	23	14	40	77	54
	Guyana	–	–	–	450	450	450
	Haiti	–	–	–	100	100	100
	Panama	–	–	–	122	122	122
	Paraguay	–	–	–	575	575	575
	Peru	6.6	406	167	2,321	2,894	2,488
	Puerto Rico	–	–	–	75	75	75
	Suriname	0.8	16	11	700	728	711
	Trinidad and Tobago	4.9	535	33	67	636	101
	Uruguay	–	–	–	275	275	275
	Venezuela, Bolivarian Rep.	115.4	10,278	47,385	46,820	104,483	94,205
	World	**4,380.7**	**192,306**	**243,286**	**448,127**	**883,718**	**691,413**
COUNTRY GROUPS	Europe	176.8	10,401	2,181	10,172	22,755	12,354
	CIS	690.4	29,643	19,738	57,428	106,809	77,166
	Africa	381.5	17,544	17,191	39,564	74,299	56,756
	Middle East	1,472.5	54,398	111,950	36,612	202,959	148,562
	Austral-Asia	366.5	15,711	6,578	44,772	67,061	51,350
	North America	929.6	46,695	34,583	183,198	264,476	217,781
	Latin America	363.5	17,915	51,064	76,381	145,359	127,445
ECCONOMIC COUNTRYGPG.	OPEC	1,860.0	77,055	174,015	97,055	348,124	271,070
	OPEC-Gulf	1,413.0	51,378	110,452	30,880	192,709	141,332
	OECD	1,115.6	57,345	37,213	198,364	292,922	235,577
	EU-28	73.9	6,214	1,002	6,424	13,640	7,426

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

Table A-9: Crude oil resources 2017 [Mt]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Total	conventional	non-conventional			
				shale oil [1]	oil sand	extra heavy oil	tight oil
1	USA	117,768	15,900	10,600	1,237	50	89,981
2	Canada	57,170	3,500	3,390	50,000	–	280
3	Venezuela, Bolivarian Rep.	46,820	3,000	1,820	–	42,000	–
4	Russian Federation	40,078	20,000	10,300	5,225	3	4,550
5	China	29,001	16,200	4,380	2,300	121	6,000
6	Brazil	15,206	13,000	720	–	–	1,486
7	Kazakhstan	12,933	4,000	1,440	7,441	–	52
8	Saudi Arabia	11,800	11,800	–	–	–	–
9	Iran, Islamic Republic	7,200	7,200	–	–	–	–
10	Iraq	6,320	6,100	220	–	–	–
11	Nigeria	5,378	5,300	–	78	–	–
12	Angola	5,095	5,000	–	95	–	–
13	Mexico	4,760	2,980	1,780	–	< 0.5	–
14	Libya	4,750	1,200	3,550	–	–	–
15	Argentina	4,183	500	3,675	–	–	8
16	U. Arab Emirates	4,160	1,100	3,060	–	–	–
17	Australia	4,055	1,100	2,380	–	–	575
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]	61.531	42.846	11.196	162	86	7.241
	World	**448,127**	**168,246**	**59,683**	**66,635**	**42,261**	**111,303**
	Europe	10,172	5,181	2,181	46	33	2,731
	CIS	57,428	27,635	11,890	12,667	23	5,213
	Africa	39,564	28,964	7,391	276	8	2,926
	Middle East	36,612	30,532	4,134	–	< 0.5	1,946
	Austral-Asia	44,772	25,314	10,207	2,397	121	6,733
	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	97,055	45,450	9,425	173	42,007	–
	OPEC-Gulf	30,880	27,600	3,280	–	–	–
	OECD	198,364	32,887	20,678	51,283	77	93,438
	EU-28	6,424	2,549	1,541	46	27	2,261

[1] crude oil from tight reservoirs

– no resources

Table A-10: Crude oil reserves 2017 [Mt]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Total	conventional	non-conventional			
				shale oil [1]	oil sand	extra heavy oil	oil shale
1	Venezuela, Bolivarian Rep.	47,385	5,485	–	–	41,900	–
2	Saudi Arabia	38,701	38,701	–	–	–	–
3	Canada	26,613	565	68	25,980	–	–
4	Iran, Islamic Republic	21,170	21,170	–	–	–	–
5	Iraq	20,030	20,030	–	–	–	–
6	Russian Federation	14,449	14,449	–	–	–	–
7	Kuwait	13,810	13,810	–	–	–	–
8	U. Arab Emirates	13,306	13,306	–	–	–	–
9	USA	6,799	4,688	2,109	–	3	–
10	Libya	6,580	6,580	–	–	–	–
11	Nigeria	5,096	5,096	–	–	–	–
12	Kazakhstan	4,082	4,082	–	–	–	–
13	China	3,496	3,496	–	–	n. s.	–
14	Qatar	3,435	3,435	–	–	–	–
15	Brazil	1,741	1,741	–	–	–	n. s.
16	Algeria	1,660	1,660	–	–	–	–
17	Angola	1,296	1,296	–	–	–	–
18	Mexico	1,170	1,170	–	–	–	–
19	Ecuador	1,126	1,126	–	–	n. s.	–
20	Norway	1,089	1,089	–	–	–	–
	...						
60	Germany	28	28	–	–	–	–
	...						
	other countries [84]	10,226	10,054	–	–	–	172
	World[2]	**243,286**	**173,054**	**2,177**	**25,980**	**41,903**	**172**
	Europe	2,181	2,010	–	–	–	172
	CIS	19,738	19,738	–	–	–	–
	Africa	17,191	17,191	–	–	–	–
	Middle East	111,950	111,950	–	–	–	–
	Austral-Asia	6,578	6,578	–	–	–	–
	North America	34,583	6,423	2,177	25,980	3	–
	Latin America	51,064	9,164	–	–	41,900	–
	OPEC	174,015	132,115	–	–	41,900	–
	OPEC-Gulf	110,452	110,452	–	–	–	–
	OECD	37,213	8,881	2,177	25,980	3	172
	EU-28	1,002	830	–	–	–	172

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

n. s. not specified
– no reserves

Table A-11: Crude oil production 2012–2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2012	2013	2014	2015 [Mt]	2016	2017	Share [%] country	Share [%] cumulative
1	USA	431.2	485.2	519.9	567.2	543.0	595.0	13.6	13.6
2	Saudi Arabia	547.0	523.6	530.1	565.3	589.1	555.1	12.7	26.3
3	Russian Federation	517.9	522.6	526.7	533.6	547.5	546.7	12.5	38.7
4	Iraq	148.1	152.6	160.3	197.0	218.9	234.2	5.3	44.1
5	Canada	179.2	192.4	208.0	215.1	218.2	224.0	5.1	49.2
6	Iran, Islamic Republic	185.8	177.7	169.2	182.6	216.4	221.5	5.1	54.2
7	China	207.5	208.1	211.4	214.6	199.7	191.5	4.4	58.6
8	U. Arab Emirates	155.0	165.7	167.3	175.5	182.4	176.3	4.0	62.6
9	Kuwait	151.6	151.3	150.1	149.1	152.7	146.0	3.3	66.0
10	Brazil	108.2	105.0	118.5	125.6	125.0	130.2	3.0	68.9
11	Venezuela, Bolivarian Rep.	155.3	155.0	149.5	148.6	134.2	115.4	2.6	71.6
12	Mexico	144.8	143.5	137.1	128.8	121.0	110.6	2.5	74.1
13	Norway	87.5	90.2	93.1	94.8	98.5	97.7	2.2	76.3
14	Nigeria	123.8	118.3	120.4	113.0	98.8	95.3	2.2	78.5
15	Kazakhstan	79.2	83.8	82.1	80.2	79.3	86.2	2.0	80.5
16	Angola	86.9	87.4	83.0	88.7	87.9	81.8	1.9	82.3
17	Qatar	83.0	84.2	83.5	79.3	79.4	79.9	1.8	84.2
18	Algeria	76.1	72.6	70.6	68.1	67.8	66.6	1.5	85.7
19	Oman	45.8	46.1	46.2	48.0	49.3	47.6	1.1	86.8
20	United Kingdom	44.6	40.6	39.6	45.7	47.9	47.0	1.1	87.9
	...								
56	Germany	2.6	2.6	2.4	2.4	2.4	2.2	0.1	99.3
	...								
	other countries [81]	600.7	574.7	555.7	539.0	516.2	530.0	12.1	100.0
	World	**4,161.7**	**4,183.3**	**4,224.8**	**4,362.1**	**4,375.6**	**4,380.7**	**100.0**	
	Europe	165.0	164.4	167.4	173.2	176.8	176.8	4.0	
	CIS	661.6	671.3	671.8	674.4	687.2	690.4	15.8	
	Africa	461.6	430.5	407.5	398.1	375.4	381.5	8.7	
	Middle East	1,343.0	1,320.1	1,324.9	1,410.4	1,501.2	1,472.5	33.6	
	Austral-Asia	388.5	384.4	387.6	391.9	377.1	366.5	8.4	
	North America	755.2	821.1	865.1	911.1	882.2	929.6	21.2	
	Latin America	386.8	391.5	400.6	402.8	375.7	363.5	8.3	
	OPEC	1,838.8	1,790.6	1,765.4	1,839.0	1,898.8	1,860.0	42.5	
	OPEC-Gulf	1,270.6	1,255.1	1,260.5	1,348.7	1,438.9	1,413.0	32.3	
	OECD	935.2	996.7	1,044.3	1,095.7	1,070.3	1,115.6	25.5	
	EU-28	73.4[1]	69.6	69.3	73.2	73.1	73.9	1.7	

[1] including Croatia (cf. economic country groupings)

Table A-12: Oil consumption 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	USA	987.1	21.5	21.5
2	China	595.5	13.0	34.5
3	India	221.8	4.8	39.3
4	Japan	179.1	3.9	43.2
5	Saudi Arabia	161.1	3.5	46.7
6	Russian Federation	147.8	3.2	49.9
7	Brazil	139.6	3.0	52.9
8	Korea, Rep.	127.8	2.8	55.7
9	Germany	112.5	2.4	58.2
10	Canada	103.6	2.3	60.4
11	Mexico	95.7	2.1	62.5
12	Iran, Islamic Republic	90.4	2.0	64.5
13	France	80.4	1.8	66.2
14	Singapore	74.8	1.6	67.9
15	Indonesia	73.7	1.6	69.5
16	United Kingdom	69.5	1.5	71.0
17	Thailand	60.9	1.3	72.3
18	Spain	58.3	1.3	73.6
19	Italy	57.6	1.3	74.8
20	Australia	49.9	1.1	75.9
	...			
	other countries [181]	1,106.1	24.1	100.0
	World	**4,593.1**	**100.0**	
	Europe	685.6	14.9	
	CIS	198.1	4.3	
	Africa	199.8	4.4	
	Middle East	414.9	9.0	
	Austral-Asia	1,588.9	34.6	
	North America	1,186.5	25.8	
	Latin America	317.5	6.9	
	OPEC	466.0	10.1	
	OPEC-Gulf	370.2	8.1	
	OECD	2,230.3	48.6	
	EU-28	608.4	13.2	

Table A-13: Crude oil export 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	Saudi Arabia	346.3	15.4	15.4
2	Russian Federation	256.7	11.4	26.7
3	Iraq	188.8	8.4	35.1
4	Canada	175.7	7.8	42.9
5	U. Arab Emirates	118.1	5.2	48.1
6	Iran, Islamic Republic	105.5	4.7	52.8
7	Kuwait	99.8	4.4	57.3
8	Nigeria	89.9	4.0	61.2
9	Venezuela, Bolivarian Rep.	79.3	3.5	64.8
10	Angola	78.3	3.5	68.2
11	Norway	77.4	3.4	71.7
12	Kazakhstan	68.1	3.0	74.7
13	Mexico	58.3	2.6	77.3
14	Brazil	56.0	2.5	79.7
15	USA	55.5	2.5	82.2
16	Oman	39.8	1.8	84.0
17	Libya	39.3	1.7	85.7
18	United Kingdom	36.7	1.6	87.3
19	Azerbaijan	33.0	1.5	88.8
20	Algeria	31.4	1.4	90.2
	...			
71	Germany	< 0.05	< 0.05	100.0
	...			
	other countries [59]	220.8	9.8	100.0
	World	**2,254.8**	**100.0**	
	Europe	130.5	5.8	
	CIS	360.7	16.0	
	Africa	296.5	13.1	
	Middle East	921.5	40.9	
	Austral-Asia	69.5	3.1	
	North America	289.5	12.8	
	Latin America	186.7	8.3	
	OPEC	1,238.0	54.9	
	OPEC-Gulf	881.7	39.1	
	OECD	432.4	19.2	
	EU-28	53.1	2.4	

Table A-14: Crude oil import 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country/Region	[Mt]	Share [%] country	Share [%] cumulative
1	China	420.0	17.9	17.9
2	USA	392.9	16.8	34.7
3	India	217.1	9.3	44.0
4	Japan	187.6	8.0	52.0
5	Korea, Rep.	152.1	6.5	58.5
6	Germany	90.7	3.9	62.4
7	Italy	66.5	2.8	65.2
8	Spain	65.9	2.8	68.0
9	Singapore	58.0	2.5	70.5
10	France	57.3	2.4	73.0
11	Netherlands	54.2	2.3	75.3
12	United Kingdom	46.5	2.0	77.3
13	Taiwan	42.5	1.8	79.1
14	Thailand	42.3	1.8	80.9
15	Canada	35.2	1.5	82.4
16	Belgium	34.3	1.5	83.9
17	Greece	29.1	1.2	85.1
18	Turkey	25.9	1.1	86.2
19	Poland	25.3	1.1	87.3
20	Sweden	20.6	0.9	88.2
	...			
	other countries [64]	277.0	11.8	100.0
	World	**2,340.9**	**100.0**	
	Europe	614.9	26.3	
	CIS	20.1	0.9	
	Africa	9.2	0.4	
	Middle East	28.1	1.2	
	Austral-Asia	1,193.0	51.0	
	North America	428.9	18.3	
	Latin America	46.8	2.0	
	OECD	1,397.3	59.7	
	EU-28	582.0	24.9	

Table A-15: Natural gas 2017 [bcm]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
EUROPE	Albania	0.1	8	1	50	59	51
	Austria	1.7	102	8	244	354	252
	Belgium	–	–	–	85	85	85
	Bulgaria	0.2	8	6	575	589	581
	Croatia	1.5	77	25	50	152	75
	Cyprus	–	–	–	250	250	250
	Czechia	0.4	16	7	181	204	188
	Denmark	4.8	196	14	236	446	250
	France	0.1	229	8	3,984	4,221	3,992
	Germany	8.3	1,046	37	1,360	2,443	1,397
	Greece	< 0.05	1	1	10	12	11
	Hungary	1.8	234	7	173	414	180
	Ireland	3.5	63	10	50	123	60
	Italy	5.4	766	38	405	1,209	443
	Lithuania	–	–	–	14	14	14
	Malta	–	–	–	10	10	10
	Netherlands	43.9	3,662	654	616	4,932	1,270
	Norway	124.2	2,348	1,729	2,475	6,552	4,204
	Poland	4.2	273	80	1,245	1,598	1,325
	Portugal	–	–	–	148	148	148
	Romania	10.3	1,328	105	1,142	2,576	1,247
	Serbia	0.5	35	48	10	93	58
	Slovakia	0.1	26	14	10	50	24
	Slovenia	< 0.05	n. s.	1	30	31	31
	Spain	< 0.05	12	3	653	668	656
	Sweden	–	–	–	48	48	48
	Turkey	0.4	15	5	1,153	1,173	1,158
	United Kingdom	42.3	2,623	275	4,540	7,438	4,815
CIS	Armenia	–	–	< 0.5	18	18	18
	Azerbaijan	17.7	614	1,319	1,800	3,733	3,119
	Belarus	0.2	14	3	10	26	13
	Georgia	< 0.05	3	8	102	113	110
	Kazakhstan	22.9	601	1,898	4,179	6,678	6,077
	Kyrgyzstan	< 0.05	8	6	20	33	26
	Moldova, Republic	–	–	–	20	20	20
	Russian Federation	691.6	23,657	47,777	152,050	223,484	199,827
	Tajikistan	< 0.05	9	6	20	34	26
	Turkmenistan	80.5	2,793	9,838	15,000	27,631	24,838
	Ukraine	19.5	2,060	950	4,495	7,505	5,445
	Uzbekistan	52.1	2,427	1,564	1,400	5,391	2,964
	Algeria	94.8	2,578	4,501	26,720	33,799	31,221
	Angola	3.1	28	308	1,200	1,536	1,508

continuation of table A-15
[bcm]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
AFRICA	Benin	–	–	–	100	100	100
	Botswana	–	–	–	1,840	1,840	1,840
	Cameroon	0.7	n. s.	135	200	335	335
	Chad	–	–	–	1,455	1,455	1,455
	Congo, DR	n. s.	n. s.	1	20	21	21
	Congo, Rep.	1.4	n. s.	91	200	291	291
	Côte d'Ivoire	2.4	34	28	400	462	428
	Egypt	51.9	963	1,777	12,330	15,070	14,107
	Equatorial Guinea	9.6	70	37	150	257	187
	Eritrea	–	–	–	29	29	29
	Ethiopia	–	–	25	151	176	176
	Gabon	0.4	6	26	650	682	676
	Gambia	–	–	–	25	25	25
	Ghana	n. s.	n. s.	23	300	323	323
	Guinea	–	–	–	160	160	160
	Guinea–Bissau	–	–	–	50	50	50
	Kenya	–	–	–	333	333	333
	Liberia	–	–	–	225	225	225
	Libya	11.5	341	1,430	4,650	6,421	6,080
	Madagascar	–	–	–	4,700	4,700	4,700
	Mali	–	–	–	30	30	30
	Mauritania	n. s.	n. s.	28	500	528	528
	Morocco	0.1	3	1	2,220	2,224	2,221
	Mozambique	5.1	47	2,830	3,160	6,037	5,990
	Namibia	–	–	62	300	362	362
	Niger	–	–	–	250	250	250
	Nigeria	43.0	620	5,201	3,200	9,021	8,401
	Rwanda	n. s.	n. s.	1	157	158	158
	São Tomé and Príncipe	–	–	–	100	100	100
	Senegal	0.1	–	–	200	200	200
	Seychelles	–	–	–	600	600	600
	Sierra Leone	–	–	–	197	197	197
	Somalia	–	–	–	261	261	261
	South Africa	1.1	47	8	7,277	7,332	7,285
	Sudan & South Sudan	n. s.	n. s.	85	250	335	335
	Tanzania	0.9	n. s.	37	1,500	1,537	1,537
	Togo	–	–	–	100	100	100
	Tunisia	2.8	61	65	750	876	815
	Uganda	–	–	14	100	114	114
	Zimbabwe	–	–	–	10	10	10

continuation of table A-15
[bcm]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
MIDDLE EAST	Bahrain	15.2	326	155	400	881	555
	Iran, Islamic Republic	238.0	3,004	33,700	10,000	46,704	43,700
	Iraq	10.7	151	3,509	4,000	7,660	7,509
	Israel	9.6	58	456	1,700	2,214	2,156
	Jordan	0.1	6	6	275	287	281
	Kuwait	17.4	386	1,783	500	2,669	2,283
	Lebanon	–	–	–	850	850	850
	Oman	32.2	506	664	2,985	4,156	3,650
	Palestinian territories	–	–	–	380	380	380
	Qatar	163.6	1,935	23,861	2,000	27,796	25,861
	Saudi Arabia	111.4	2,117	8,035	24,664	34,816	32,699
	Syrian	3.1	148	269	300	716	569
	U. Arab Emirates	54.1	1,376	5,939	7,315	14,630	13,253
	Yemen	0.7	52	267	500	819	767
AUSTRAL-ASIA	Afghanistan	0.2	58	50	400	508	450
	Australia	113.9	1,357	3,173	32,875	37,406	36,049
	Bangladesh	26.6	428	186	800	1,414	986
	Brunei	12.0	446	252	200	898	452
	Cambodia	–	–	–	50	50	50
	China	154.0	1,925	5,437	63,400	70,762	68,837
	India	35.2	853	1,241	7,039	9,133	8,281
	Indonesia	70.4	2,294	2,914	9,980	15,188	12,894
	Japan	3.0	144	21	10	175	31
	Korea, Rep.	0.4	n. s.	7	50	57	57
	Laos	–	–	–	10	10	10
	Malaysia	78.4	1,482	2,485	1,900	5,867	4,385
	Mongolia	–	–	–	133	133	133
	Myanmar	18.0	236	637	2,000	2,873	2,637
	New Zealand	5.1	176	34	353	563	387
	Pakistan	38.9	961	588	4,560	6,109	5,148
	Papua New Guinea	0.2	4	192	1,000	1,196	1,192
	Philippines	3.9	51	98	502	651	600
	Sri Lanka	–	–	–	300	300	300
	Taiwan	0.2	53	6	5	64	11
	Thailand	38.2	691	200	740	1,631	940
	Timor–Leste	n. s.	n. s.	88	300	388	388
	Viet Nam	9.5	132	646	1,355	2,133	2,001
NORTH AMERICA	Canada	176.3	6,483	2,040	34,201	42,724	36,241
	Mexico	40.7	1,749	196	17,720	19,664	17,916
	USA	761.1	36,566	9,067	53,246	98,879	62,313

continuation of table A-15
[bcm]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
LATIN AMERICA	Argentina	38.2	1,252	327	23,710	25,289	24,037
	Barbados	n. s.	n. s.	< 0.5	100	100	100
	Belize	–	–	–	10	10	10
	Bolivia	17.1	321	270	1,620	2,211	1,890
	Brazil	27.5	363	370	18,446	19,179	18,816
	Chile	1.2	112	5	1,745	1,862	1,750
	Colombia	10.3	291	110	2,307	2,708	2,417
	Cuba	1.2	19	71	400	490	471
	Ecuador	0.5	8	11	20	39	31
	Falkland Islands	–	–	–	1,500	1,500	1,500
	(French) Guiana	–	–	–	400	400	400
	Grenada	–	–	–	25	25	25
	Guatemala	–	–	–	10	10	10
	Guyana	–	–	–	300	300	300
	Haiti	–	–	–	40	40	40
	Paraguay	–	–	–	2,420	2,420	2,420
	Peru	13.0	156	439	1,340	1,934	1,779
	Puerto Rico	–	–	–	30	30	30
	Suriname	–	–	–	350	350	350
	Trinidad and Tobago	33.8	737	260	–	998	260
	Uruguay	–	–	–	828	828	828
	Venezuela, Bolivarian Rep.	29.8	1,193	5,736	7,130	14,059	12,866
	World	**3,781.9**	**120,655**	**198,960**	**627,639**	**947,254**	**826,599**
COUNTRY GROUPS	Europe	253.7	13,068	3,076	19,747	35,891	22,823
	CIS	884.6	32,184	63,368	179,114	274,666	242,482
	Africa	228.8	4,798	16,714	77,050	98,561	93,763
	Middle East	656.1	10,066	78,644	55,869	144,579	134,513
	Austral-Asia	608.1	11,290	18,256	127,962	157,509	146,219
	North America	978.1	44,797	11,303	105,167	161,267	116,470
	Latin America	172.6	4,452	7,599	62,731	74,782	70,330
ECONOMIC COUNTRY GRP.	OPEC	787.8	13,814	94,077	92,199	200,089	186,275
	OPEC-Gulf	595.1	8,970	76,827	48,479	134,275	125,306
	OECD	1,352.5	58,257	17,890	159,546	235,693	177,436
	EU-28	128.6	10,662	1,293	16,059	28,014	17,352

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

Table A-16: Natural gas resources 2017 [bcm]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Total	conventional	non-conventional		
				tight gas	shale gas	CBM
1	Russian Federation	152,050	110,000	20,000	9,500	12,550
2	China	63,400	20,000	10,500	22,000	10,900
3	USA	53,246	23,000	8,500	17,276	4,470
4	Canada	34,201	6,500	7,400	16,230	4,071
5	Australia	32,875	7,278	8,000	11,756	5,841
6	Algeria	26,720	1,200	5,500	20,020	–
7	Saudi Arabia	24,664	19,000	–	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	12,330	9,500	–	2,830	–
13	Iran, Islamic Republic	10,000	10,000	–	–	–
14	Indonesia	9,980	5,500	–	1,300	3,180
15	U. Arab Emirates	7,315	1,500	–	5,815	–
16	South Africa	7,277	1,000	–	5,707	570
17	Venezuela, Bolivarian Rep.	7,130	2,400	–	4,730	–
18	India	7,039	2,000	–	2,720	2,319
19	Madagascar	4,700	4,700	–	–	–
20	Libya	4,650	1,200	–	3,450	–
	...					
46	Germany	1,360	20	90	800	450
	...					
	other countries [122]	93,826	57,433	1,367	28,088	6,939
	World	**627,639**	**311,981**	**61,357**	**202,976**	**51,326**
	Europe	19,747	5,802	327	12,416	1,202
	CIS	179,114	130,888	20,000	11,274	16,952
	Africa	77,050	34,658	5,500	35,482	1,410
	Middle East	55,869	42,155	670	13,044	–
	Austral-Asia	127,962	45,303	18,690	40,996	22,973
	North America	105,167	31,750	15,900	48,946	8,571
	Latin America	62,731	21,425	270	40,818	218
	OPEC	92,199	47,020	5,500	39,679	–
	OPEC-Gulf	48,479	37,000	–	11,479	–
	OECD	159,546	46,510	24,462	73,013	15,561
	EU-28	16,059	3,067	327	11,746	919

– no resources / not specified

Table A-17: Natural gas reserves 2017 [bcm]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Total	conventional [1]	non-conventional [2]	
				shale gas	CBM
1	Russian Federation	47,777	47,734	–	43
2	Iran, Islamic Republic	33,700	33,700	–	–
3	Qatar	23,861	23,861	–	–
4	Turkmenistan	9,838	9,838	–	–
5	USA	9,067	2,825	5,942	300
6	Saudi Arabia	8,035	8,035	–	–
7	U. Arab Emirates	5,939	5,939	–	–
8	Venezuela, Bolivarian Rep.	5,736	5,736	–	–
9	China	5,437	4,974	122	340
10	Nigeria	5,201	5,201	–	–
11	Algeria	4,501	4,501	–	–
12	Iraq	3,509	3,509	–	–
13	Australia	3,173	2,189	n. s.	984
14	Indonesia	2,914	2,914	–	–
15	Mozambique	2,830	2,830	–	–
16	Malaysia	2,485	2,485	–	–
17	Canada	2,040	1,994	n. s.	46
18	Kazakhstan	1,898	1,898	–	–
19	Kuwait	1,783	1,783	–	–
20	Egypt	1,777	1,777	–	–
	...				
62	Germany	37	37	–	–
	...				
	other countries [80]	17,420	17,306	–	114
	World	**198,960**	**191,069**	**6,065**	**1,826**
	Europe	3,076	3,070	–	6
	CIS	63,368	63,326	–	43
	Africa	16,714	16,714	–	–
	Middle East	78,644	78,644	–	–
	Austral-Asia	18,256	16,702	122	1,432
	North America	11,303	5,015	5,942	345
	Latin America	7,599	7,599	–	–
	OPEC	94,077	94,077	–	–
	OPEC-Gulf	76,827	76,827	–	–
	OECD	17,890	10,613	5,942	1,335
	EU-28	1,293	1,287	–	6

[1] including tight gas
[2] partly data status 2016

n. s. not specified
– no reserves

Table A-18: Natural gas production 2012–2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2012	2013	2014	2015	2016	2017	Share [%]	
				[bcm]				country	cumulative
1	USA	681.5	687.2	729.1	768.1	755.8	761.1	20.1	20.1
2	Russian Federation	609.7	627.6	610.1	636.0	640.7	691.6	18.3	38.4
3	Iran, Islamic Republic	158.2	159.1	172.6	183.9	202.4	238.0	6.3	44.7
4	Canada	156.5	154.8	161.3	154.8	157.1	176.3	4.7	49.4
5	Qatar	157.0	158.5	160.0	171.3	165.4	163.6	4.3	53.7
6	China	110.7	119.3	132.8	138.2	141.9	154.0	4.1	57.8
7	Norway	114.8	107.1	108.8	121.3	121.2	124.2	3.3	61.0
8	Australia	48.8	50.1	55.3	69.9	88.2	113.9	3.0	64.1
9	Saudi Arabia	95.2	103.0	108.2	106.4	109.4	111.4	2.9	67.0
10	Algeria	81.5	79.6	79.7	82.3	93.2	94.8	2.5	69.5
11	Turkmenistan	64.4	62.3	69.3	80.2	77.0	80.5	2.1	71.6
12	Malaysia	63.0	69.1	66.4	68.2	73.8	78.4	2.1	73.7
13	Indonesia	76.7	70.4	71.8	72.7	74.0	70.4	1.9	75.6
14	U. Arab Emirates	51.7	56.0	55.6	55.8	61.9	54.1	1.4	77.0
15	Uzbekistan	57.7	58.7	59.3	58.8	51.6	52.1	1.4	78.4
16	Egypt	60.9	56.1	48.7	44.3	41.8	51.9	1.4	79.8
17	Netherlands	80.1	84.5	66.3	51.2	47.4	43.9	1.2	80.9
18	Nigeria	37.9	36.1	40.3	43.7	41.2	43.0	1.1	82.1
19	United Kingdom	41.1	38.5	38.7	41.3	42.0	42.3	1.1	83.2
20	Mexico	47.0	45.8	44.8	46.0	47.2	40.7	1.1	84.2
	...								
46	Germany	12.1	11.1	10.5	9.7	9.0	8.3	0.2	98.3
	...								
	other countries [70]	582.6	585.4	594.0	568.9	565.7	587.4	15.5	100.0
	World	**3,389.2**	**3,420.4**	**3,483.7**	**3,573.0**	**3,607.9**	**3,781.9**	**100.0**	
	Europe	286.8	276.3	258.2	256.5	253.2	253.7	6.7	
	CIS	795.9	817.1	807.6	832.5	826.9	884.6	23.4	
	Africa	210.6	202.2	200.9	201.7	206.8	228.8	6.1	
	Middle East	541.7	566.0	587.2	605.4	628.6	656.1	17.3	
	Austral-Asia	492.0	492.6	515.2	535.1	564.8	608.1	16.1	
	North America	885.0	887.8	935.2	968.9	960.1	978.1	25.9	
	Latin America	177.3	178.3	179.5	172.8	167.5	172.6	4.6	
	OPEC	654.8	662.3	689.3	711.2	739.8	787.8	20.8	
	OPEC-Gulf	482.5	498.0	520.0	540.6	563.4	595.1	15.7	
	OECD	1,218.8	1,216.4	1,251.7	1,298.9	1,307.7	1,352.5	35.8	
	EU-28	170.8[1]	168.0	148.3	134.3	130.9	128.6	3.4	

[1] including Croatia (cf. economic country groupings)

Table A-19: Natural gas consumption 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[bcm]	Share [%] country	Share [%] cumulative
1	USA	767.1	20.6	20.6
2	Russian Federation	468.0	12.6	33.2
3	China	235.3	6.3	39.5
4	Iran, Islamic Republic	231.1	6.2	45.7
5	Japan	117.1	3.1	48.8
6	Saudi Arabia	111.4	3.0	51.8
7	Germany	105.9	2.8	54.7
8	Canada	93.7	2.5	57.2
9	Mexico	81.8	2.2	59.4
10	United Kingdom	79.7	2.1	61.5
11	Italy	72.1	1.9	63.5
12	U. Arab Emirates	71.6	1.9	65.4
13	Egypt	56.0	1.5	66.9
14	India	54.2	1.5	68.3
15	Turkey	53.5	1.4	69.8
16	Thailand	50.8	1.4	71.1
17	Argentina	50.3	1.4	72.5
18	Korea, Rep.	49.4	1.3	73.8
19	France	43.5	1.2	75.0
20	Netherlands	43.4	1.2	76.2
	...			
	other countries [90]	887.9	23.8	100.0
	World	**3,723.7**	**100.0**	
	Europe	555.4	14.9	
	CIS	621.4	16.7	
	Africa	135.0	3.6	
	Middle East	543.4	14.6	
	Austral-Asia	758.0	20.4	
	North America	942.6	25.3	
	Latin America	168.0	4.5	
	OPEC	571.0	15.3	
	OPEC-Gulf	481.4	12.9	
	OECD	1,702.6	45.7	
	EU-28	489.9	13.2	

Table A-20: Natural gas export 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[bcm]	Share [%] country	Share [%] cumulative
1	Russian Federation	224.2	18.6	18.6
2	Qatar	126.7	10.5	29.1
3	Norway	122.0	10.1	39.2
4	USA	86.0	7.1	46.4
5	Canada	84.7	7.0	53.4
6	Australia	74.7	6.2	59.6
7	Netherlands	55.6	4.6	64.2
8	Turkmenistan	55.3	4.6	68.8
9	Algeria	53.9	4.5	73.3
10	Malaysia	36.6	3.0	76.3
11	Indonesia	29.8	2.5	78.8
12	Nigeria	27.2	2.3	81.0
13	Germany	25.6	2.1	83.2
14	Belgium	24.3	2.0	85.2
15	Bolivia	15.5	1.3	86.5
16	Kazakhstan	14.6	1.2	87.7
17	Iran, Islamic Republic	12.9	1.1	88.7
18	Trinidad and Tobago	12.6	1.0	89.8
19	Myanmar	12.2	1.0	90.8
20	U. Arab Emirates	12.1	1.0	91.8
	...			
	other countries [27]	98.9	8.2	100.0
	World	**1,205.3**	**100.0**	
	Europe	261.4	21.7	
	CIS	310.8	25.8	
	Africa	100.4	8.3	
	Middle East	162.8	13.5	
	Austral-Asia	165.0	13.7	
	North America	170.7	14.2	
	Latin America	34.1	2.8	
	OPEC	247.3	20.5	
	OPEC-Gulf	151.7	12.6	
	OECD	506.9	42.1	
	EU-28	138.8	11.5	

Table A-21: Natural gas import 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country/Region	[bcm]	Share [%] country	Share [%] cumulative
1	Germany	125.7	10.4	10.4
2	Japan	115.3	9.5	19.9
3	China	94.6	7.8	27.7
4	USA	86.0	7.1	34.8
5	Italy	69.6	5.7	40.5
6	Turkey	55.2	4.6	45.1
7	Korea, Rep.	54.0	4.5	49.6
8	Netherlands	53.8	4.4	54.0
9	Mexico	50.3	4.2	58.1
10	France	48.3	4.0	62.1
11	United Kingdom	47.6	3.9	66.1
12	Belgium	42.7	3.5	69.6
13	Spain	34.6	2.9	72.4
14	U. Arab Emirates	26.0	2.1	74.6
15	India	24.4	2.0	76.6
16	Canada	23.5	1.9	78.5
17	Belarus	17.5	1.4	80.0
18	Taiwan	16.6	1.4	81.4
19	Poland	15.7	1.3	82.7
20	Thailand	14.1	1.2	83.8
	...			
	other countries [54]	195.9	16.2	100.0
	World	**1,211.7**	**100.0**	
	Europe	561.7	46.4	
	CIS	54.9	4.5	
	Africa	16.9	1.4	
	Middle East	42.5	3.5	
	Austral-Asia	346.4	28.6	
	North America	159.8	13.2	
	Latin America	29.3	2.4	
	OPEC	35.5	2.9	
	OPEC-Gulf	35.5	2.9	
	OECD	892.8	73.7	
	EU-28	502.5	41.5	

Table A-22: Hard coal 2017 [Mt]

	Country / Region	Production	Reserves	Resources	Total Resources
EUROPE	Belgium	–	–	4,100	4,100
	Bulgaria	–	192	3,920	4,112
	Czechia	4.9	110	15,414	15,523
	France	–	–	160	160
	Germany	3.8	3	82,964	82,967
	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	65.8	20,542	161,171	181,713
	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	2.8	868	3,363	4,231
	Sweden	–	1	4	5
	Turkey	1.2	551	787	1,338
	United Kingdom	3.0	29	186,700	186,729
CIS	Armenia	–	163	154	317
	Georgia	0.4	201	700	901
	Kazakhstan	105.9	25,605	123,090	148,695
	Kyrgyzstan	0.3	971	27,528	28,499
	Russian Federation	333.0	69,634	2,658,281	2,727,915
	Tajikistan	1.8	375	3,700	4,075
	Turkmenistan	–	–	800	800
	Ukraine	34.9	32,039	49,006	81,045
	Uzbekistan	0.4	1,375	9,477	10,852
AFRICA	Algeria	–	59	164	223
	Botswana	2.2	40	21,200	21,240
	Congo, DR	–	88	900	988
	Egypt	0.3	16	166	182
	Eswatini	0.2	144	4,500	4,644
	Madagascar	–	–	150	150
	Malawi	0.1	2	800	802
	Morocco	–	14	82	96
	Mozambique	11.8	1,792	30,528	32,321
	Namibia	–	–	350	350
	Niger	0.2	–	90	90
	Nigeria	0.4	287	1,857	2,144
	South Africa	252.3	9,893	203,667	213,560
	Tanzania	0.6	269	1,141	1,410
	Uganda	–	–	800	800
	Zambia	0.3	45	900	945
	Zimbabwe	2.9	502	25,000	25,502
ME	Iran, Islamic Republic	1.5	1,203	40,000	41,203

continuation of table A-22
[Mt]

	Country / Region	Production	Reserves	Resources	Total Resources
AUSTRAL-ASIA	Afghanistan	2.2	66	n. s.	66
	Australia	435.9	70,927	1,545,942	1,616,869
	Bangladesh	1.2	293	2,967	3,260
	Bhutan	0.1	n. s.	n. s.	n. s.
	China	3,236.1	130,851	5,326,420	5,457,270
	India	680.5	96,468	170,233	266,701
	Indonesia	420.0	26,122	86,185	112,307
	Japan	1.3	340	13,543	13,883
	Korea, DPR	20.0	600	10,000	10,600
	Korea, Rep.	1.5	326	1,360	1,686
	Laos	0.1	4	58	62
	Malaysia	1.4	141	1,068	1,209
	Mongolia	42.7	1,170	39,854	41,024
	Myanmar	0.3	3	248	252
	Nepal	< 0.05	1	7	8
	New Caledonia	–	2	n. s.	2
	New Zealand	2.6	825	2,350	3,175
	Pakistan	3.2	207	5,789	5,996
	Papua New Guinea	–	–	11	11
	Philippines	13.0	215	1,074	1,289
	Taiwan	–	1	101	102
NORTH-AMERICA	Canada	52.1	4,346	183,260	187,606
	Greenland	–	183	200	383
	Mexico	9.0	1,160	3,000	4,160
	USA	639.1	220,167	6,459,241	6,679,408
LATIN AMERICA	Argentina	0.1	500	300	800
	Bolivia	–	1	n. s.	1
	Brazil	3.3	1,547	4,665	6,212
	Chile	2.5	1,181	4,135	5,316
	Colombia	90.9	4,881	9,928	14,809
	Costa Rica	–	–	17	17
	Peru	0.3	102	1,465	1,567
	Venezuela, Bolivarian Rep.	0.4	731	5,981	6,712
	World	**6,529.2**	**734,901**	**17,708,211**	**18,443,112**
COUNTRY GROUPS	Europe	81.8	23,709	470,258	493,967
	CIS	476.6	130,362	2,872,737	3,003,098
	Africa	271.3	13,150	292,295	305,445
	Middle East	1.5	1,203	40,000	41,203
	Austral–Asia	4,900.3	331,679	7,210,729	7,542,408
	North America	700.2	225,856	6,645,701	6,871,557
	Latin America	97.5	8,943	26,491	35,434
	Antarctica [1]	–	–	150,000	150,000
ECONOMIC COUNTRY GRP.	OPEC	2.3	2,279	48,002	50,281
	OPEC–Gulf	1.5	1,203	40,000	41,203
	OECD	1,225.7	322,417	8,676,286	8,998,703
	EU–28	80.3	22,612	468,740	491,352

[1] The exploration and production of raw materials in the Antarctic is prohibited under international law

n. s. not specified

– no production, reserves or resources

Table A-23: Hard coal resources 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	USA	6,459,241	36.5	36.5
2	China	5,326,420	30.1	66.6
3	Russian Federation [1]	2,658,281	15.0	81.6
4	Australia	1,545,942	8.7	90.3
5	South Africa	203,667	1.2	91.4
6	United Kingdom	186,700	1.1	92.5
7	Canada	183,260	1.0	93.5
8	India	170,233	1.0	94.5
9	Poland	161,171	0.9	95.4
10	Kazakhstan	123,090	0.7	96.1
11	Indonesia	86,185	0.5	96.6
12	Germany	82,964	0.5	97.1
13	Ukraine [1]	49,006	0.3	97.3
14	Iran, Islamic Republic	40,000	0.2	97.6
15	Mongolia [1]	39,854	0.2	97.8
16	Mozambique	30,528	0.2	98.0
17	Kyrgyzstan	27,528	0.2	98.1
18	Zimbabwe	25,000	0.1	98.3
19	Botswana	21,200	0.1	98.4
20	Czechia [1]	15,414	0.1	98.5
	...			
	other countries [58]	272,528	1.5	100.0
	World	**17,708,211**	**100.0**	
	Europe	470,258	2.7	
	CIS	2,872,737	16.2	
	Africa	292,295	1.7	
	Middle East	40,000	0.2	
	Austral-Asia	7,210,729	40.7	
	North America	6,645,701	37.5	
	Latin America	26,491	0.1	
	Antarctica [2]	150,000	0.8	
	OPEC	48,002	0.3	
	OPEC-Gulf	40,000	0.2	
	OECD	8,676,286	49.0	
	EU-28	468,740	2.6	

[1] Hard coal resources contains only bituminous coal and anthracite according to national classification
[2] The exploration and production of raw materials in the Antarctic is prohibited under international law

Table A-24: Hard coal reserves 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	USA	220,167	30.0	30.0
2	China	130,851	17.8	47.8
3	India	96,468	13.1	60.9
4	Australia	70,927	9.7	70.5
5	Russian Federation [1]	69,634	9.5	80.0
6	Ukraine [1]	32,039	4.4	84.4
7	Indonesia	26,122	3.6	87.9
8	Kazakhstan	25,605	3.5	91.4
9	Poland	20,542	2.8	94.2
10	South Africa	9,893	1.3	95.6
11	Colombia	4,881	0.7	96.2
12	Canada	4,346	0.6	96.8
13	Viet Nam	3,116	0.4	97.2
14	Mozambique	1,792	0.2	97.5
15	Brazil	1,547	0.2	97.7
16	Uzbekistan	1,375	0.2	97.9
17	Iran, Islamic Republic	1,203	0.2	98.0
18	Chile	1,181	0.2	98.2
19	Mongolia [1]	1,170	0.2	98.4
20	Mexico	1,160	0.2	98.5
	...			
63	Germany [2]	3	< 0.05	100.0
	...			
	other countries [50]	10,879	1.5	100.0
	World	**734,901**	**100.0**	
	Europe	23,709	3.2	
	CIS	130,362	17.7	
	Africa	13,150	1.8	
	Middle East	1,203	0.2	
	Austral-Asia	331,679	45.1	
	North America	225,856	30.7	
	Latin America	8,943	1.2	
	OPEC	2,279	0.3	
	OPEC-Gulf	1,203	0.2	
	OECD	322,417	43.9	
	EU-28	22,612	3.1	

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

[2] Deviating from the BGR reserves definition, RAG AG refers to a „Technically extractable planned inventory“ of 2.5 billion t (status 2011)

Table A-25: Hard coal production 2012–2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country/Region	2012	2013	2014	2015 [Mt]	2016	2017	Share [%] country	Share [%] cumulative
1	China	3,532.6	3,601.5	3,495.2	3,423.2	3,102.5	3,236.1	49.6	49.6
2	India	556.4	565.8	609.2	639.2	657.9	680.5	10.4	60.0
3	USA	850.5	823.4	835.1	748.8	594.4	639.1	9.8	69.8
4	Australia	381.0	411.3	441.5	440.0	443.4	435.9	6.7	76.4
5	Indonesia	406.3	430.0	410.8	401.6	396.2	420.0	6.4	82.9
6	Russian Federation	276.1	279.0	287.0	300.1	312.0	333.0	5.1	88.0
7	South Africa	259.0	256.6	261.9	252.2	250.6	252.3	3.9	91.8
8	Kazakhstan	112.8	112.9	107.7	101.8	97.3	105.9	1.6	93.5
9	Colombia	89.7	85.9	88.8	86.6	91.1	90.9	1.4	94.9
10	Poland	79.8	77.1	73.3	72.7	70.6	65.8	1.0	95.9
11	Canada	57.0	59.9	60.9	53.5	51.4	52.1	0.8	96.7
12	Mongolia[1]	23.6	27.0	18.1	18.2	28.4	42.7	0.7	97.3
13	Viet Nam	42.1	41.0	41.1	41.7	38.7	38.2	0.6	97.9
14	Ukraine[1]	85.6	83.4	65.0	39.7	40.9	34.9	0.5	98.4
15	Korea, DPR[2]	32.2	31.6	34.0	34.0	34.0	20.0	0.3	98.7
16	Philippines	8.2	7.2	8.4	8.2	12.1	13.0	0.2	98.9
17	Mozambique	5.0	5.9	6.3	6.6	6.2	11.8	0.2	99.1
18	Mexico	13.7	13.1	13.5	7.5	8.1	9.0	0.1	99.3
19	Czechia[1]	10.8	8.6	8.3	7.6	6.1	4.9	0.1	99.3
20	Germany	11.6	8.3	8.3	6.6	4.1	3.8	0.1	99.4
	...								
	other countries [35]	53.7	52.3	58.0	49.4	38.5	39.3	0.6	100.0
	World	**6,887.5**	**6,981.7**	**6,932.4**	**6,739.2**	**6,284.4**	**6,529.2**	**100.0**	
	Europe	131.7	117.6	109.5	101.4	89.0	81.8	1.3	
	CIS	475.5	476.6	461.3	443.7	452.5	476.6	7.3	
	Africa	268.0	268.3	277.5	266.5	262.4	271.3	4.2	
	Middle East	0.8	0.9	1.4	1.5	1.5	1.5	< 0.05	
	Austral-Asia	4,998.2	5,130.9	5,073.6	5,021.0	4,727.3	4,900.3	75.1	
	North America	921.2	896.4	909.5	809.8	653.9	700.2	10.7	
	Latin America	92.0	91.0	99.7	95.4	97.8	97.5	1.5	
	OPEC	2.7	3.3	3.8	2.4	2.8	2.3	< 0.05	
	OPEC-Gulf	0.8	0.9	1.4	1.5	1.5	1.5	< 0.05	
	OECD	1,439.2	1,432.7	1,471.1	1,360.2	1,194.5	1,225.7	18.8	
	EU-28	128.0[3]	113.6	105.9	98.7	86.8	80.3	1.2	

[1] Hard coal production contains only bituminous coal and anthracite according to national classification
[2] preliminary
[3] including Croatia (cf. economic country groupings)

Table A-26: Hard coal consumption 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	China	3,499.1	53.4	53.4
2	India	887.2	13.5	67.0
3	USA	558.2	8.5	75.5
4	Japan	194.2	3.0	78.4
5	Russian Federation [1]	173.4	2.6	81.1
6	South Africa	171.8	2.6	83.7
7	Korea, Rep.	149.7	2.3	86.0
8	Kazakhstan	79.1	1.2	87.2
9	Poland	72.1	1.1	88.3
10	Taiwan	67.3	1.0	89.3
11	Australia	63.1	1.0	90.3
12	Ukraine [1]	54.1	0.8	91.1
13	Germany	52.6	0.8	91.9
14	Viet Nam	50.7	0.8	92.7
15	Turkey	39.5	0.6	93.3
16	Indonesia	35.0	0.5	93.8
17	Malaysia	31.9	0.5	94.3
18	Canada	28.6	0.4	94.8
19	Philippines	27.5	0.4	95.2
20	Brazil	24.3	0.4	95.6
	...			
	other countries [88]	291.1	4.4	100.0
	World	**6,550.4**	**100.0**	
	Europe	286.1	4.4	
	CIS	311.2	4.8	
	Africa	191.1	2.9	
	Middle East	12.1	0.2	
	Austral-Asia	5,094.5	77.8	
	North America	606.3	9.3	
	Latin America	49.2	0.8	
	OPEC	3.5	0.1	
	OPEC-Gulf	3.0	< 0.05	
	OECD	1,317.9	20.1	
	EU-28	243.6	3.7	

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

Table A-27: Hard coal export 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	Indonesia	389.5	28.9	28.9
2	Australia	373.0	27.7	56.6
3	Russian Federation	186.3	13.8	70.4
4	USA	88.0	6.5	76.9
5	Colombia	86.1	6.4	83.3
6	South Africa	83.0	6.2	89.5
7	Mongolia	33.4	2.5	91.9
8	Canada	31.0	2.3	94.2
9	Kazakhstan	27.0	2.0	96.2
10	Mozambique	12.6	0.9	97.2
11	China	8.1	0.6	97.8
12	Poland	7.1	0.5	98.3
13	Philippines	6.4	0.5	98.8
14	Korea, DPR	4.8	0.4	99.1
15	Czechia	2.4	0.2	99.3
16	Viet Nam	2.2	0.2	99.5
17	India	1.5	0.1	99.6
18	New Zealand	1.2	0.1	99.7
19	Malaysia	1.0	0.1	99.8
20	Chile	1.0	0.1	99.8
	...			
26	Germany	0.2	< 0.05	100.0
	...			
	other countries [6]	2.1	0.2	100.0
	World	**1,347.9**	**100.0**	
	Europe	10.5	0.8	
	CIS	213.9	15.9	
	Africa	95.6	7.1	
	Austral-Asia	821.2	60.9	
	North America	118.9	8.8	
	Latin America	87.7	6.5	
	OPEC	0.3	< 0.05	
	OECD	504.6	37.4	
	EU-28	10.5	0.8	

Table A-28: Hard coal import 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	China	271.1	19.9	19.9
2	India	208.3	15.3	35.1
3	Japan	192.8	14.1	49.2
4	Korea, Rep.	148.2	10.9	60.1
5	Taiwan	67.6	4.9	65.0
6	Germany	49.0	3.6	68.6
7	Turkey	38.3	2.8	71.4
8	Malaysia	31.5	2.3	73.7
9	Russian Federation	26.7	2.0	75.7
10	Thailand	22.1	1.6	77.3
11	Brazil	21.0	1.5	78.8
12	Philippines	20.9	1.5	80.4
13	Ukraine	19.8	1.4	81.8
14	Spain	19.2	1.4	83.2
15	Italy	15.4	1.1	84.3
16	Netherlands	14.9	1.1	85.4
17	Viet Nam	14.7	1.1	86.5
18	France	14.1	1.0	87.5
19	Poland	13.3	1.0	88.5
20	Chile	11.1	0.8	89.3
	...			
	other countries [72]	145.7	10.7	100.0
	World	**1,365.7**	**100.0**	
	Europe	211.9	15.5	
	CIS	48.5	3.5	
	Africa	14.6	1.1	
	Middle East	10.6	0.8	
	Austral-Asia	1,015.7	74.4	
	North America	25.0	1.8	
	Latin America	39.4	2.9	
	OPEC	1.5	0.1	
	OPEC-Gulf	1.5	0.1	
	OECD	593.9	43.5	
	EU-28	171.0	12.5	

Table A-29: Lignite 2017 [Mt]

	Country / Region	Production	Reserves	Resources	Total Resources
EUROPE	Albania	0.1	522	205	727
	Austria	–	–	333	333
	Bosnia & Herzegovina	14.0	2,264	3,010	5,274
	Bulgaria	34.4	2,174	2,400	4,574
	Croatia	–	n. s.	300	300
	Czechia	39.3	2,547	7,073	9,620
	France	–	n. s.	114	114
	Germany	171.3	36,100	36,500	72,600
	Greece	37.8	2,876	3,554	6,430
	Hungary	8.0	2,633	2,704	5,337
	Italy	–	7	22	29
	Kosovo	7.6	1,564	9,262	10,826
	Macedonia	5.0	332	300	632
	Montenegro	1.5	n. s.	n. s.	n. s.
	Poland	61.2	5,937	222,392	228,329
	Portugal	–	33	33	66
	Romania	25.7	280	9,640	9,920
	Serbia	39.8	7,112	13,074	20,186
	Slovakia	1.8	135	938	1,073
	Slovenia	3.4	315	341	656
	Spain	–	319	n. s.	319
	Turkey	74.1	10,975	5,284	16,259
	United Kingdom	–	–	1,000	1,000
CIS	Belarus	–	–	1,500	1,500
	Kazakhstan	5.2	n. s.	n. s.	n. s.
	Kyrgyzstan	1.6	n. s.	n. s.	n. s.
	Russian Federation	75.0	90,730	1,288,894	1,379,623
	Tajikistan	0.1	n. s.	n. s.	n. s.
	Ukraine	0.2	2,336	5,381	7,717
	Uzbekistan	3.6	n. s.	n. s.	n. s.
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
	Australia	56.1	76,508	403,382	479,890
	Bangladesh	–	–	3	3
	China	145.0	7,968	324,354	332,323

continuation of table A-29
[Mt]

	Country / Region	Production	Reserves	Resources	Total Resources
AUSTRAL-ASIA	India	46.7	4,895	38,878	43,773
	Indonesia	60.0	10,878	32,899	43,777
	Japan	–	10	1,026	1,036
	Korea, DPR	6.0	n. s.	n. s.	n. s.
	Laos	13.4	499	22	521
	Malaysia	–	39	412	451
	Mongolia	6.8	1,350	119,426	120,776
	Myanmar	0.2	3	2	5
	New Zealand	0.3	6,750	4,600	11,350
	Pakistan	1.2	2,857	176,739	179,596
	Philippines	–	146	842	988
	Thailand	16.3	1,063	826	1,889
	Viet Nam	–	244	199,876	200,120
NORTH AMERICA	Canada	9.2	2,236	118,270	120,506
	Mexico	–	51	n. s.	51
	USA	63.6	30,052	1,368,065	1,398,117
LATIN AMERICA	Argentina	–	–	7,300	7,300
	Brazil	1.5	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
	World	**1,036.9**	**319,878**	**4,424,395**	**4,744,273**
COUNTRY GROUPS	Europe	524.9	76,126	318,478	394,604
	CIS	85.6	93,065	1,295,775	1,388,840
	Africa	< 0.05	66	402	468
	Middle East	–	–	–	–
	Austral-Asia	352.0	113,209	1,303,288	1,416,498
	North America	72.9	32,339	1,486,335	1,518,674
	Latin America	1.5	5,073	20,118	25,191
ECONOMIC COUNTRY GRP.	OPEC	–	81	320	401
	OECD	526.1	177,485	2,175,638	2,353,123
	EU-28	382.8	53,356	287,344	340,700

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

Table A-30: Lignite resources 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	USA	1,368,065	30.9	30.9
2	Russian Federation [1]	1,288,894	29.1	60.1
3	Australia	403,382	9.1	69.2
4	China	324,354	7.3	76.5
5	Poland	222,392	5.0	81.5
6	Viet Nam	199,876	4.5	86.0
7	Pakistan	176,739	4.0	90.0
8	Mongolia [1]	119,426	2.7	92.7
9	Canada	118,270	2.7	95.4
10	India	38,878	0.9	96.3
11	Germany	36,500	0.8	97.1
12	Indonesia	32,899	0.7	97.9
13	Serbia	13,074	0.3	98.2
14	Brazil	12,587	0.3	98.4
15	Romania	9,640	0.2	98.7
16	Kosovo	9,262	0.2	98.9
17	Argentina	7,300	0.2	99.0
18	Czechia [1]	7,073	0.2	99.2
19	Ukraine	5,381	0.1	99.3
20	Turkey	5,284	0.1	99.4
	...			
	other countries [32]	25,119	0.6	100.0
	World	**4,424,395**	**100.0**	
	Europe	318,478	7.2	
	CIS	1,295,775	29.3	
	Africa	402	< 0.05	
	Austral-Asia	1,303,288	29.5	
	North America	1,486,335	33.6	
	Latin America	20,118	0.5	
	OPEC	320	< 0.05	
	OECD	2,175,638	49.2	
	EU-28	287,344	6.5	

[1] Lignite resources contains subbituminous coal

Table A-31: Lignite reserves 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	Russian Federation [1]	90,730	28.4	28.4
2	Australia	76,508	23.9	52.3
3	Germany	36,100	11.3	63.6
4	USA	30,052	9.4	73.0
5	Turkey	10,975	3.4	76.4
6	Indonesia	10,878	3.4	79.8
7	China	7,968	2.5	82.3
8	Serbia	7,112	2.2	84.5
9	New Zealand	6,750	2.1	86.6
10	Poland	5,937	1.9	88.5
11	Brazil	5,049	1.6	90.1
12	India	4,895	1.5	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]	2,547	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]	7,001	2.2	100.0
	World	**319,878**	**100.0**	
	Europe	76,126	23.8	
	CIS	93,065	29.1	
	Africa	66	< 0.05	
	Austral-Asia	113,209	35.4	
	North America	32,339	10.1	
	Latin America	5,073	1.6	
	OPEC	81	< 0.05	
	OECD	177,485	55.5	
	EU-28	53,356	16.7	

[1] Lignite reserves contains subbituminous coal

Table A-32: Lignite production 2012–2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2012	2013	2014	2015 [Mt]	2016	2017	Share [%] country	Share [%] cumulative
1	Germany	185.4	183.0	178.2	178.1	171.5	171.3	16.5	16.5
2	China	145.0	147.0	145.0	140.0	140.0	145.0	14.0	30.5
3	Russian Federation [1]	77.9	73.0	70.0	73.2	73.7	75.0	7.2	37.7
4	Turkey	68.1	57.5	62.6	56.1	70.2	74.1	7.1	44.9
5	USA	71.6	70.1	72.1	64.9	66.3	63.6	6.1	51.0
6	Poland	64.3	65.8	63.9	63.1	60.2	61.2	5.9	56.9
7	Indonesia [1]	60.0	65.0	60.0	60.0	60.0	60.0	5.8	62.7
8	Australia	69.1	59.9	58.0	61.0	59.8	56.1	5.4	68.1
9	India	46.5	44.3	48.3	43.8	45.2	46.7	4.5	72.6
10	Serbia [1]	38.0	40.1	29.7	37.7	38.4	39.8	3.8	76.5
11	Czechia [1]	43.7	40.6	38.3	38.3	38.6	39.3	3.8	80.2
12	Greece	62.4	54.0	50.4	45.6	32.3	37.8	3.6	83.9
13	Bulgaria [2]	31.0	26.5	31.3	35.9	31.2	34.4	3.3	87.2
14	Romania [1]	34.1	24.7	23.6	25.5	23.0	25.7	2.5	89.7
15	Thailand	18.1	18.1	18.0	15.2	17.0	16.3	1.6	91.3
16	Bosnia & Herzegovina [1]	12.2	11.8	11.7	12.2	13.6	14.0	1.4	92.6
17	Laos	0.5	0.4	< 0.05	4.5	13.1	13.4	1.3	93.9
18	Canada	9.5	9.0	8.5	8.4	9.0	9.2	0.9	94.8
19	Hungary [1]	9.3	9.6	9.6	9.3	9.2	8.0	0.8	95.6
20	Kosovo	8.0	8.2	7.2	8.2	8.8	7.6	0.7	96.3
	...								
	other countries [17]	49.9	50.4	44.4	42.0	41.3	38.4	3.7	100.0
	World	**1,104.6**	**1,058.8**	**1,030.7**	**1,022.8**	**1,022.6**	**1,036.9**	**100.0**	
	Europe	572.2	536.3	519.8	522.6	508.9	524.9	50.6	
	CIS	90.6	84.9	82.6	84.6	85.3	85.6	8.3	
	Africa	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	
	Austral-Asia	353.6	349.5	344.1	338.6	349.6	352.0	33.9	
	North America	81.1	79.0	80.6	73.4	75.3	72.9	7.0	
	Latin America	7.1	9.1	3.6 [3]	3.6 [3]	3.5 [3]	1.5 [3]	0.1	
	OECD	590.8	556.3	547.3	530.1	522.7	526.1	50.7	
	EU-28	436.8 [4]	410.3	400.5	400.7	371.3	382.8	36.9	

[1] Lignite production contains subbituminous coal
[2] Lignite production contains subbituminous coal from 2014
[3] Lignite production in 2014 is not comparable with previous years due to changes in statistics
[4] including Croatia (cf. economic country groupings)

Table A-33: Lignite consumption 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	Germany	171.3	16.5	16.5
2	China	145.0	14.0	30.5
3	Russian Federation [1]	75.0	7.2	37.7
4	Turkey	74.1	7.1	44.9
5	USA	63.6	6.1	51.0
6	Poland	61.2	5.9	56.9
7	Indonesia [1]	60.0	5.8	62.7
8	Australia	56.1	5.4	68.1
9	India	46.7	4.5	72.6
10	Serbia [1]	39.8	3.8	76.5
11	Czechia [1]	39.3	3.8	80.2
12	Greece	37.8	3.6	83.9
13	Bulgaria [1]	34.4	3.3	87.2
14	Romania [1]	25.7	2.5	89.7
15	Thailand	16.3	1.6	91.3
16	Bosnia & Herzegovina [1]	14.0	1.4	92.6
17	Laos	13.4	1.3	93.9
18	Canada	9.2	0.9	94.8
19	Hungary [1]	8.0	0.8	95.6
20	Kosovo [1]	7.6	0.7	96.3
	...			
	other countries [17]	38.4	3.7	100.0
	World	**1,036.9**	**100.0**	
	Europe	524.9	50.6	
	CIS	85.6	8.3	
	Africa	< 0.05	< 0.05	
	Austral-Asia	352.0	33.9	
	North America	72.9	7.0	
	Latin America	1.5	0.1	
	OECD	526.1	50.7	
	EU-28	382.8	36.9	

[1] Lignite consumption contains subbituminous coal

Table A-34: Uranium 2017 [kt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
EUROPE	Bulgaria	–	–	–	25	25	25
	Czechia	< 0.05	112	–	342	455	342
	Finland	n. s.	< 0.5	–	36	36	36
	France	< 0.05	76	–	12	88	12
	Germany	< 0.05	220	–	7	227	7
	Greece	–	–	–	13	13	13
	Hungary	–	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	–	34	39	34
	Sweden	n. s.	< 0.5	–	10	10	10
	Turkey	–	–	6	1	7	7
CIS	Kazakhstan	23.4	318	258	1,229	1,804	1,486
	Russian Federation	2.9	168	30	799	996	828
	Ukraine	0.6	22	42	321	386	363
	Uzbekistan	2.4	57	37	118	212	155
AFRICA	Algeria	–	–	–	20	20	20
	Botswana	–	–	–	74	74	74
	Central African Rep.	–	–	–	32	32	32
	Chad	–	–	–	2	2	2
	Congo, DR	–	26	–	3	28	3
	Egypt	–	–	–	2	2	2
	Gabon	n. s.	25	–	6	31	6
	Malawi	< 0.05	4	–	14	19	14
	Mali	–	–	–	13	13	13
	Mauritania	–	–	–	24	24	24
	Namibia	4.2	132	–	520	652	520
	Niger	3.4	147	18	459	623	476
	Somalia	–	–	–	8	8	8
	South Africa	0.3	161	168	851	1,180	1,019
	Tanzania	–	–	38	20	58	58
	Zambia	–	< 0.5	–	54	54	54
	Zimbabwe	–	–	–	26	26	26
MIDDLE EAST	Iran, Islamic Republic	–	< 0.5	–	16	16	16
	Jordan	–	–	–	98	98	98

continuation of table A-34
[kt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
AUSTRAL-ASIA	Australia	5.9	212	–	1,781	1,992	1,781
	China	1.9	44	95	185	324	280
	India	0.4	13	–	245	257	245
	Indonesia	–	–	2	33	35	35
	Japan	n. s.	< 0.5	–	7	7	7
	Mongolia	–	1	108	1,444	1,553	1,553
	Pakistan	< 0.05	2	–	–	2	–
	Viet Nam	–	–	–	85	85	85
NORTH AMERICA	Canada	13.1	524	228	1,462	2,214	1,690
	Greenland	–	–	–	278	278	278
	Mexico	n. s.	< 0.5	1	5	7	6
	USA	0.9	377	11	119	507	130
LATIN AMERICA	Argentina	–	3	5	85	92	90
	Brazil	< 0.05	4	156	421	581	577
	Chile	–	–	–	4	4	4
	Colombia	–	–	–	228	228	228
	Peru	–	–	14	59	73	73
	World	**59.6**	**2,696**	**1,236**	**11,709**	**15,641**	**12,945**
COUNTRY GROUPS	Europe	< 0.05	457	26	561	1,044	587
	CIS	29.3	565	366	2,467	3,398	2,833
	Africa	8.0	495	224	2,127	2,846	2,351
	Middle East	–	< 0.5	–	114	114	114
	Austral-Asia	8.2	271	205	3,780	4,255	3,985
	North America	14.1	901	240	1,864	3,006	2,104
	Latin America	< 0.05	7	175	797	978	972
ECONOMIC COUNTRY GRP.	OPEC	–	26	–	42	67	42
	OPEC-Gulf	–	< 0.5	–	16	16	16
	OECD	20.0	1,551	266	4,179	5,996	4,445
	EU-28	< 0.05	457	20	560	1,037	580

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

Table A-35: Uranium resources 2017 (>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	spekulative <260 USD/kg		country	cumu-lative
1	2	3	4 = 2+3	5	6	7= 4+5+6	8	9
Australia	1,150	631	1,781	n. s.	n. s.	1,781	15.2	15.2
Canada	395	217	612	150	700	1,462	12.5	27.7
Mongolia	–	33	33	21	1,390	1,444	12.3	40.0
Kazakhstan	157	536	693	236	300	1,229	10.5	50.5
South Africa	92	190	281	159	411	851	7.3	57.8
Russian Federation	275	397	672	126	n. s.	799	6.8	64.6
Namibia	298	165	463	57	n. s.	520	4.4	69.1
Niger	298	95	394	14	51	459	3.9	73.0
Brazil	–	121	121	300	n. s.	421	3.6	76.6
Czechia	51	68	119	223	–	342	2.9	79.5
Ukraine	97	81	179	23	120	321	2.7	82.2
Greenland	103	125	228	n. s.	50	278	2.4	84.6
India	121	18	139	106	n. s.	245	2.1	86.7
Colombia	–	n. s.	–	11	217	228	1.9	88.6
China	33	144	178	4	4	185	1.6	90.2
USA	119	n. s.	119	–	–	119	1.0	91.2
Uzbekistan	18	76	93	25	–	118	1.0	92.3
Jordan	–	48	48	–	50	98	0.8	93.1
Viet Nam	1	3	4	81	n. s.	85	0.7	93.8
Argentina	3	11	14	14	56	85	0.7	94.5
Botswana	14	60	74	n. s.	n. s.	74	0.6	95.2
Peru	–	19	19	20	20	59	0.5	95.7
Zambia	10	15	25	30	n. s.	54	0.5	96.1
Finland	1	35	36	–	–	36	0.3	96.4
Spain	13	21	34	–	–	34	0.3	96.7
Indonesia	4	2	6	28	n. s.	33	0.3	97.0
Central African Rep.	32	n. s.	32	n. s.	n. s.	32	0.3	97.3
Hungary	–	14	14	13	n. s.	27	0.2	97.5
Zimbabwe	1	n. s.	1	–	25	26	0.2	97.7
Bulgaria	–	–	–	25	n. s.	25	0.2	98.0
Mauritania	1	23	24	–	–	24	0.2	98.2
...								
Germany	3	4	7	–	–	7	0.1	99.7

continuation of table A-35
[kt]

Country/Region	Discovered RAR 80-260 USD/kg	Discovered inferred <260 USD/kg	Total	Undiscovered prognosticated <260 USD/kg	Undiscovered spekulative <260 USD/kg	Total	Share [%] country	Share [%] cumu-lative
1	*2*	*3*	*4=2+3*	*5*	*6*	*7=4+5+6*	*8*	*9*
World	**3,373**	**3,224**	**6,597**	**1,704**	**3,408**	**11,709**	**100.0**	
Europe	90	174	264	284	13	561	4.8	
CIS	547	1,090	1,637	409	420	2,467	21.1	
Africa	797	583	1,380	259	487	2,127	18.2	
Middle East	1	50	52	12	50	114	1.0	
Austral-Asia	1,316	831	2,147	239	1,394	3,780	32.3	
North America	617	344	961	153	750	1,864	15.9	
Latin America	4	152	156	347	293	797	6.8	
OPEC	26	4	29	12	–	42	0.4	
OPEC-Gulf	1	3	4	12	–	16	0.1	
OECD	1,862	1,146	3,007	411	760	4,179	35.7	
EU-28	90	173	263	284	13	560	4.8	

n. s. not specified
– no resources

Table A-36: Uranium reserves 2017 (extractable < 80 USD / kg U)
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[kt]	Share [%] country	Share [%] cumulative
1	Kazakhstan	258	20.9	20.9
2	Canada	228	18.5	39.3
3	South Africa	168	13.6	52.9
4	Brazil	156	12.6	65.5
5	Mongolia	108	8.7	74.3
6	China	95	7.7	82.0
7	Ukraine	42	3.4	85.4
8	Tanzania	38	3.1	88.5
9	Uzbekistan	37	3.0	91.5
10	Russian Federation	30	2.4	93.8
11	Niger	18	1.4	95.3
12	Peru	14	1.1	96.4
13	USA	11	0.9	97.3
14	Slovakia	9	0.7	98.0
15	Turkey	6	0.5	98.5
16	Argentina	5	0.4	98.9
17	Italy	5	0.4	99.3
18	Portugal	5	0.4	99.6
19	Slovenia	2	0.1	99.8
20	Indonesia	2	0.1	99.9
	...			
	other countries [1]	1	0.1	100.0
	World	**1,236**	**100.0**	
	Europe	26	2.1	
	CIS	366	29.6	
	Africa	224	18.1	
	Austral-Asia	205	16.6	
	North America	240	19.4	
	Latin America	175	14.2	
	OECD	266	21.5	
	EU-28	20	1.6	

Table A-37: Uranium resources 2017 (extractable < 130 USD / kg U)
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[kt]	Share [%] country	Share [%] cumulative
1	Australia	1,135.2	32.0	32.0
2	Canada	372.0	10.5	42.5
3	Kazakhstan	309.1	8.7	51.2
4	Russian Federation	268.2	7.6	58.7
5	South Africa	237.6	6.7	65.4
6	Niger	235.3	6.6	72.1
7	Namibia	189.6	5.3	77.4
8	Brazil	155.9	4.4	81.8
9	China	128.3	3.6	85.4
10	Mongolia	108.1	3.0	88.5
11	Ukraine	82.9	2.3	90.8
12	USA	82.5	2.3	93.1
13	Uzbekistan	54.6	1.5	94.7
14	Tanzania	40.4	1.1	95.8
15	Central African Rep.	32.0	0.9	96.7
16	Peru	14.0	0.4	97.1
17	Botswana	13.7	0.4	97.5
18	Zambia	9.9	0.3	97.8
19	Slovakia	8.8	0.2	98.0
20	Argentina	8.6	0.2	98.3
	...			
	other countries [16]	62.0	1.7	100.0
	World	**3,548.7**	**100.0**	
	Europe	37.5	1.1	
	CIS	714.8	20.1	
	Africa	776.9	21.9	
	Middle East	1.2	0,0	
	Austral-Asia	1,383.5	39.0	
	North America	456.3	12.9	
	Latin America	178.5	5.0	
	OPEC	6.0	0.2	
	OPEC-Gulf	1.2	0,0	
	OECD	1,632.5	46.0	
	EU-28	31.4	0.9	

Table A-38: Natural uranium production 2012–2017
The most important countries and distribution by regions and economic country groupings

Rank	Country / Region	2012	2013	2014	2015 [kt]	2016	2017	Share [%] country	Share [%] cumulative
1	Kazakhstan	21.3	22.6	23.1	23.8	24.6	23.4	39.3	39.3
2	Canada	9.0	9.3	9.1	13.3	14.0	13.1	22.0	61.3
3	Australia	7.0	6.4	5.0	5.7	6.3	5.9	9.9	71.2
4	Namibia	4.5	4.3	3.3	3.0	3.7	4.2	7.1	78.3
5	Niger	4.7	4.5	4.1	4.1	3.5	3.4	5.8	84.0
6	Russian Federation	2.9	3.1	3.0	3.1	3.0	2.9	4.9	88.9
7	Uzbekistan	2.4	2.4	2.4	2.4	2.4	2.4	4.0	93.0
8	China	1.5	1.5	1.5	1.6	1.6	1.9	3.2	96.1
9	USA	1.6	1.8	1.9	1.3	1.1	0.9	1.6	97.7
10	Ukraine	1.0	1.1	0.9	1.2	1.0	0.6	0.9	98.6
11	India	0.4	0.4	0.4	0.4	0.4	0.4	0.7	99.4
12	South Africa	0.5	0.5	0.6	0.4	0.5	0.3	0.5	99.9
13	Pakistan	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.1	99.9
14	Germany [1]	0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.1	100.0
15	Malawi	1.1	1.1	0.4	< 0.05	< 0.05	< 0.05	< 0.05	100.0
	France	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	100.0
	Romania	0.1	0.1	0.1	0.1	0.1	< 0.05	< 0.05	100.0
	Czechia	0.2	0.2	0.2	0.2	0.1	< 0.05	< 0.05	100.0
	Brazil	0.2	0.2	0.2	< 0.05	< 0.05	< 0.05	< 0.05	100.0
	...								
	World	**58.4**	**59.6**	**56.2**	**60.5**	**62.4**	**59.6**	**100.0**	
	Europe	0.4	0.3	0.3	0.2	0.2	< 0.05	0.1	
	CIS	27.5	29.2	29.4	30.4	31.0	29.3	49.1	
	Africa	10.7	10.5	8.3	7.5	7.6	8.0	13.4	
	Austral-Asia	8.9	8.2	6.9	7.7	8.4	8.2	13.8	
	North America	10.6	11.2	11.1	14.6	15.2	14.1	23.6	
	OECD	17.9	17.8	16.3	20.4	21.7	20.0	33.5	
	EU-28	0.4 [2]	0.3	0.3	0.2	0.2	< 0.05	0.1	

[1] only in the form of uranium concentrate as part of the remediation of production sites
[2] including Croatia (cf. economic country groupings)

Table A-39: Uranium consumption 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[kt]	Share [%] country	Share [%] cumulative
1	USA	19.00	29.2	29.2
2	France	9.50	14.6	43.8
3	China	8.29	12.7	56.6
4	Russian Federation	5.38	8.3	64.9
5	Korea, Rep.	4.73	7.3	72.1
6	Ukraine	1.94	3.0	75.1
7	United Kingdom	1.77	2.7	77.8
8	Canada	1.59	2.4	80.3
9	Germany	1.48	2.3	82.6
10	Spain	1.28	2.0	84.5
11	Sweden	1.19	1.8	86.4
12	Taiwan	1.13	1.7	88.1
13	Belgium	0.99	1.5	89.6
14	India	0.84	1.3	90.9
15	Japan	0.66	1.0	91.9
16	Slovakia	0.65	1.0	92.9
17	Czechia	0.65	1.0	93.9
18	U. Arab Emirates	0.63	1.0	94.9
19	Switzerland	0.50	0.8	95.7
20	Finland	0.49	0.8	96.4
	...			
	other countries [12]	2.33	3.6	100.0
	World	**65.01**	**100.0**	
	Europe	19.58	30.1	
	CIS	7.40	11.4	
	Africa	0.28	0.4	
	Middle East	0.78	1.2	
	Austral-Asia	15.87	24.4	
	North America	20.59	31.7	
	Latin America	0.52	0.8	
	OPEC	0.78	1.2	
	OPEC-Gulf	0.78	1.2	
	OECD	45.05	69.3	
	EU-28	19.08	29.3	

Table A-40: Geothermal energy 2017[1]

Region	El. Power [MW_e]	El. Energy Consumption [GWh_{th}]	Therm. Power without heat pumps [MW_e]	Therm. Energy Consumption without heat pumps [GWh_{th}]
Argentina	–	–	164	278
Australia	2	–	18	–
Austria	1	–	60	–
Belgium	–	–	10	–
Brazil	–	–	360	1,840
Canada	–	–	1,467	3,227
Chile	48	–	20	–
China	27	145	17,870	48,435
Costa Rica	207	1,538	1	6
Croatia	–	–	20	–
Czechia	–	–	8	–
Denmark	–	–	33	–
El Salvador	204	1,558	3	16
Ethiopia	7	< 0.5	2	12
Finland	–	–	1,560 [2]	5,000 [2]
France	17	115 [2]	509	–
Germany	36	160	374	1,377
Greece	–	–	232	–
Guatemala	49	247	2	16
Honduras	35	–	–	–
Hungary	3	–	253	–
Iceland	708	5,170	2,172	7,422
India	–	–	986	1,195
Indonesia	1,950	10,038	2	12
Iran, Islamic Republic	–	–	153	428
Israel	–	–	82	609
Italy	916	5,900 [2]	160	–
Japan	527	2,489	2,094	7,250
Jordan	–	–	153	428
Kenya	673	3,178	22	51
Korea, Rep.	–	–	44	165
Madagascar	–	–	3	21
Mexico	916	5,937	149	1,159
Mongolia	–	–	20	95

Region	El. Power [MW_e]	El. Energy Consumption [GWh_{th}]	Therm. Power without heat pumps [MW_e]	Therm. Energy Consumption without heat pumps [GWh_{th}]
Morocco	–	–	5	–
Nepal	–	–	3	23
Netherlands	–	–	142	–
New Zealand	1,005	7,453	487	2,395
Nicaragua	155	662	–	–
Norway	–	–	1,300	2,295
Pakistan	–	–	< 0.5	–
Papua New Guinea	53	–	–	–
Philippines	1,928	10,308	3	11
Poland	–	–	64	–
Portugal	33	200 [2]	–	–
Romania	< 0.5	–	88	–
Russian Federation	78	–	–	–
Saudi Arabia	–	–	44	–
Slovenia	–	–	4	–
South Africa	–	–	2	10
Sweden	–	–	44	–
Switzerland	–	–	13	–
Tajikistan	–	–	3	15
Thailand	< 0.5	–	129	–
Tunisia	–	–	44 [2]	–
Turkey	1,131	6,000 [2]	872	–
USA	2,486	16,060	17,416	21,075
United Kingdom	–	2	3	15
Viet Nam	–	–	31	–
Yemen	–	–	1	–

[1] Reliable actual data for countries outside of Europe covering the year 2017 is not available as of yet

[2] data partly from 2016 and older

– no data available

Data based on
EGEC, LIAG-GeotIS (for Germany), IRENA Renewable Statistics 2018

Table A-41: Geothermal – electricity installed power 2012–2017[1]

Rank	Country / Region	2012	2013	2014	2015 [MW$_e$]	2016	2017	Share [%] country	Share [%] cumulative
1	USA	3,442	3,525	3,450	3,567	3,596	2,486[2]	18.9	18.9
2	Indonesia	1,333	1,401	1,340	1,404	1,590	1,950	14.8	33.6
3	Philippines	1,904	1,917	1,870	1,930	1,929	1,928	14.6	48.3
4	Turkey	167	368	397	624	775	1,131	8.6	56.8
5	New Zealand	895	971	1,005	973	971	1,005	7.6	64.5
6	Mexico	1,017	834	1,017	1,069	907	916	6.9	71.4
7	Italy	876	916	916	915	916	916	6.9	78.4
8	Iceland	664	665	665	661	665	708	5.4	83.7
9	Kenya	249	590	594	607	676	673	5.1	88.8
10	Japan	537	539	519	540	544	527	4.0	92.8
11	Costa Rica	207	208	207	218	208	207	1.6	94.4
12	El Salvador	204	204	204	204	204	204	1.5	95.9
13	Nicaragua	150	160	159	155	160	155	1.2	97.1
14	Russian Federation	82	82	82	97	82	78	0.6	97.7
15	Papua New Guinea	56	56	50	56	56	53	0.4	98.1
16	Guatemala	48	48	52	49	48	49	0.4	98.5
17	Chile	–	–	–	–	–	48	0.4	98.8
18	Germany	24	27	27	31	38	36	0.3	99.1
19	Honduras	–	–	–	–	–	35	0.3	99.4
20	Portugal	29	29	29	23	29	33	0.3	99.6
	...								
	other countries [5]	55	54	53	55	53	48	0.4	100.0
	World	**11,938**	**12,594**	**12,636**	**13,178**	**13,447**	**13,187**	**100.0**	
	Europe	1,850	1,850	2,133	2,273	2,440	2,845	21.6	
	CIS	82	82	82	97	82	78	0.6	
	Africa	200	200	601	614	683	673	5.1	
	Austral-Asia	4,800	4,800	4,812	4,930	5,119	5,490	41.6	
	North America	5,100	5,100	5,089	4,636	4,503	3,402	25.8	
	Latin America	609	620	622	626	620	698	5.3	
	OECD	7,670	7,894	8,043	8,423	8,460	7,827	59.4	
	EU-28	946[3]	991	989	988	1,000	1,006	7.6	

[1] Data based on
BP Statistical Review 2017, IRENA Renewable Statistics 2018

[2] U.S. Energy Information Administration, U.S. Renewable Electricity Generation and CapacityShort-Term Energy Outlook – September 2018, https://www.eia.gov/renewable/data.php [10.2018]

[3] including Croatia (cf. economic country groupings)

A direct comparison with figures from previous years is not possible for all countries due to delayed data reporting or data publication. Total amounts may differ from the sum of individual values due to rounding errors.

Note in the REN21 report: current data cannot be easily compared with those of previous years, as revisions had to be made due to improved or adapted data or technologies (REN21 2018).

Table A-42: Geothermal energy – resources 2017

Region	theoretical potential up to 5 km depth [EJ] total	technical potenzial [EJ/year]		
		electricity	heat	total
Europe	2,342,000	37.1	3.5	40.6
CIS	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 of renewable energy 2017 [Mtoe]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Total	hydroelectric power	renewable energy (without hydroelectric power)
1	China	368.3	261.5	106.7
2	USA	161.9	67.1	94.8
3	Brazil	105.8	83.6	22.2
4	Canada	100.1	89.8	10.3
5	India	52.5	30.7	21.8
6	Germany	49.3	4.5	44.8
7	Russian Federation	41.7	41.5	0.3
8	Japan	40.3	17.9	22.4
9	Norway	32.7	32.0	0.7
10	Italy	23.7	8.2	15.5
11	United Kingdom	22.4	1.3	21.0
12	Sweden	21.4	14.6	6.8
13	France	20.5	11.1	9.4
14	Spain	19.9	4.2	15.7
15	Turkey	19.9	13.2	6.6
16	Venezuela, Bolivarian Rep.,	17.4	17.4	< 0.05
17	Viet Nam	16.0	15.9	0.1
18	Colombia	13.4	13.0	0.4
19	Austria	11.7	8.8	2.8
20	Mexico	11.6	7.2	4.4
	...			
	other countries [60]	255.2	175.1	80.1
	World	**1,405.5**	**918.6**	**486.8**
	Europe	292.2	130.4	161.8
	CIS	57.5	56.7	0.9
	Africa	34.6	29.1	5.5
	Middle East	5.9	4.5	1.4
	Austral-Asia	546.7	371.6	175.1
	North America	273.6	164.1	109.5
	Latin America	194.9	162.3	32.6
	OPEC	26.7	26.1	0.6
	OPEC-Gulf	4.6	4.2	0.4
	OECD	619.7	314.8	304.9
	EU-28	220.2	67.8	152.3

Table A-44: Renewable energy – installed electrical capacity 2017
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[MW]	Share [%]	
			country	cumulative
1	China	618,803	28.4	28.4
2	USA	229,913	10.6	38.9
3	Brazil	128,293	5.9	44.8
4	Germany	113,058	5.2	50.0
5	India	106,282	4.9	54.9
6	Canada	98,606	4.5	59.4
7	Japan	82,696	3.8	63.2
8	Italy	51,951	2.4	65.6
9	Russian Federation	51,779	2.4	68.0
10	Spain	47,989	2.2	70.2
11	France	46,678	2.1	72.3
12	United Kingdom	40,789	1.9	74.2
13	Turkey	38,725	1.8	76.0
14	Norway	33,283	1.5	77.5
15	Sweden	28,217	1.3	78.8
16	Austria	19,880	0.9	79.7
17	Australia	19,112	0.9	80.6
18	Mexico	19,025	0.9	81.5
19	Viet Nam	18,162	0.8	82.3
20	Switzerland	16,858	0.8	83.1
	...			
	other countries [193]	368,926	16.9	100.0
	World	**2,179,026**	**100.0**	
	Europe	544,123	25.0	
	CIS	77,646	3.6	
	Africa	41,753	1.9	
	Middle East	18,920	0.9	
	Austral-Asia	932,714	42.8	
	North America	347,635	16.0	
	Latin America	215,809	9.9	
	OPEC	40,978	1.9	
	OPEC-Gulf	15,106	0.7	
	OECD	996,105	45.7	
	EU-28	444,704	20.4	

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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 (Slovakia)
National Coal and Mineral Industries Holding Corporation – Vinacomin (Viet Nam)
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

Office Djiboutien de Developpement de l`Energie Geothermique, Djiboutian Office for the Development of Geothermal Energy – ODDEG

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 Steinkohlegesellschaft)
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

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
Aquifer gas	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
Associated gas	Natural gas dissolved in the crude oil in the reservoir which is released when the oil is produced
b, bbl	Barrel; standard American unit for 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
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 on 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); english energy unit
CBM	Coal-bed methane; gas contained in coal, including methane
ce	Coal equivalent; corresponds to the amount of energy released when burning 1 kg hard coal, cf.: Conversion factors
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 out after production. Also known as natural gas liquids (NGL) (density >45°API or < 0.80 g/cm³)
Crude oil	Natural occurring mixture of liquid hydrocarbons. The liquid hydrocarbons such as natural gas liquids (NGL) and condensates co-produced from a natural gas well 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). *Non-conventional crude oil:* Hydrocarbons that cannot be produced used "classic" 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; synthetic fuel made from coal
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	Renewable Energy Sources Act in Germany
EGC	European Geothermal Congress

EGS	Enhanced geothermal systems: geothermal systems artificially enlarged by fracking and without any naturally convecting fluids
EIA	U.S. Energy Information Administration
EIB	European Investment Bank
EITI	Extractive Industries Transparency Initiative
EOR	Enhanced oil recovery: processes used to improve the natural recovery rate of an oilfield
ESA	Euratom Supply Agency – European Commission
ESMAP	Energy Sector Management Assistance Program
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 (cf. Reserves growth)
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 thermal-water-filled horizons (hydrothermal).
Gas hydrate	Solid (snow-like) molecular compound consisting of gas and water which is stable under high pressures and low temperatures
GDC	Geothermal Development Company
GDP	Gross Domestic Product

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 m^3 natural gas, Super-Giant: > 680 million t oil or > 850 billion m^3 natural gas, Mega-Giant: > 6,800 million t oil or > 8,500 billion m^3 natural gas
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
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
IAEA	International Atomic Energy Agency; UN agency; headquarters in Vienna. cf. Economic country groupings
ICEIDA	Icelandic International Development Agency
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., ExxonMobil Corp., BP plc, Royal Dutch Shell plc, Total, 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*

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 Geophysics), 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)
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 (H_2S) in the ppm range *Conventional natural gas*: free natural gas or crude oil gas in structural or stratigraphic traps *Natural gas from non-conventional deposits (in short: non-conventional 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 non-conventional deposits of natural gas include shale gas, tight gas, coal bed methane (CBM), aquifer gas and gas from gas hydrates
NCG	Non-condensable gases
NEA	Nuclear Energy Agency; part of OECD, headquarters in Paris
NGB	North German Basin

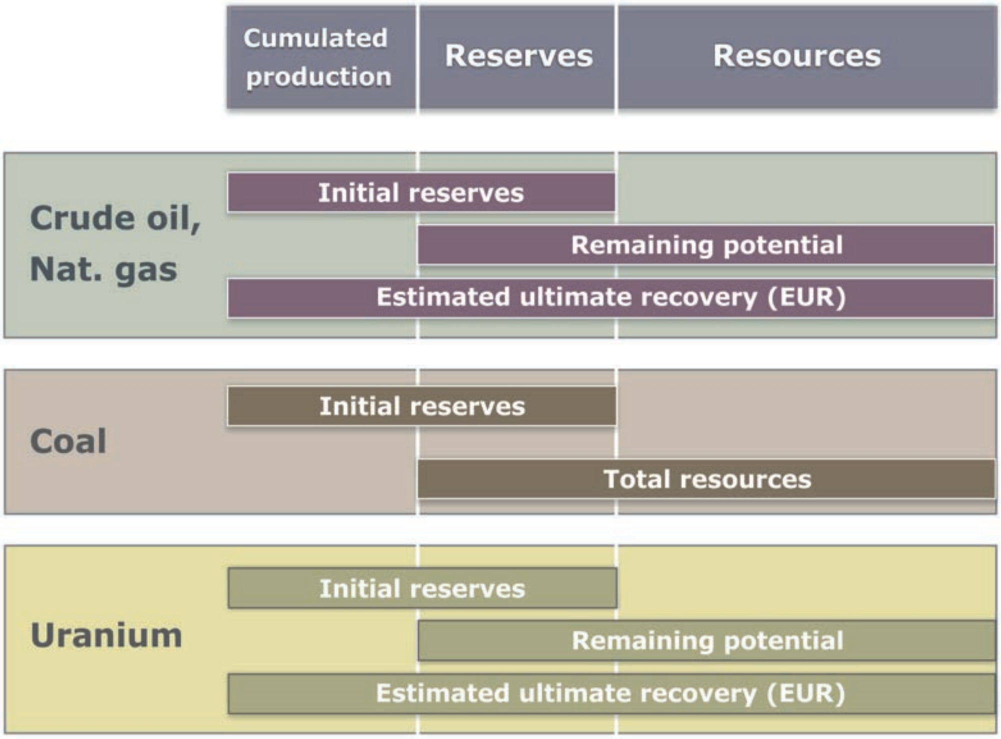
NGL	Natural gas liquids
NGPL	Natural gas plant liquids: constituents of produced natural gas which are liquefied separately in the processing plant, (→ Condensate)
OECD	Organisation for Economic Co-operation and Development, headquarters in Paris; cf. Economic country groupings
OPEC	Organization of Petroleum 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
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
Petroleum	Crude oil and petroleum products produced in refineries
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
Recovery rate	Amount of oil which can be recovered from an oilfield in per cent
REEGLE	Renewable Energy and Energy Efficiency Partnership
REmap 2030	Renewable Energy Roadmap
REN21	Renewable Energy Policy Network for the 21st Century
Renewable energy resources	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.
reserve growth	(→ field growth)

Reserves	Proven volumes of energy resources economically exploitable at today's prices and using today's technology *Original reserves: cumulative production plus remaining reserves*
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
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 (→CE, here: in tonnes) corresponds to approx. 29.308 x 109 Joules; cf.: Conversion factors
Tight Gas	Natural gas from tight sandstones and limestones
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 non-conventional deposits (in short: non-conventional 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 extractable.

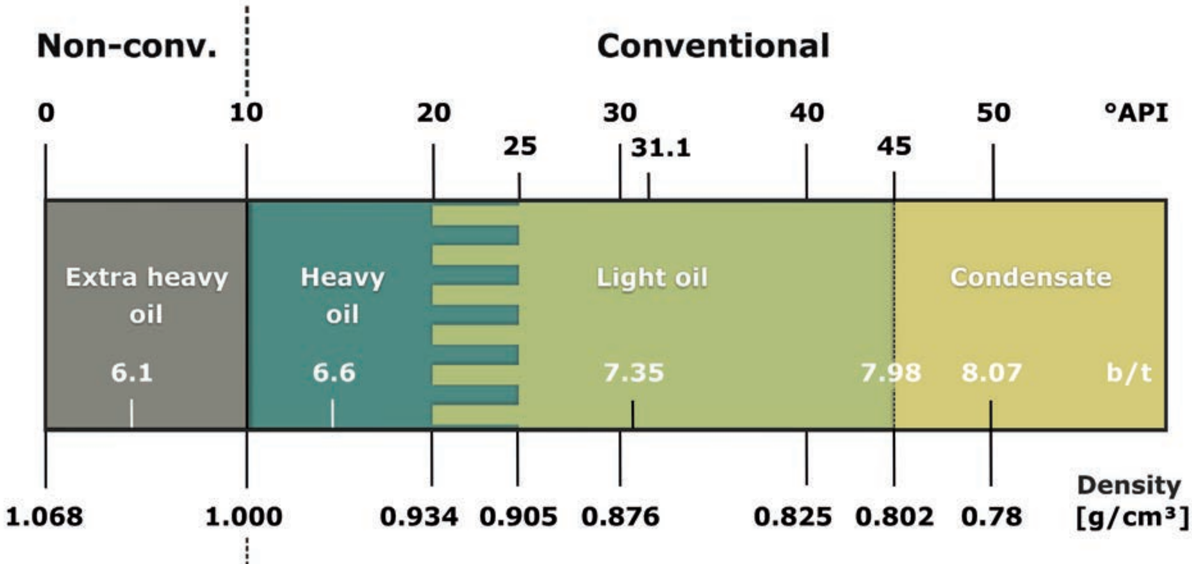
URG	Upper Rhine Graben
USAID	United States Agency for International Development
USD	US-Dollar; currency of the United States of America
USGS	United States Geological Survey
VDKi	Verein der Kohlenimporteure e.V. (Coal Importer Association); headquarters in Berlin
WEC	World Energy Council, headquarters 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 is collected at a national level on the current situation regarding shallow and deep geothermal energy. This data is presented at the congress.
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 for the American market

DEFINITIONS

Distinction between reserves and resources



Classification of crude oil according to its density

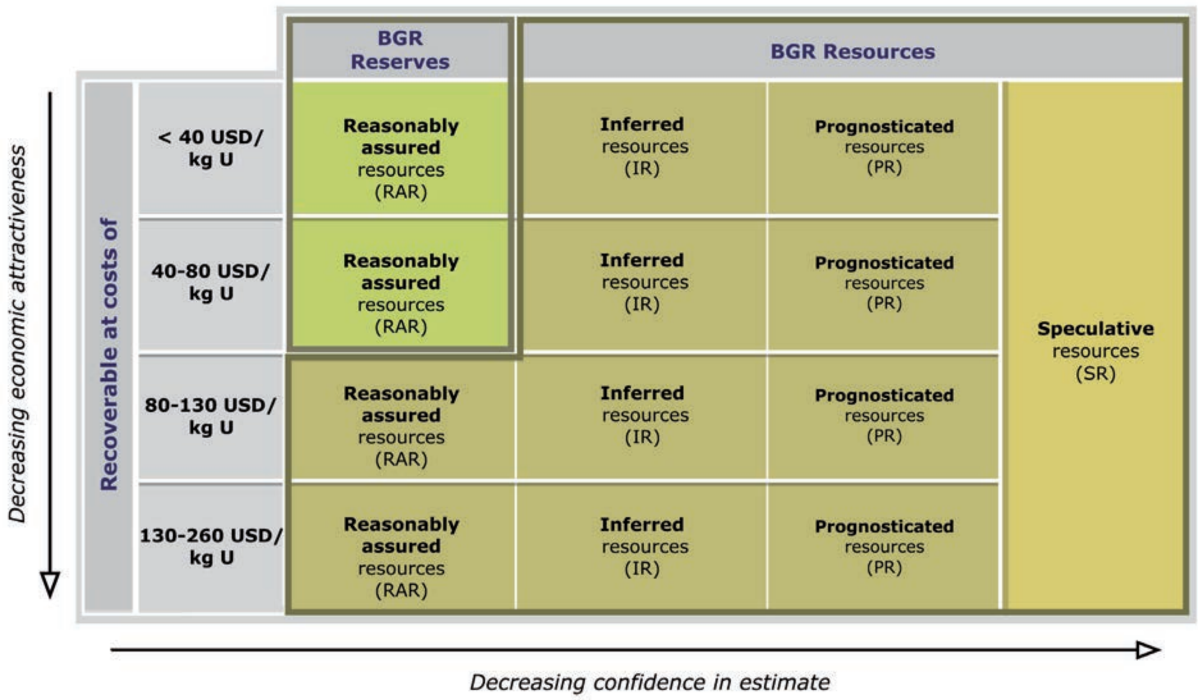


Uranium reserves classification according to cost categories

Unlike the 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 information on the one hand (e.g. about size and position) of uranium deposits, but could also be due on the other hand 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 are classified as reserves (green). All resources with higher extraction costs are classified as resources (brown) from the point of view of BGR.

Diagram showing uranium reserves classification according to cost categories

(modified after IAEA and OECD 2014)



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 inc. Georgia

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

Africa

Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo (Democratic Republic), Congo (Republic), Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kap Verde,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, Swaziland, 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, Saint Kitts and Nevis, Saint Lucia, Saint Pierre and Miquelon, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay, Venezuela (Bolivarian Republic), Virgin Islands (Brit.), Virgin Islands (Americ.).

ECONOMIC COUNTRY GROUPINGS STATUS: 2017

BRICS-nations

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

European Union

EU-15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
EU-25	European Union (from 01.05.2004): EU-15 plus new Member: Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia
EU-27	European Union (from 01.01.2007): EU-25 plus new Member: Bulgaria and Romania
EU-28	European Union (from 01.07.2013): EU-27 plus new Member: Croatia

IAEA (International Atomic Energy Agency; 169 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, Central African Republic, Chad, Chile, China, Colombia, 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, Ethiopia, Fiji, Finland, France, Gabon, Georgia, Germany, Ghana, Greece, 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, Saindt Vincent nd the Grenadines, San Marino, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, South Africa, Spain, Sri Lanka, Sudan, Swaziland, 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; 35 coutries)

Australia, Austria, Belgium, Canada, Chile, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea (Republic), Lativa, 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; 14 countries)

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

OPEC-Gulf

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

UNITS

b, bbl	barrel	1 bbl = 158.984 liter
cf	cubic feet	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 1,013 mbar [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	Billionen 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	1Wh = 3.6 kWs = 3.6 kJ
k	Kilo	10^3
M	Mega	10^6
G	Giga	10^9
T	Tera	10^{12}
P	Peta	10^{15}

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 G. 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

DISCLAIMER

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