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Data and Developments Concerning German and Global Energy Supplies

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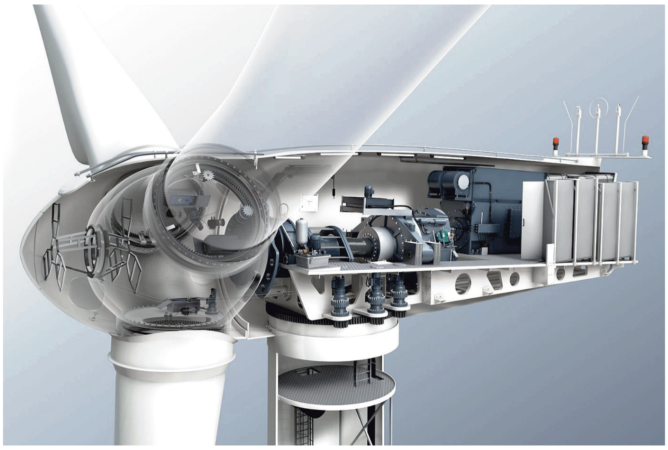
The Federal Institute for Geoscience and Natural Resources (BGR) is a technical and scientific agency of the Federal Ministry for Economic Affairs and Energy (BMWi).

FOREWORD

The crude oil and natural gas markets are oversupplied. The main concerns are not geological availability but rather questions concerning production cuts and the reduction of the volumes held in strategic crude oil reserves. At the same time, cheap natural gas is forcing coal out of the market in the USA, and production is also being considerably cut back in China for political reasons despite the country's immense reserves. These specific aspects typify in a highly simplified way the energy situation characterising the preceding year. Taken together with the rapid increase in the growth rates of renewable energy, does this indicate an end to all questions concerning the security of energy supplies?

In terms of the geology of natural resources, the reserves of crude oil, natural gas, coal and uranium will be capable of continuing to cover increasing demand for many decades. Together with the renewables, this means that energy supplies can be maintained in the long term. Fossil fuels are still indispensable as the main energy sources in the short to medium term, and it is essential that their supplies match the demand. The overall supply situation for all energy resources is currently considered to be comfortable. The production of crude oil for instance primarily comes from conventional fields which were developed prior to the continuing low price phase affecting oil prices. Without a quick and continuing rise in the price of crude oil, it appears unlikely that investments will be made in new projects to the extent required to smoothly cover a rise in global demand. It remains to be seen whether the relatively flexible crude oil production from shale deposits can act as an „economic swing producer" to bridge any potential shortages in supplies. Given the complex and instable geopolitical situations affecting many crude oil producers and production regions, it will also be necessary to include unforeseeable problems affecting the global crude oil supply situation in the calculations.



Whilst renewables exhibit the highest growth rates amongst all of the energy resources in terms of power production, their share of total primary energy consumption is still only growing slowly. Instead of already displacing fossil energy resources today, they are merely covering the rise in energy demand, supporting the withdrawal from nuclear power production, and ameliorating urgent environmental problems. One can therefore expect the continuing existence of a „dual energy system" in the next years and decades, where energy supplies are maintained jointly by fossil fuels and renewable energy.

The BGR Energy Study 2017 provides information in the form of data and facts on the status and developments concerning German and global energy supplies with respect to all energy resources: crude oil, natural gas, coal, uranium, and renewable energy, including deep geothermal energy. In the „Energy resources in focus" section of this year's Energy Study, a more detailed look will be taken at „Lithium – A key natural resource for the energy and mobility transition", „Underground coal gasification: background, potential and risks" and „Options for utilising associated gas – situation analysis in Algeria and Cameroon".

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1 SUMMARY

Introduction – Global energy consumption grew further in 2016. 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 is now covered roughly equally by renewable energy resources and fossil energy resources. Nevertheless, crude oil, natural gas and coal continue to form the backbone of energy supplies. This means that the dependency of energy supplies on fossil energy resources will continue for the foreseeable future. A rise in the international competition for energy resources is therefore expected against this background. In Germany as well, there is no end in sight of the country descreasing its high dependency on imports of fossil energy resources despite the high growth rate of renewables – and due in part to the decline in domestic production and the withdrawal from nuclear power generation. 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 2016 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 are derived from BGR's energy resources database.

Results – All of the renewables together cover around 17 % of global energy consumption. Despite the almost inexhaustible potential, making energy generation from renewable sources available at a large scale and commensurate with demand is still in its infancy. By way of contrast, very large reserves of fossil energy resources have already been developed for many years, and are being used in growing quantities. The global comparison of already produced and therefore consumed energy resources, and the still existing reserves and resources, reveals that large non-depleted energy potential still exists in all regions around the world (Fig. 1-1). Whilst the potential hardly appears to be touched in Austral-Asia, the CIS and North America, only a small part has been produced to date even in Europe. This wealth in resources is primarily attributable to the large deposits of coal found on all continents, which, unlike conventional crude oil and natural gas, are not restricted to a few special regions. Although the Middle East is an extremely important region for crude oil and natural gas, the minor coal reserves in the area mean that its overall potential is comparatively small.

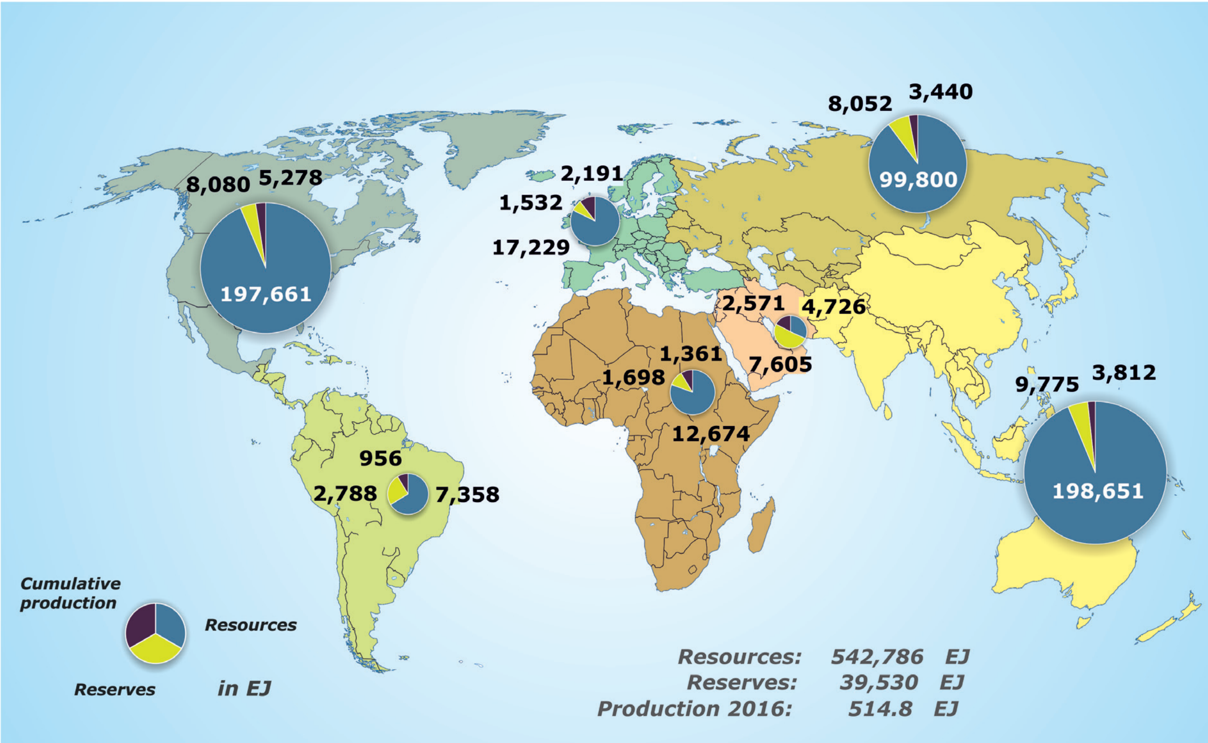

Figure 1-1: Total potential of fossil energy resources including uranium for 2016 (excluding the Antarctic). Regional distributions excluding resources of aquifer gas, natural gas from gas hydrates, and thorium, because these cannot be classified regionally (estimated accumulative production of coal since 1950).

With a share of 550,690 Exajoules (EJ), 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 compared to the previous year which have no influence on the global resource figures. The energy content of all reserves rose last year to 39,530 EJ (plus 2.8 %) in particular because of a re-evaluation of the extra-heavy oil deposits in Venezuela. 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 and again managed to slightly increase its shares compared to the previous year. Because of the larger non-conventional shares 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 assessment of the global energy mix, i.e. the actual energy consumed including renewables. In terms of geological 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. 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 30.6 % during the reporting period.

- **In terms of the geology of natural resources, a moderate rise in demand can be satisfied in the next few years.** The reserves and resources mainly rose because of a re-evaluation of the Venezuelan extra-heavy oil reserves as well as global oil shale resources, which led to a significant increase. Conventional crude oil reserves, however, which are crucial for the supply of petroleum, remained almost constant.

- **Germany and Europe are highly dependent on crude oil imports.** Although Germany and Europe are amongst the world's largest consumers of petroleum, only a very small proportion of their demand can be covered from domestic production.

- **A properly functioning global crude oil market is indispensable for maintaining the security of global supplies.** Countries in the Middle East and the Russian Federation account for around 54.5 % of global crude oil exports. Geopolitical instabilities in these countries could very quickly lead to production shortages and a rise in prices.

- **The supplies of crude oil to Germany are currently comprehensively diversified with 33 supplying countries.** The most important supplier continues to be the Russian Federation, followed by Norway and the United Kingdom. These three countries alone account for almost 62 % of German imports.

- **Discoveries of new conventional oil fields have declined considerably world-wide.** As a consequence of the strong decline in investments in the upstream sector, discoveries of new conventional oil fields have dropped to a relatively low level. The amounts of oil produced so far have largely been compensated for by a growth in the reserves of existing fields.

Natural gas

- **From a geological point of view, supplying the world with natural gas will be possible for many decades to come.** Natural gas is still present in very large quantities world-wide.

- **Around 80 % of global natural gas reserves are located in OPEC countries and the CIS, and are almost exclusively conventional.** The proportion of non-conventional reserves world-wide is around 5 %.

- **The largest natural gas reserves are in the Middle East.** The region has substantial offshore as well as onshore reserves. The most extensive onshore reserves are in the Russian Federation.

- **The global trade in natural gas rose again in 2016.** The trade in liquefied natural gas (LNG) increased more than gas transported by pipelines. The largest share of the LNG export growth is attributable to Australia which boosted its exports by almost 50 %.

- **The closer integration of the various natural gas markets driven by the generous supplies of LNG contributed to the increased convergence of global prices.** At the same time, the trend of falling natural gas prices seen in 2016 continued against the background of the relatively cheap crude oil prices.

- **The dependency of Germany and Europe on imports is increasing because of declining domestic natural gas production.** Although Europe has access to a large share of global reserves, geopolitical risks are a key factor affecting its natural gas supplies.

- **Germany is the world‘s largest importer of natural gas, and with a share of 23 %, accounts for almost one quarter of the total gas imports to Europe.** Germany is also one of the largest gas consumers in the world with a consumption of around 101.5 bcm.

Coal

- **From a geological point of view, the reserves and resources of hard coal and lignite are capable of covering the foreseeable demand for decades.** With a share of around 54 % of reserves and around 89 % of resources, coal has the largest potential of all non-renewable energy resources.

- **Coal will continue to play a major role in future against the background of the expected rise in global primary energy consumption.** The absolute global demand for coal will probably remain relatively constant in the medium term, however, in relative terms, the significance of coal will tend to decrease.

- **The global coal sector has been experiencing a restructuring phase since 2012, and the global production of coal sank by almost 10 % in the last four years because of the decreasing demand.** Global coal production increased again for the first time in 2017 since 2013, and could be three per cent higher than 2016 according to preliminary estimates.

- **There was a strong rise in prices on the world market for hard coal from summer 2016. Coal prices also stabilised at a relatively high level in 2017 as well although the price of coking coal was very volatile.** The higher coal prices indicate the end of the many years of oversupply. This situation will probably not change to any significant degree in the short term because of inadequate investment in the export coal mines.

- **The development in global and therefore also European coal prices will primarily be determined by the current situation in Asia, and especially in China.** China increased its coal imports in 2016 by around 25 % to around 256 Mt, and a further increase in imports of possibly around 10 % can be expected in 2017 as well. Other countries, especially in Southeast Asia, such as Vietnam and the Philippines, have also reported significant increases in their import volumes.

- **Germany reduced its imports of hard coal in 2016 by almost four per cent to around 53.1 Mt.** Together with coke and briquettes, Germany currently imports 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.** The decline in uranium prices which has continued since 2011, and is driven by the consequences of the reactor accident in Fukushima, continued for the fifth year in a row.

- **Global uranium production continues to grow.** Production was expanded in Kazakhstan in particular. With a share of almost 40 %, Kazakhstan is still the most important uranium producer world-wide. Australia and Namibia also reported growing production figures. In Namibia, the Chinese-owned Husab mine went into production in 2016 and could advance to become the world‘s largest uranium mine in future.

- **There continues to be a growing interest in the use of nuclear fuels for the generation of energy world-wide.** 61 nuclear reactors were under construction in 15 countries at the end of 2016. 21 of these in China alone. The demand for uranium will continue to grow further in the long term in Asia in particular.

- **No shortage in the supplies of nuclear fuels is anticipated from a geological point of view.** Global reserves, despite a current reduction, are very extensive, and currently total 1.2 Mt reserves (cost category < 80 USD/kg U) as well as 11.6 Mt uranium resources. The reduction in uranium resources compared to the previous year is primarily because of the absence of resources in the USA reported as inferred resources. These inferred resources are currently being revised and will probably make a contribution to a growth in the resource volumes in the next few years.

- **The withdrawal from commercial power generation from nuclear power plants in Germany is laid down in law.** Nine of the 17 nuclear power plants in Germany have been shut down since the amendment to the Atomic Energy Act in 2011. Complete withdrawal takes place by the end of 2022.

Deep geothermal energy

- **Deep geothermal energy is a successfully tested type of energy production which is attractive in the context of climate change, as well as from a geopolitical point of view.** The innovative, low-emmision technology, is capable of generating base load power and has a relatively small spatial demand (on the earth surface).

- **The global geothermal energy potential is very large although it has only been exploited to a very minor extent so far.** The share of geothermal energy in global power production in 2016 was around 0.3 %. The global potential for geothermal energy down to a depth of 3 km is estimated at around 300 EJ/a for heat generation, and around 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 challenging.** There are considerable variations in investment costs, and they are very difficult to estimate in advance. Typical amortisation periods are in excess of 25 years.

- **Globally, the use of geothermal energy shows an extremely diverse picture.** Countries with high enthalpy resources enjoy favourable conditions. Geothermal energy could become particularly important for developing countries with such resources where it can help provide electricity and heat in regions with poor infrastructures.

- **The use of geothermal energy has risen in Germany over a period of many years.** In the last five years (2011 to 2016) the installed capacity has increased more than fivefold and is currently around 38 MW_e, whilst the installed capacity for thermal generation during this time period has approximately doubled and is now around 391 MW_{th}. The share of primary energy consumption continues to remain low, however, at 0.3 %. Geothermal energy is subsidised in Germany by the Renewable Energy Act (EEG).

Renewable energy

- **Around 17 % of global primary energy consumption was accounted for by renewable energy in 2016, and particularly by "classic" renewables such as solid biomass and hydropower.** The share of "modern" energy sources such as windpower and photovoltaics is still relatively low despite extremely rapid expansion world-wide.

- **The globally installed power generation capacity has reached new record levels.** 2,008 GW of renewables are installed world-wide for power generation. This corresponds to around 30 % of estimated global power generation capacities. Photovoltaics boast the highest growth rates for the first time. The new installed capacity totals 71 GW, of which around 44 % was accounted for by China alone.

- **International activities to promote renewables continue at a high level.** Around 176 countries have currently formulated concrete targets for further expansion. Currently, 62 % of the global expansion of installed power generation capacities are accounted for by the addition of renewables. Investment in new projects was, however, down in 2016.

- **Renewable energy is the most important power source in Germany.** The share of renewables in the German power mix reached around 29 % in 2016. Windpower, biomass and photovoltaics accounted for the lion‘s share. The influence of the weather, however, led to lower levels of power generation from renewables compared to the previous year.

- **The energy transition continues to boast in Germany.** Compared with 2001, there has been a quadrupling of the share of renewable energy in Germany‘s overall primary energy consumption. Further expansion of renewable energy in the power, transport and heat sector is to be expected in the future.

2 ENERGY SITUATION IN GERMANY

2.1 Primary energy consumption and energy supplies

Germany is making progress in fundamentally restructuring its energy supplies: away from nuclear and fossil fuels, towards renewable energy. It is therefore expected that around 40 % to 45 % of electrical energy will be provided by renewable sources in 2025, and at least 80 % by 2050 (BMWi 2017a). At the same time, the energy demand in all sectors is expected to be significantly and sustainably reduced where this can be implemented prudently at a macroeconomic level. Total primary energy consumption (PEC) is to be reduced by 20 % by 2020, and by 50 % by 2050 compared to the 2008 reference year (BMWi 2017b, Fig. 2-1). The remaining energy demand is then intended to be largely provided via the direct use of renewables as well as via sector decoupling (efficient use of renewable power in the heat, transport and industrial sectors) (BMWi 2017b).

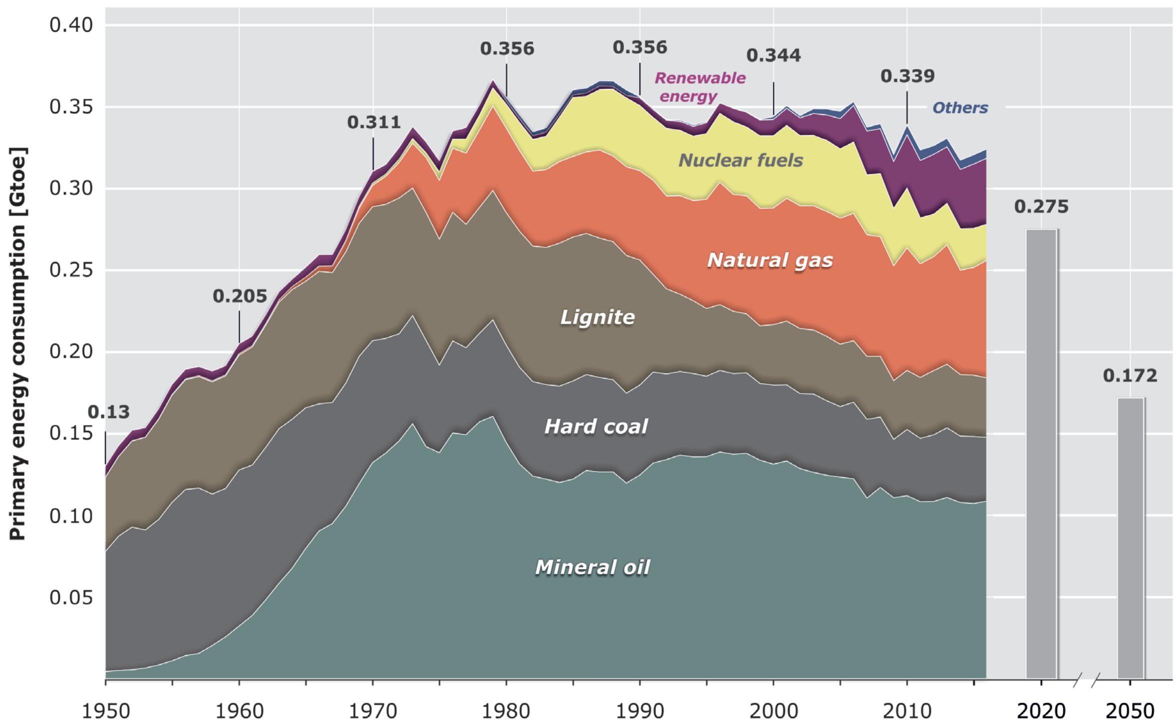

Figure 2-1: Development of German primary energy consumption (AGEB 2017) and forecast targets for 2020 and 2050 (BMWi 2017b).

Primary energy consumption (PEC) reached an all-time high as far back as the end of the 1970s, at the same time as peak German crude oil consumption was reached. Since then, energy consumption has remained at a relatively high level but with an overall slightly declining trend, despite economic growth. The increasing decoupling of economic growth and energy consumption is attributable to technical advances made in the energy sector, more frugal and rational energy utilisation, and changes in economic structures. Fluctuations in energy consumption in recent years are mainly attributable to the influence of the weather. As in the past decades, the most important source of energy is petroleum, followed by natural gas. Third place is occupied in 2016 for the first time by renewable energy which is now ahead of coal, lignite, nuclear power and others.

Compared to the previous year, PEC in Germany rose again slightly in 2016 by around 1.1 % to total 13,383 PJ in 2016 and therefore now matches the level last reached in the 1970s. This is attributable to the increase in the population (plus 0.8 million inhabitants), and the colder weather compared to the previous year, and the associated rise in demand for heating energy. 2016 was also a leap year with an additional “energy consuming” day. Adjusting for the effect of the weather and the leap year, growth would have been 0.4 % and attributable only to economic activity (AGEB 2017).

The rise in energy demand was primarily covered by the rise in the consumption of natural gas (plus 9.5 %), renewables (plus 2.8 %) and petroleum (plus 1.5 %). Reductions were recorded by nuclear power (minus 7.8 %), coal (minus 5.1 %) and lignite (minus 2.8 %) (AGEB 2017). There was therefore a slight increase overall in the share of fossil fuels, which as in the past ten years, account for around 80 % of total primary energy consumption.

As a highly-developed industrial nation, Germany is one of the ten largest energy consumers in the world, and covers most of its energy demand (over 80 %) by importing energy resources. Of all of the resources (energy resources, metal resources and non-metals) with a total value of € 136.8 billion imported in 2016, the largest part amounting to 52 % was accounted for by the energy resources crude oil, natural gas and coal. In 2016, Germany imported 406 Mt of natural resources, which was 1 % down on the previous year. Energy resources decreased by 1.2 % (BGR 2017). The most important countries from which Germany imports fossil energy resources are the Russian Federation, Norway, and the Netherlands.

Around 2 % of the crude oil and 8 % of the natural gas in 2016 was accounted for by domestic production (Fig. 2-2), where the declining trend continues. The decline in production is largely attributable to the increasing depletion of the fields and the lack of new discoveries. The biggest decline is associated with coal: when the planned withdrawal from subsidised coal production is implemented at the end of 2018, this sector of domestic energy production will disappear completely. Domestic production of coal accounted for 7 % of consumption in 2016. The foreseeable continuing demand for coal will then have to be covered exclusively by imports. Of all the energy resources, lignite is the only non-renewable energy resource which is available in large economically extractable amounts in Germany. Germany supplies all of its own needs here, and is the world‘s largest producer and consumer. Nevertheless, lignite production also declined slightly. Renewable energy has now established itself as the most important domestic energy source (accounting for around 43 % of all of the energy generated in Germany), followed by lignite which accounts for around 39 %. Way behind, come domestically produced natural gas, coal and crude oil (AGEB 2017).

The 10-year comparison reveals that all fossil energy resources, and nuclear power in particular, had lower shares of PEC in Germany, whilst the share of renewables increased (Fig. 2-2). This means that there was a relative as well as an absolute decline in the share of fossil fuels used to cover German primary energy consumption. The contribution from domestic production is set to decline further because of the declining production from domestic conventional crude oil and natural gas fields, and the end of subsidised coal production. There will therefore be no foreseeable reduction in Germany‘s high import dependency on fossil energy resources.

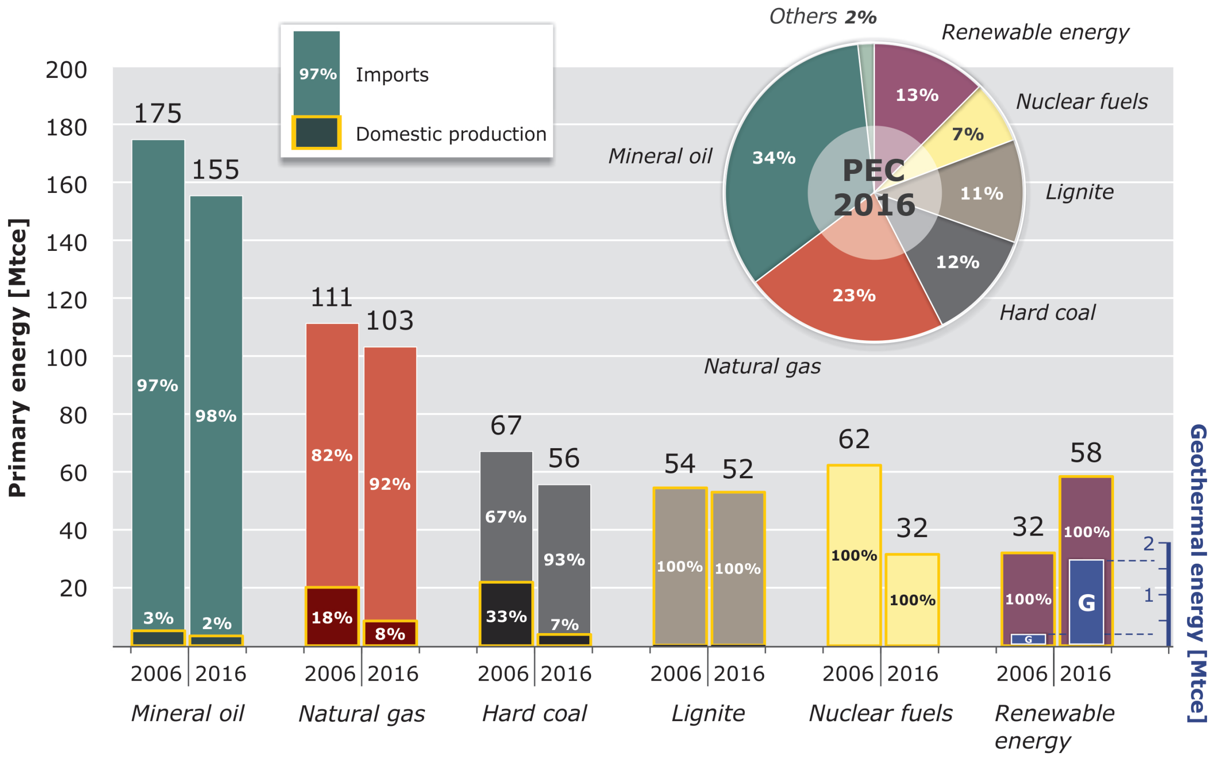

Figure 2-2: Import-dependency and domestic supply level in Germany of specific primary energy resources in 2006 and 2016 (AGEB 2017, BMU 2013).

2.2 Energy resources and energy in detail

Crude oil

Crude oil is by far the most important primary energy resource in Germany. And crude oil will also remain an indispensable pillar of German energy supplies in the coming decades. Crude oil products are primarily used as fuel in the transport sector. The German government is pursuing the objective of reducing the final energy consumption in the transport sector by 10 % in 2020 compared to 2005, and by 40 % by 2050 (BMWi 2017c). This target can only be achieved by the phased conversion to electromobility and climate-friendlier natural gas – although this will take decades to achieve. Crude oil is also the most important basic raw material for the organic-chemical industry (VCI 2017). As one of the largest consumers of petroleum world-wide, Germany is almost completely dependent on crude oil imports.

The total of proven and probable crude oil reserves declined by 2.1 Mt (minus 6 %) year-on-year and totalled 31.8 Mt at the end of 2016. The crude oil produced during the reporting year was therefore only compensated for to a minor degree by the development of new parts of fields. German crude oil reserves are mainly located in the North German Basin, where Schleswig-Holstein (50.7 %) and Niedersachsen (21.1 %) account for over 70 % of German reserves. No new fields were discovered during the reporting period (LBEG 2017).

Crude oil and condensate production in Germany declined slightly compared to the previous year to 2.36 Mt in 2016 (2015: 2.42 Mt). As in the previous year, 50 oil fields were in production at the end of 2016. The 10 fields with the highest production covered almost 90 % of the total. The production volumes from the largest German oil field by far at Mittelplate/Dieksand declined slightly by around 1.8 % to 1.29 Mt, and therefore continued to account for almost 55 % of domestic crude oil production. Crude oil production from the next most important oil fields changed as follows: Rühle 0.179 Mt (plus 5.7 %), Römerberg 0.166 Mt (minus 6.8 %) and Emlichheim 0.152 Mt (minus 4.6 %). A total of 991 production wells were in operation with an average daily output of 6.51 t. Condensate accounted for 13,270 t of crude oil production in 2016, corresponding to 0.6 % of total German domestic production. 13 % of German condensate production was accounted for alone by the only offshore natural gas field in the German North Sea: A6/B4. Enhanced oil recovery (EOR) methods have been used for many years to boost the recovery factors of the Emlichheim, Georgsdorf and Rühle fields using techniques such as steam and hot/warm water flooding. The production of 0.28 Mt achieved using EOR methods accounted for around 12 % of total production (LBEG 2017).

Exploration and development activity in the oil and gas sector continued to be held back by the low crude oil prices which have held sway since the end of 2014. Although the total number of metres drilled rose slightly year-on-year by 4,400 m to 37,000 m, it has still remained at a low level (LBEG 2017). The German oil and gas industry had 8,655 employees at the end of 2016, which is a decline of 1,149 year-on-year. This is one of the most severe drops for decades (BVEG 2017). The production royalties paid by the crude oil and natural gas producers to the sates of Germany declined to around € 219 million (minus 39.6 %) compared to the previous year because of the low prices for crude oil and natural gas. € 62 million of these production royalties were accounted for by crude oil production. The size of the production royalties depends primarily on the value of crude oil on the market, as well as the quantities of crude oil produced.

The most important oil production companies and their production levels in 2016 in Germany according to consortium shares were as follows (BVEG 2017):

- Wintershall Holding AG — 904,692 t
- DEA Deutsche Erdöl AG — 670,584 t
- ENGIE E&P Deutschland GmbH — 381,604 t
- BEB Erdgas und Erdöl GmbH & Co. KG — 239,800 t

The amount of crude oil imported by Germany in 2016 declined very slightly year-on-year by 0.2 % (minus 0.19 Mt) to around 91.1 Mt. Germany imports crude oil from around 33 countries. However, the three most important suppliers – the Russian Federation, Norway and the UK – account for almost 62 %. The main supplying regions continue to be the CIS states (54.4 %), Europe (23.7 %) and Africa (13.8 %) (Fig. 2-3).

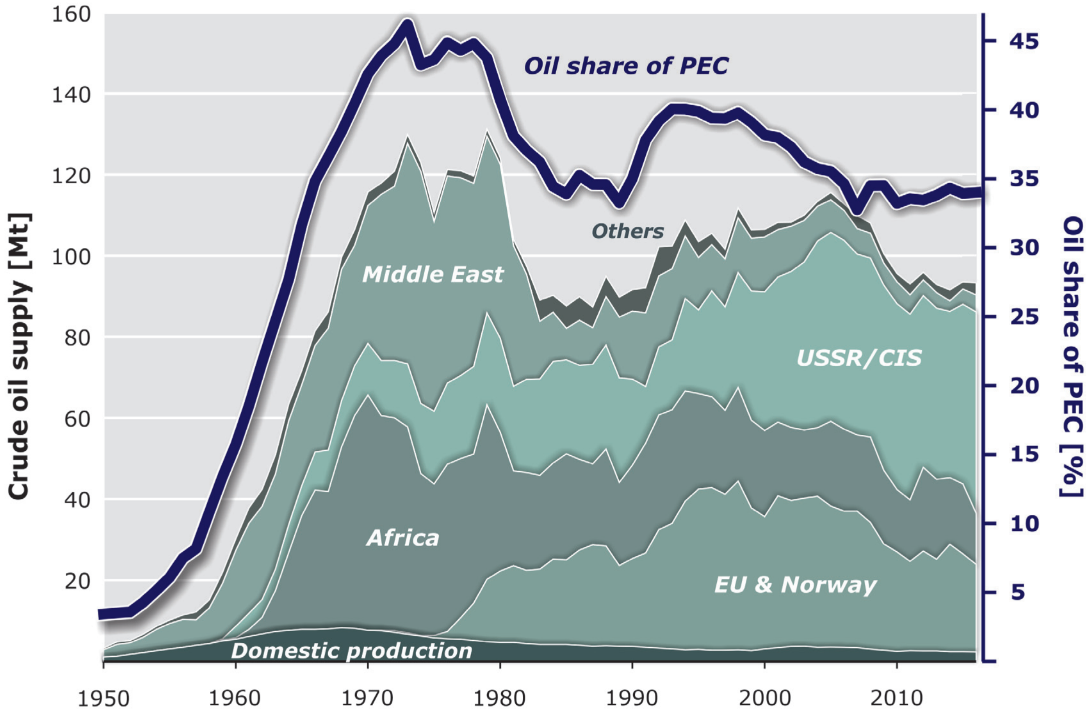

Figure 2-3: Germany's crude oil supplies from 1950 to 2016.

The quantities imported from the Russian Federation grew considerably (plus 3.471 Mt), as well as from Kazakhstan (plus 1.988 Mt). There was also a significant growth in imports from Iraq (plus 32 %) and Angola (plus 99 %).

Smaller amounts were imported from Nigeria (minus 2.881 Mt), and Norway (minus 1.344 Mt). Because of the civil war, the volumes imported from Libya declined further and were down another 38 % to almost 1.78 Mt (BAFA 2017a). Table A-5 (Appendix) lists all of the crude oil supplying countries in 2016.

German companies produced around 8.4 Mt crude oil overseas in 2016. This is a reduction of around 0.1 Mt year-on-year. Wintershall was able to significantly increase its production by over 1 Mt, primarily in Norway. DEA Deutsche Erdoel AG1[1] also reported a considerable increase in production.

The restructuring of the energy company E.ON in 2015/16 led to the spinning off of its energy production segments to the independent company Uniper SE. The crude oil and natural gas concessions in the Norwegian North Sea were sold to DEA Deutsche Erdoel AG at the end of 2015, whilst the concessions in the British North Sea were acquired by the British crude oil producer Premier Oil at the beginning of 2016.

1 DEA Deutsche Erdoel AG was acquired by the LetterOne investment company from Luxemburg in 2015, and is therefore no longer a German company according to BGR's definition.

The most important German crude oil producing companies and their foreign production in 2016 according to consortium shares (BVEG 2017, BGR research):

- Wintershall Holding AG 5.6 Mt
- DEA Deutsche Erdoel AG 2.5 Mt
- Bayerngas Norge AS 0.2 Mt
- VNG-Verbundnetz Gas AG 0.1 Mt

Natural gas

Natural gas will continue to make a significant contribution to German energy supplies in the next decades. The heating market is the most important market for natural gas as it has been in the past. However, natural gas today is not only limited to the generation of heat, but is also a flexible and diverse energy resource for power generation, apart from its function as a raw material for the chemical industry. In addition, natural gas is also more climate-friendly than other fossil energy resources because its use is associated with lower CO_2 emissions. Finally, natural gas is also playing an increasingly important role as a cheap and climate-friendly fuel in the mobility sector (BMWi 2017d).

The total proven and probable natural gas reserves in Germany as at 31 December 2016 totalled 70.1 bcm (V_n) raw gas (minus 5.8 %) and 65.4 bcm (V_n) pure gas (minus 3.3 %). Although reserves declined for another year in a row, half of the raw gas volumes produced in 2016 (4.3 bcm (V_n)) and almost three quarters of the produced pure gas volume (5.6 bcm V_n)) were replaced by an increase in reserves (LBEG 2017). Around 81 % of German natural gas reserves are located in Permian reservoirs. Of which 43 % in Rotliegend sandstones and 39 % in Zechstein carbonate rocks (LBEG 2017).

Natural gas definitions in Germany

The figures for production and reserves of natural gas are reported by the German production industry as “raw gas volumes” in reservoir engineering terms, as well as “pure gas volumes” in gas industry terms The raw gas volumes correspond to the gas extracted from the reservoirs with the natural calorific values, which can vary considerably from field to field in Germany. The pure gas figure refers to a standard higher calorific value of Ho = 9.7692 kWh/m³ (V_n), which is also known as the “Groningen calorific value” by the gas production industry, and is a fundamental parameter in the gas industry (LBEG 2017).

Natural gas production in Germany declined further in 2016 by 0.7 bcm (V_n) to 8.6 bcm (V_n) raw gas, and 7.8 bcm (V_n) pure gas in each case. This corresponds to a year-on-year reduction of 7.7 % of raw gas and 8.1 % of pure gas. The declining production volumes are primarily attributable to the increasing depletion of the large fields, and therefore naturally declining production rates. The key natural gas province in Germany is in Niedersachsen, whose share of raw gas production in Germany was around 94 % in 2016.

In addition, around 65 million m^3 (V_n) of oil-associated gas were extracted during crude oil production in 2016. This type of gas is primarily produced in Niedersachsen (59.8 %) and Schleswig-Holstein (28.2 %).

During the reporting year, a total of 469 (previous year: 476) production wells were operating in 77 fields, of which over 90 % were located in Niedersachsen. As in previous years, around two thirds of the total annual production in Germany came from 10 fields in 2016 (LBEG 2017).

Based on their consortium shares, five companies accounted for more than 98 % of domestic pure gas production in 2016. These are as follows according to BVEG (2017):

▪ BEB Erdgas und Erdöl GmbH & Co. KG	3.206 bcm
▪ Mobil Erdgas-Erdöl GmbH	1.897 bcm
▪ DEA Deutsche Erdoel AG	1.395 bcm
▪ ENGIE E&P Deutschland GmbH	0.600 bcm
▪ Wintershall Holding GmbH	0.555 bcm
Total	**7.653 bcm**

Around 40 % of domestic natural gas reserves contain varying high concentrations of hydrogen sulphide (H_2S). The processing of the sulphurous natural gas primarily derived from fields in the production area between the Weser and Ems rivers, generated around 0.58 Mt of elemental sulphur in the Großenkneten gas processing plant. This is mainly used by the chemical industry, and is even exported in part.

The production of natural gas on a large scale did not begin in Germany until the 1960s after the development of the Bunter Sandstone and Zechstein reservoirs in Niedersachsen. Natural gas production in 2003 was still at around 22 bcm but has continuously declined since 2004, and was only 39 % of the 2003 figure during the reporting period.

The potentially extractable volumes of natural gas in Germany (resources) from shale gas deposits are estimated at approximately 0.32 to 2.03 tcm, and lie at a depth of 1,000 to 5,000 m (BGR 2016a). In addition, coal seams are estimated to have a potential of 0.45 tcm of natural gas resources (BGR 2016b).

Developing shale gas deposits and coal seam gas requires the use of hydraulic stimulation ("fracking"). The German Bundestag (parliament) vetoed the use of fracking to develop natural gas or crude oil deposits in shale, claystone or marlstone, as well as in coal seams, in a resolution adopted in June 2016. Permission was only allowed for a maximum of four testing measures – under the supervision of an expert commission – for the purposes of scientific research, in particular looking at the environmental impact. The testing measures also have to be approved by the government of the state in question. The German Bundestag is to review the appropriateness of the ban in 2021. The exploration and development of domestic shale gas deposits in the coming years is therefore unlikely against the background of the legislation currently in place. Within the foreseeable future, domestically produced shale gas will therefore not help compensate for the decline in domestic natural gas production.

The production of natural gas by German companies outside of Germany (CIS/Russian Federation, South America, Europe and North Africa) increased by 2.7 % compared to 2015, and totalled around 26.1 bcm in the reporting year. The highest levels of production by far (accounting for around 65 %) was again generated by Wintershall AG, the largest internationally active German oil and gas producing company. The group is mainly active in Europe, North Africa and South America, but also in the Russian Federation and around the Caspian Sea, and also reports increasing activities in the Middle East. Wintershall is one of the largest natural gas producers in the Netherlands, too.

The new E.ON and Uniper SE have been operating as independent companies since 1 January 2016. The new E.ON concentrates on renewables, energy grids and customer solutions, whilst Uniper SE is in the energy supply sector with its conventional production and global energy trading departments. Uniper Exploration & Production GmbH produced a pro rata share estimated at 5.9 bcm in 2016 from one of the largest natural gas fields in the world: Yushno Russkoje in the Russian Federation. E.ON Ruhrgas AG sold this trade investment to the Austrian oil and gas company OMV Exploration & Production GmbH at the beginning of 2017. E.ON had already sold its shares in the Norwegian and British North Sea concessions at an earlier date.

The natural gas production of DEA Deutsche Erdoel AG rose significantly year-on-year (BVEG 2017). The main reasons being newly acquired Norwegian fields, and in particular Skarv (formerly owned by E.ON Ruhrgas).There was also more production from older Norwegian fields, primarily Gjøa and Snøhvit.

The share of natural gas in primary energy consumption rose significantly compared to the previous year (21.1 %) to 22.6 %, and natural gas was again the second most important energy resource in Germany in 2016 behind crude oil (AGEB 2017).

With respect to natural gas volumes (raw gas), the calculated volume of the total amount of natural gas turned over from domestic production and imports was down year-on-year by around 3.4 % to a calculated amount of 120.6 bcm (Tab. A-6 in the Appendix).

Unlike 2015, less natural gas was re-exported, and smaller amounts of natural gas were extracted from the German natural gas storages. This equates to a year-on-year rise in consumption of 5.6 % to around 101.5 bcm. Around 8.4 % of the natural gas volume consumed in Germany was derived from domestic raw gas production.

Imports of natural gas in the reporting period from January to December 2016 according to preliminary estimates totalled 4,156,376 TJ (BAFA 2017b) and were therefore 3 % lower than the corresponding volume in 2015 (4,283,360 TJ). However, in December 2016, natural gas imports were around 3 % higher than the same month the previous year at 409,833 TJ (397,552 TJ).
The Federal Agency for Economic Affairs and Export Controls (BAFA) at the beginning of 2016

no longer supplies information on the amounts supplied by individual export countries for data protection reasons. It can be assumed, however, that the three most important countries supplying Germany with natural gas in the reporting year were again the Russian Federation, followed by Norway and the Netherlands (Fig. 2-4).

The value of natural gas imports in 2016 totalled € 17.8 billion compared to € 24.5 billion in the same period the previous year (BAFA 2017b).

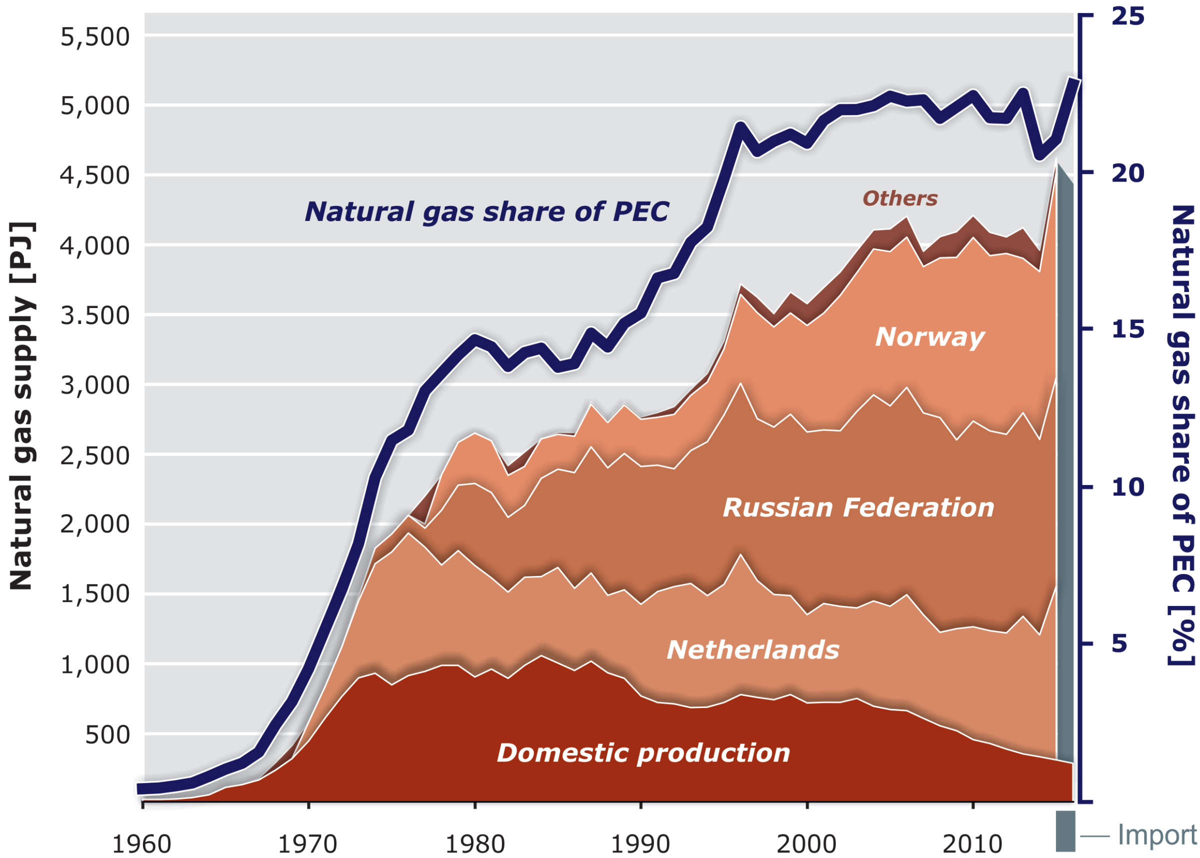

Figure 2-4: Natural gas supplies in Germany from 1960 to 2016.

Hard coal

Domestic hard coal was a major factor behind Germany's economic development in the previous century. Hard coal production has been in decline ever since. The highest hard coal production figures after 1945 were reached in 1956 with 152.5 Mt saleable output (Fig. 2-5). The figures in 2016 were 3.8 Mt saleable output (2.5 % compared to 1956). Domestic hard coal has been replaced in previous decades by crude oil, natural gas, uranium and in particular by imported hard coal. Germany's total hard coal resources (total reserves and resources) are around 83 Gt, of which around 8 Mt are still exploitable to the end of 2018.

The Prosper-Haniel mine in the Ruhr coalfield produced around two thirds (2.5 Mt saleable output) of German hard coal production in 2016. German hard coal produced from one mine in the Ibbenbüren coalfield (Ibbenbüren mine) accounted for around one third (1.3 Mt saleable output) of German hard coal production (Fig. 2-5). Because of the closure of the Auguste Victoria mine in the Ruhr coalfield according to plan on 1 January 2016, the number of active German hard coal mines reduced to just two. Hard coal production in the Saar coalfield ended back in June 2012.

Total sales of German coal declined in line with the drop in production in the reporting year by 29 %. It declined by 1.9 to 4.7 Mt. Shift output across the country in 2016 declined by 8.4 % to 6,645 kg saleable output (GVST 2017, SDK 2017).

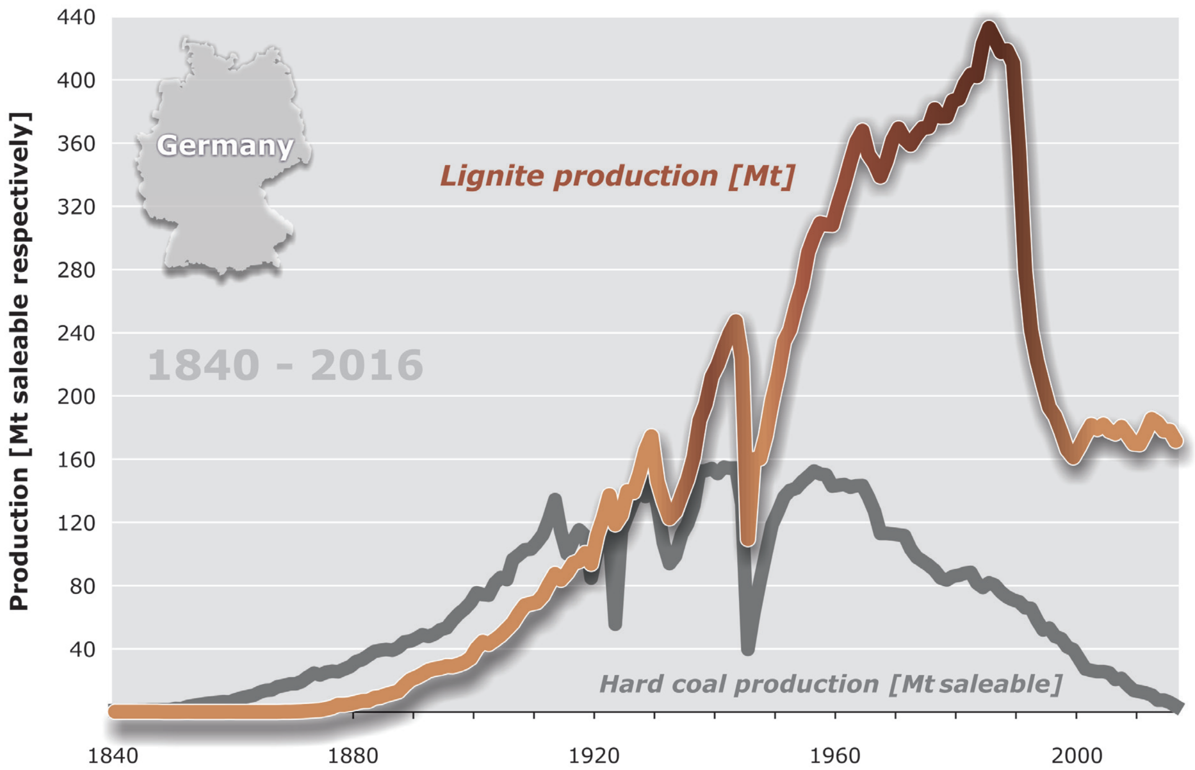

Figure 2-5: German coal production from 1840 to 2016 (after SDK 2017).

Hard coal mining in Germany has not been internationally competitive for many years because of the unfavourable geological conditions in particular. This has also been demonstrated in recent years by the increasing depths from which German hard coal has been produced in the past decades. Whilst the average production depth in 1971 was still only 758 m, this increased by more than 500 m to 1,261 m in 2016 (Fig. 2-6). The clear increase in the average thickness of the mined hard coal seams shown in Figure 2-6 is primarily attributable to the closure of mines with relatively thin hard coal seams and their often associated higher production costs. The significant increase in the

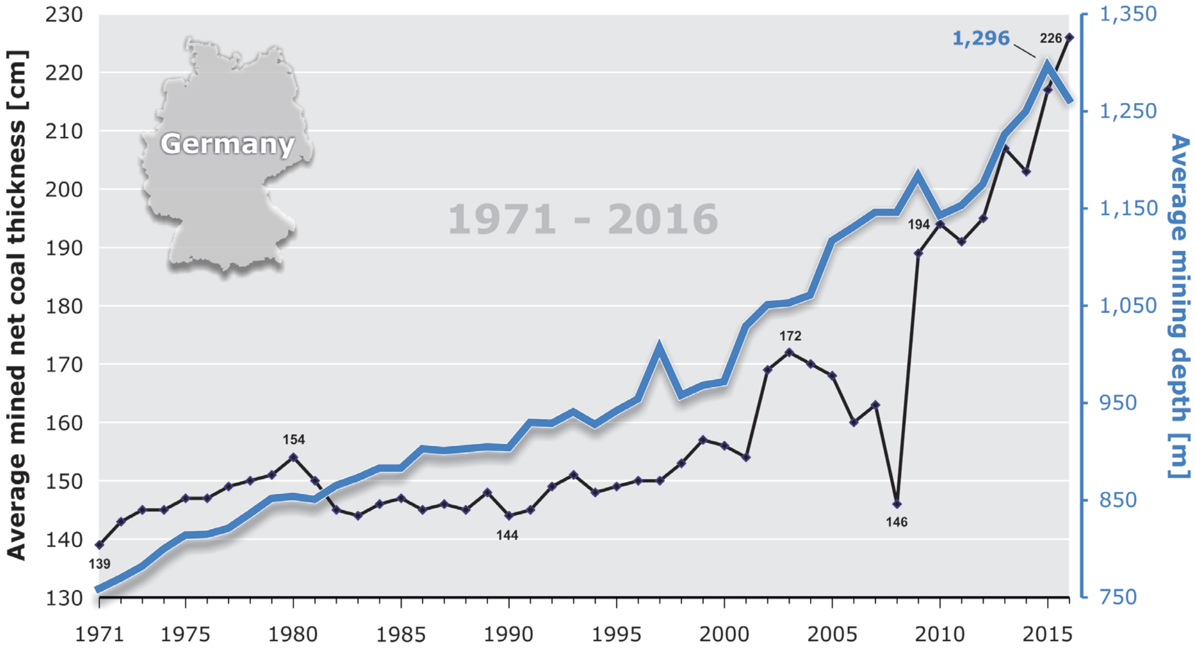

Figure 2-6: Change in average mined hard coal seam thickness and average mining depth in German coal mines from 1971 to 2016 (SDK 1985, 1990, 2017, GVST 2017).

average thickness of the mined hard coal seams in the last two years to 2.26 m in 2016 is primarily a consequence of the hard coal production begun in November 2014 from the Zollverein 1/2 coal seam which has an average thickness of 4 m in the Prosper-Haniel mine (van de Loo & Sitte 2015).

According to the estimates of the Coal Importer Association (Verein der Kohlenimporteure e.V. (VDKI)), average German hard coal production costs in 2016 were 180 €/tce. The average annual price for imported steam coal, however, was 67.07 €/tce (VDKI 2017a). Nevertheless, domestic hard coal mining was publically subsidised to enable it to make a contribution to supplying hard coal to steel works and power plants, as well as for political reasons to support the job market. Hard coal mining was scheduled to receive € 1,224.5 million in public subsidies in the 2016 reporting year (BMWi 2017e).

In February 2007, the German government, the state of Nordrhein-Westfalen and the Saarland, reached an agreement to end the subsidised production of 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 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 2017e).

The workforce in the German hard coalfields has declined continuously since 1958. The number of employees at the end of 2016 declined by 22.4 % compared to 2015 to 7,480.

Compared to 2015, the consumption of hard coal in Germany was slightly lower during the reporting year according to preliminary estimates. It reduced by around 5.1 % to around 55.6 Mtce. The share of hard coal in primary energy consumption therefore dropped to 12.2 % compared to 13 % the previous year (AGEB 2017). Only around 7 % of German hard coal consumption in 2016 was derived from domestic production.

Imports of hard coal and hard coal products declined by around 4 % year-on-year to 55.2 Mt. They were mainly derived from the Russian Federation, Colombia, the USA, Australia, Poland and South Africa. The Russian Federation with around 17.8 Mt (32.2 %) was again the largest supplier in 2016, followed by Colombia (19.4 %), and the USA (16.5 %) (Fig. 2-7). Imports from Poland – the last major coal exporting country in the European Union (EU-28) – declined significantly to 2.8 Mt. This included around 1.3 Mt of coke (VDKI 2017a). The share of imports in total coal turnover in Germany rose year-on-year to around 93 %. Import dependency on coal will increase further with the additional mine closures at the end of 2018. The Ibbenbüren and Prosper-Haniel hard coal mines will close at the end of 2018 (van de Loo & Sitte 2017).

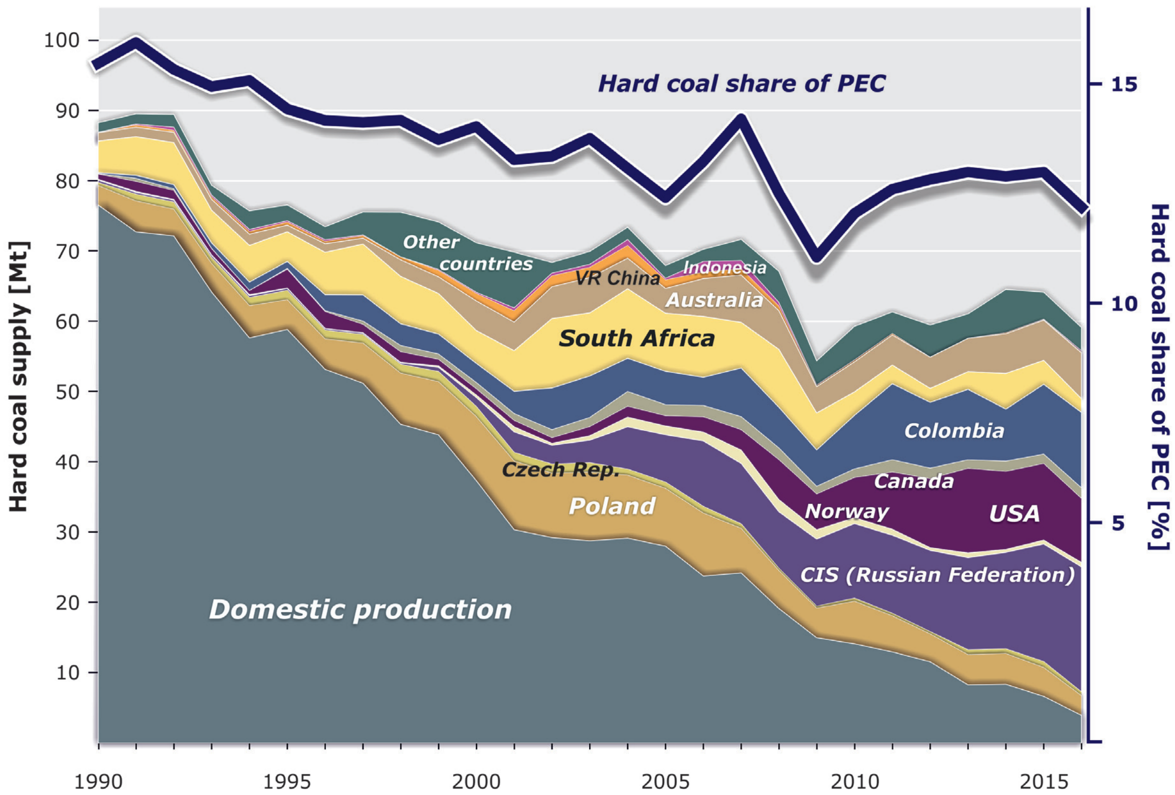

Figure 2-7: Germany's hard coal supplies from 1990 to 2016 (AGEB 2017, IEA 2017a, SDK 2017, VDKI 2017a).

The price (here: cross-border price) for imported steam coal dropped from around 59 €/tce at the beginning of 2016 to around 54 €/tce in spring, to then rise continuously to around 96 €/tce at the end of the year. The annual average price was therefore 67.07 €/tce (minus 1.2 % compared to 2015). The same also applied to coking coal and coke. The annual average price for coking coal declined 14 % year-on-year from 100.52 €/t to 86.36 €/t. The price of coke declined by 14.5 % year-on-year and had an annual average price of 159.82 €/t (BAFA 2017c, VDKI 2017a, b).

Lignite

Unlike hard coal, German lignite remains competitive with imported energy resources even without subsidies, and can be profitably mined. The favourable geological conditions in the deposits make it possible to use efficient opencast mining technology so that large amounts can be sold at competitive market prices to adjacent power plants for electricity generation. Germany has been the largest producer of lignite world-wide since the beginning of industrial lignite production at the end of the 19th century.

Around 4.9 Gt of lignite reserves are accessible in Germany via developed and planned opencast mines. The remaining reserves total around 31 Gt. The resources total 36.5 Gt.

Before the closure of the Helmstedt lignite field in summer 2016, lignite was produced in Germany in four fields. Lignite production across the country in 2016 totalled 171.5 Mt and was thus down 3.7 % on the previous year (Fig. 2-5).

In the **Rhenish lignite field**, RWE Power AG operates three opencast mines at Garzweiler, Hambach and Inden which had a total production of 90.5 Mt in 2016. The Garzweiler and Hambach opencast mines supplied lignite by rail to the Frimmersdorf, Goldenberg, Neurath and Niederaußem power plants. The Frimmersdorf power plant went into safety stand-by mode on 1 October 2017. 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 maintaining the system stability of the transmission/power grids. The Weisweiler power plant is supplied with lignite from the Inden opencast mine.

Production in the **Lausitz lignite field** totalling 62.3 Mt in the reporting year came from four opencast mines: Jänschwalde, Welzow-Süd, Nochten and Reichwalde. The lignite is almost completely supplied to the modernised or new Jänschwalde, Boxberg and Schwarze Pumpe power plants. In spring 2016, the former operator Vattenfall announced the sale of its opencast mines in Lausitz mining area (Vattenfall Europe Mining AG) and the Jänschwalde, Boxberg, Lippendorf/Block R and Schwarze Pumpe (Vattenfall Europe Generation AG & Co. KG) power plants to the Czech energy company Energetický a Průmyslový Holding (EPH) and its finance partner PPF Investments. The change in ownership came into force on 30 September 2016 after gaining the consent of the EU competition authorities. An announcement was made in October 2016 that the opencast lignite mines and the lignite power plants will in future be operated under the new names of Lausitz Energie Bergbau AG and Lausitz Energie Kraftwerke AG. Both companies share the same brand name LEAG (2017).

The production of 17.7 Mt from the **central German lignite field** in 2016 primarily came from the two opencast mines in Profen and Vereinigtes Schleenhain operated by Mitteldeutsche Braunkohlengesellschaft mbH (MIBRAG), which has been fully owned by the Czech EPH Group since 2012. Most of the lignite from these two opencast mines is used for power generation in the Schkopau and Lippendorf power plants. The lignite production from the Amsdorf opencast mine operated by ROMONTA GmbH is primarily used for the production of montan waxes.

In the **Helmstedt lignite field**, the Schöningen opencast mine supplied around 1.1 Mt of lignite to the Buschhaus power plant during the reporting year – another 0.5 Mt of lignite were also supplied by the Profen opencast mine. MIBRAG (Helmstedter Revier GmbH – HSR) acquired the opencast mine as well as the power plant in the second half of 2015 from E.ON Kraftwerke GmbH (DEBRIV 2015, Kaltenbach & Maaßen 2016, Maaßen & Schiffer 2016, SDK 2016). The lignite production begun in the Schöningen opencast mine in August 1981 ended on 20 August 2016 because of the depletion of the lignite reserves. This marks the end of over 150 years of mining in the Helmstedt lignite field (HSR 2016a), as well as the end of lignite production in Lower Saxony. The Buschhaus power plant was mothballed on 24 September 2016, and transferred to safety stand-by mode for four years on 1 October 2016 – the first German lignite power plant to do so (HSR 2016b).

The total sales of lignite in the reporting year declined by around 3.7 % to around 171.5 Mt. The share of primary energy consumption reduced year-on-year slightly to 11.4 % (51.9 Mtce).

The sale of lignite briquettes as well as the sale of lignite dust (processing product) declined slightly compared to the previous year by 0.5 % to 1.6 Mt and by 3 % to 4.7 Mt respectively.

A workforce of 14,693 (minus 4.8 % year-on-year) was employed in lignite mining (AGEB 2017, SDK 2017).

The external trade balance with lignite and lignite products was positive in 2016, albeit at a relatively low level. The total imports sank to 45,000 t. At the same time, there was also a decline in exports (briquettes, coke, dust and lignite) of 41.5 % to 1.38 Mt. The main customers are EU-28 countries (SDK 2017).

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. 37 nuclear power plants in total were built in Germany since 1962 for commercial power generation. There are currently only eight nuclear power plants in operation. They will be switched off according to the follow timetable at the end of the year in each case: 2017: Gundremmingen B, 2019: Philippsburg 2, 2021: Grohnde, Gundremmingen C and Brokdorf, 2022: Isar 2, Emsland and Neckarwestheim 2.

The contribution of nuclear power to primary energy consumption declined further to 923 PJ (2015: 1,001 PJ), which corresponds to 31.5 Mtce. Its share of primary energy consumption was therefore down to 6.9 % (2015: 7.6 %). In terms of public power supplies as well, nuclear power with a share of 13.1 % now only comes in fourth place behind renewables (29.0 %), lignite (23.1 %) and coal (17.2 %).

648.4 TWh of power was produced in total in Germany. Power generation is therefore at around the same level as the previous year (plus 0.2 %; 2015: 646.9 TWh). The share of nuclear energy in gross power generation declined further by 7.8 % to 84.6 TWh compared to 91.8 TWh in 2015. Net power generation was 80.1 TWh (2015: 86.8 TWh). Before the shut-down of eight nuclear power plants in 2011, there were 17 nuclear power plants operating with a gross capacity of 21,517 MWe. The eight nuclear power plants currently operating are only supplying 11,357 MW_e (gross) to the grid. The temporal and the productive operational availabilities were 88.91 % (2015: 91.76 %) and 88.40 % (2015: 91.17 %) respectively.

The demand for natural uranium in nuclear fuel was 1,620 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 (2015: 0 t; 2016: 45 t).

The decommissioning and remediation of former production sites and facilities operated by SDAG WISMUT entered the 26th year of clean-up operations in 2016. 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 87 % (€ 6.2 billion) had already been spent by the end of 2016.

One of the remaining major issues is treating the contaminated water from the flooded underground workings, and the remediation of the industrial settling facilities. 18.6 million m^3 of contaminated water was treated in 2016, and discharged into the nearest rivers.

Approvals were issued for the conversion of the existing water treatment plant at the Königstein site. Applications for the construction and operation of a new water treatment plant are being prepared for the industrial settling pond in Helmsdorf at the Crossen site. This new plant is needed to handle the changed water qualities in connection with the declining volumes of water after removing the free water from the industrial settling pond.

After the modernisation and expansion of the system for containing the rising flooding waters in Gessental at the Ronneburg site, this year will see the re-containment of the mine waters. In connection with the temporary shut-down of the Ronneburg water treatment plant for a general overhaul, this will lead to a planned rise in the water level in the mine.

Work on the so-called Südumbruch – a new drifted section of the Marcus-Semmler drift – will be completed this year at the Aue site. This will enable the water from the neighbouring underground workings to flow out under gravity via this drainage drift.

Deep geothermal energy

The first „Energy research and energy technologies“ programme started by the German government to promote renewable energy (BMWi 2017f) began in 1977 with the aim of improving energy efficiency and environmental compatibility. Although at the time, geothermal energy – alongside solar and windpower – only formed a side issue at the time, precisely 40 years later, as part of the sixth energy research programme, the focus of geothermal energy research is on specific technology developments, reducing the exploration and success risks, and raising acceptance (BMWi 2011). In the seventh energy research programme currently under preparation, the main focus is on dialogue between industry, science and politics (BMWi 2017e). In 2016, BMWi granted almost € 20 million for 22 new projects: whilst ongoing projects were funded to the tune of € 12 million (BMWi 2011). Around half of this involves prospecting and exploration, around 8 % on warm water and steam reservoirs, and the rest on hot-dry-rock projects and others.

In accordance with funding by the Expansion of Renewable Energy Act (EEG 2017), the feed-in tariff for geothermally-generated power stayed at 25.2 cents per kilowatt hour in 2017 (BMJV 2017). However, a degression rate of 5 % per year is scheduled from 2021. The beneficiaries of this statutory regulation in 2016 in Germany were eight geothermal power generating plants, see Table 1 (Agemar et al. 2014; LIAG 2017). These are among the 30 geothermal plants currently in operation whose geographic distribution is limited to only six federal German states. A glance at the application categories reveals that most of the plants currently operating are for the production of district heating (18). The remainder involve power plants (4), combined projects (4), as well as four research locations (Fig. 2-8). Two other projects are currently under construction in Bavaria, and around 30 more projects are still currently in the planning phase.

Table 1: Deep geothermal energy locations in Germany in 2016 (LIAG 2017).

	District Heating	Electricity	Combination	Research	Total
Baden-Württemberg		1 Bruchsal			1
Bayern	15 Aschheim Erding Freiham Garching Ismaning Kirchweidach München-Riem Poing Pullach Simbach-Braunau Straubing Unterföhring I Unterföhring II Unterschleißheim Waldkraiburg	2 Dürrnhaar Kirchstockach	3 Grünwald (Laufzorn) Sauerlach	1 Mauerstetten (Allgäu)	21
Brandenburg	1 Prenzlau			1 Groß Schönebeck	2
Mecklenburg-Vorpommern	2 Neustadt-Glewe Waren(Müritz)				2
Niedersachsen				2 Horstberg Hannover	2
Rheinland-Pfalz		1 Insheim	1 Landau in der Pfalz (0.00 GWh_e)		2
Germany total	**18**	**4**	**4**	**4**	**30**

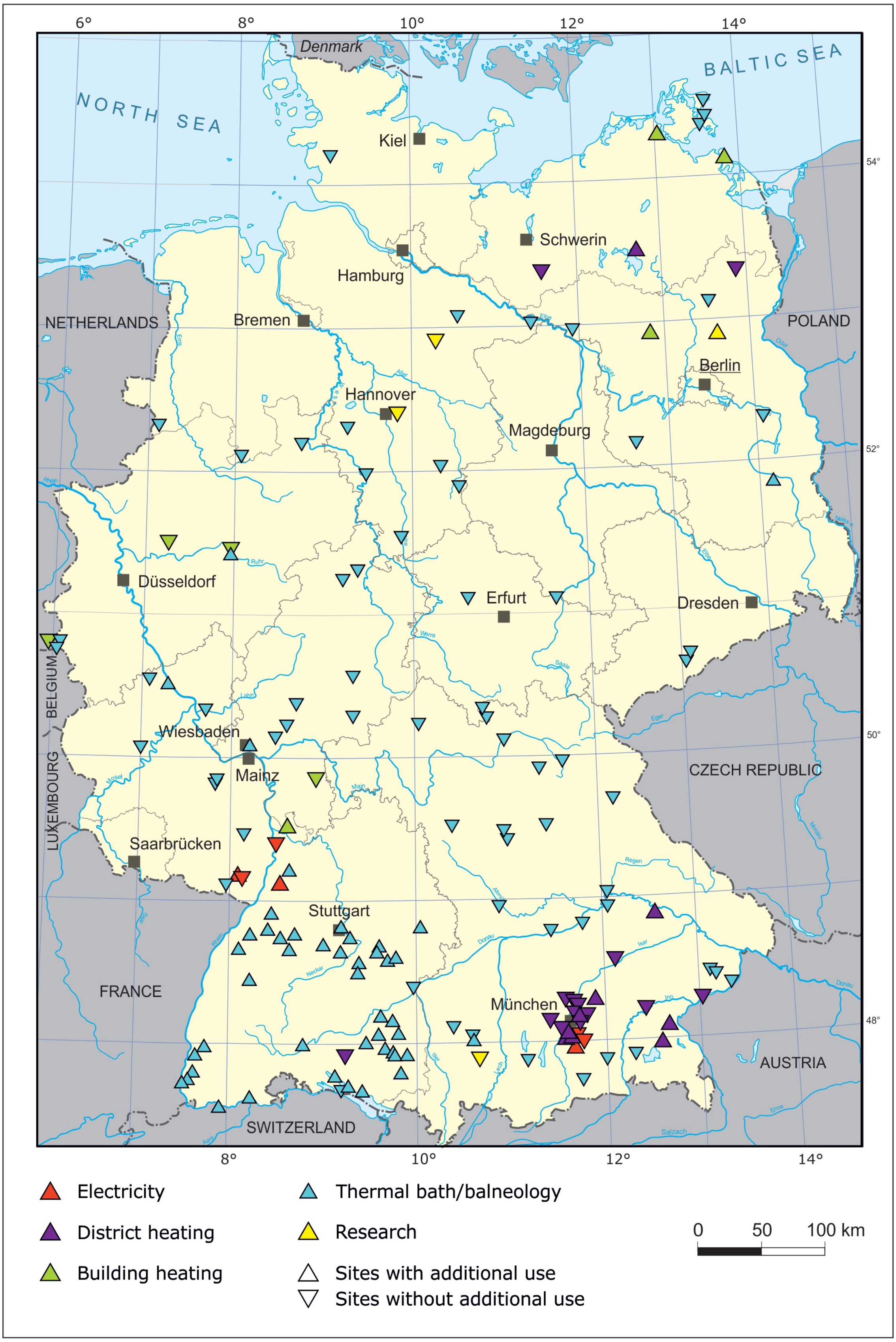

Figure 2-8: Location of geothermal sites in Germany in 2017 (after LIAG 2017).

The amount of geothermally-generated energy in Germany in 2016 totalled around 1,474 GWh/a (LIAG 2017). The amount of power generated here was around 174 GWh_e/a (Fig. 2-9), which corresponded to an increase of around 40 GWh_e/a, or up 30 % year-on-year. The thermal energy production was 1,300 GWh_{th}/a, and therefore much higher by comparison, and representing an increase of almost 200 GWh_{th}/a within only a year, or an actual rise of 18 %. The thermal output is shared amongst district heating (around 816 GWh_{th}/a, 62.8 %), thermal baths (475 GWh_{th}/a, 36.5 %), and building heating (9 GWh_{th}/a, 0.7 %).

These increases were achieved by the addition of installed capacities in 2016 to raise the total from around 33 MW_e to around 38 MW_e, and from around 337 MW_{th} to 391 MW_{th} (Fig. 2-9). Despite this large growth and the enormous potential of geothermal energy, the share of geothermally-generated energy of total primary energy consumption in Germany remained very small at only 0.04 % in 2016. Over the same time period, geothermal power plants contributed almost 0.1 % of the total power generated by renewables totalling 188.3 billion KWh (BMWi 2017f).

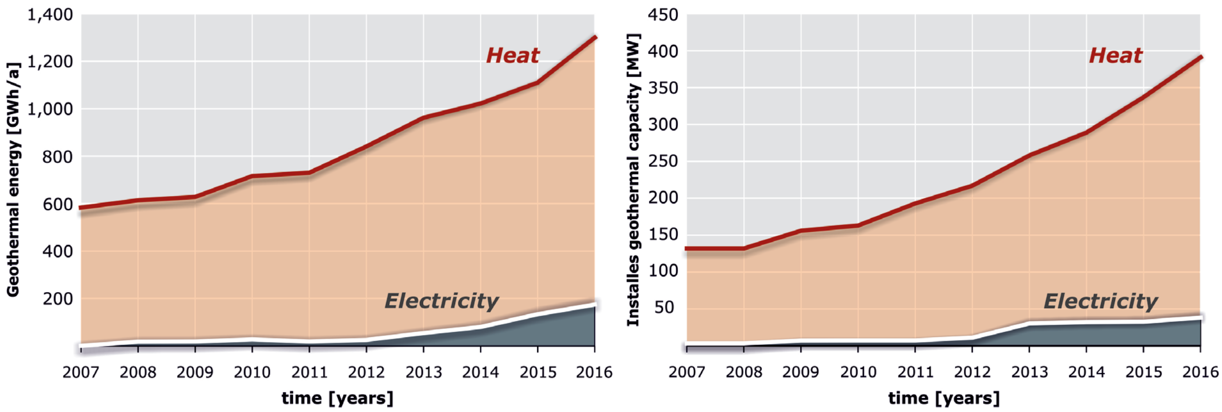

Figure 2-9: Change in geothermally-generated electricity (grey) and thermal energy (red) (left), and installed capacity (right) over the last ten years in Germany (LIAG 2017).

A ten-year analysis reveals a continuous increase in the amount of geothermally-produced electricity from 0.4 GWh_e to almost 174 GWh_e at the end of 2016. The installed capacity rose in the last ten years from 0.4 MW_e to 38 MW_e. Over the same time period, the proportion of deep geothermal energy for heat generation doubled from 568 GWh_{th} to 1304 GWh_{th}, with a growth in installed capacity from 100 MW_{th} in 2006 to 391 MW_{th} in 2016 (Fig. 2-9) (LIAG 2017). Although the amount of energy produced was boosted with the current number of plants, it is still clear that deep geothermal energy will continue to make hardly any relevant contribution to German energy supplies in future without significant expansion.

The reasons for the minor realisation of geothermal projects are still the same: uncertainties in predicting the parameters underground relevant for geothermal energy production, exploration risks, the necessary risk analyses, uncertainty amongst investors, induced seismicity, the possibility of gas leaks occurring, e.g. radon or H_2S, lack of public approval, economic problems, e.g. because of the high maintenance costs (Janczik & Kaltschmitt 2017), inadequate customer structures, and difficulties connecting up to existing or still to be built district heating networks. Other reasons listed by BMWi for the relatively low expansion of geothermal energy include major technical problems, low competitive intensity, as well as long planning and development times (BMWi 2017d).

Enabling deep geothermal energy to contribute to a larger proportion of the energy mix not only requires more intensive research at a national and international level, but also continuously building up more mutual trust between all of the stakeholders, i.e. project owners, representatives of public and private funding bodies, scientific experts, engineering firms and drilling companies, not to mention the local inhabitants and society as a whole. This highlights the significance of transparent and honest public relations work, as well as an appropriate public mutual exchange of ideas and the involvement of relevant research activities.

Renewable energy

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 2017a). The target for 2035 is 55 % to 60 %, and rises further to 80 % by 2050 (Fig. 2-10). 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 2017b).

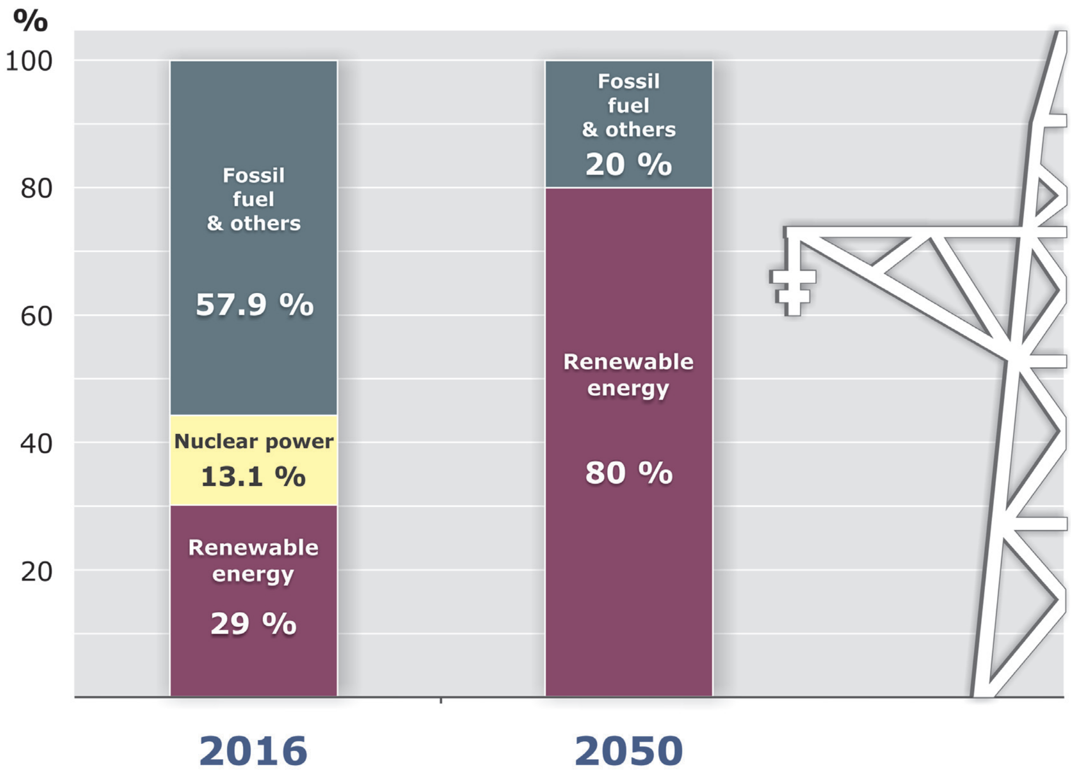

Figure 2-10: Proportion of each energy resource in gross power generation.

The implementation of renewable energy has primarily focused to date on the power sector. Around 29 % of the power in Germany is currently generated by renewables (Fig. 2-10). 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 31.7 % in 2016, and is therefore, however, only slightly higher than the level in 2015 (31.5 %). This latter statistic has less to do with the stagnation in the expansion of renewables, and much more to do with the influence of the weather.

The wind conditions were not as good in 2016 as in the previous year (2015 was a strong wind year), so that despite the further expansion of windpower, power generation from windpower was actually slightly down year-on-year. Power generation from windpower (onshore and offshore) overall totalled 77.4 billion kWh (around 2 % less than 2015), and accounted for a share of 11.9 % of the German power mix (AGEB 2017). Nevertheless, the offshore plants generated around 50 % more power than in the previous year. This is mainly attributable to the enormous expansion of offshore windpower plants during the course of the year. Whereas power generation offshore in 2014 was only 1.4 billion kWh, this had already grown to 12.4 billion kWh in 2016. The onshore windpower plants generated 65 billion kWh, and thus 8 % less power than in the preceding year. Almost 49,800 MW of installed windpower capacity (onshore and offshore) are available in total in Germany (Tab. A-44 in the Appendix).

The second most important renewable energy resource for power generation in Germany is biomass. 51.6 billion kWh of power were produced from biogenic energy resources in 2016 (solid, liquid and gaseous biomass). In addition to biogas itself, this also includes landfill and sewage works gas, as well as sewage sludge, and biogenic waste for the generation of power in domestic refuse power plants (AGEB 2017). The share of biomass in the German power mix was 8 % and therefore up around 1 % year-on-year, and is probably set to rise further in the years to come. At around 210 MW, almost twice as much capacity was added in the reporting period than in the previous year. Investment is being made in particular in boosting the capacities of existing biogas plants (UBA 2017). Around 8,200 MW of capacity are installed in Germany.

Power generation from solar energy (photovoltaic) continues to be massively expanded in Germany and boasts the highest installed capacity of all of the renewables with the exception of windpower. Around 41,275 MW of installed photovoltaic capacity is currently available in total in Germany (Tab. A-44 in the Appendix). Nevertheless, power generation from this source still remains relatively low. The contribution to the German power mix with 38.2 billion kWh was around 5.9 %. This corresponds to a slight decline of around 1.4 % compared to the previous year. This was also primarily due to the weather conditions. The number of sunshine hours in 2016 was much lower than in the previous year. Around 1.4 GW of installed photovoltaic capacity was added in 2016, corresponding to a slight rise in the growth rate, following a decline in the amount of added capacity in the last three years. Nevertheless, this is the third year in a row in which the expansion framework of 2.4 GW to 2.6 GW per year defined in the EEG failed to be realised (UBA 2017). One of the reasons for this is no doubt the decline in the feed-in tariffs for solar power stipulated in the EEG.

The use of renewables for heat generation has also increased in 2016. This was helped in particular by the weather-related rise in wood consumption in private households (68 billion kWh: plus 10 %), as well as the consumption of wood pellets (2 Mt; plus 8 %) (UBA 2017). With a share of around 75 %, solid biomass (including biogenic waste) accounts for the most important share of renewables in thermal generation. The share of all renewables in thermal generation remained stable at 13.4 % in 2016 because of the overall higher energy consumption in Germany. In the transport sector, biofuels such as bioethanol, biodiesel and biogas account for around 5.1 % of fuel consumption in Germany (UBA 2017).

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 54 %. 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 32.3 % easily dominates the applications, whilst the use of heat generation in industrial power plants only accounts for 5.8 %. Another 6.4 % is used in the transport sector as ad-mixtures to petrol and diesel fuels (AGEB 2017). With a share of the renewables in PEC of over 58.5 %, biomass is the dominant energy form (Fig. 2-11), followed by windpower (16.5 %), solar power (9.8 %), waste (7.8 %), hydropower (4.5 %), and geothermal energy (3 %).

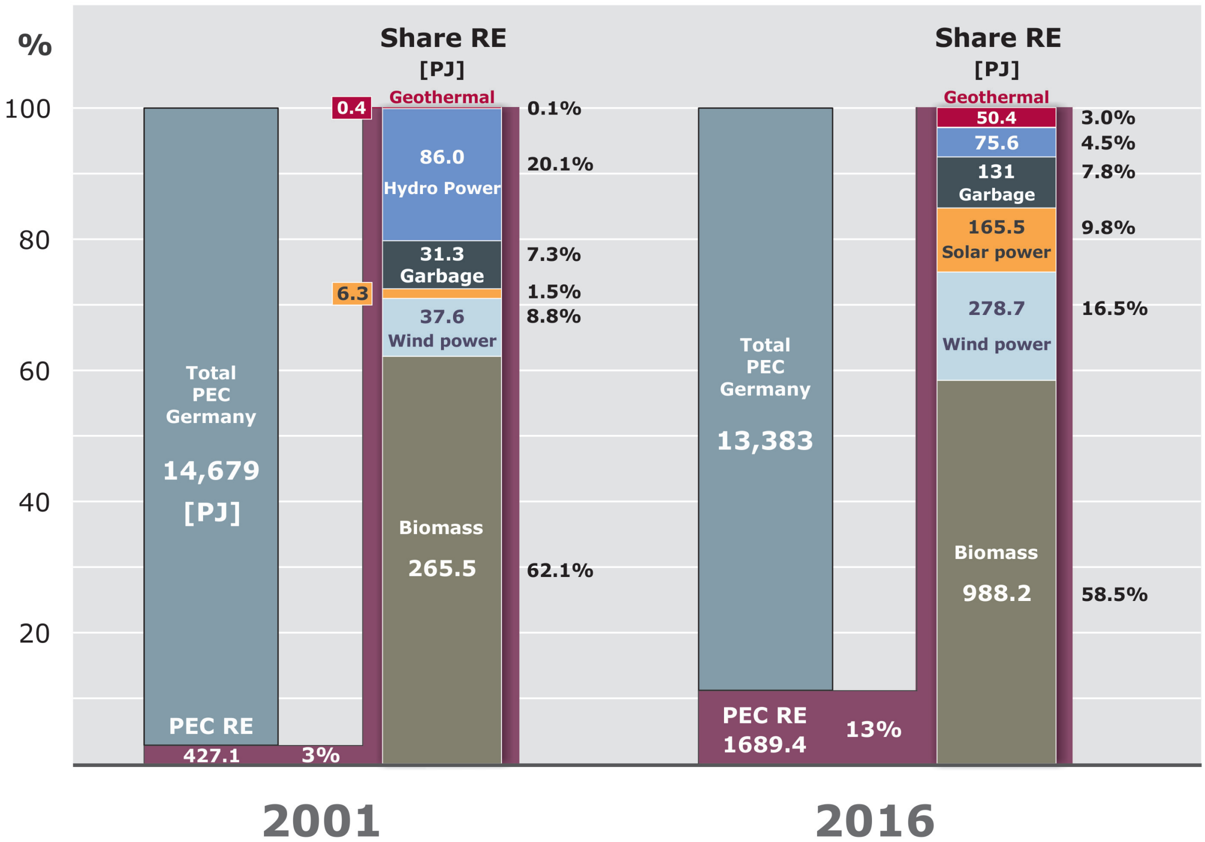

Figure 2-11: Primary energy consumption (PJ) in Germany in 2001 and 2016, and also showing the share (%) of each renewable energy source in comparison.

PEC in Germany rose slightly to 13,383 PJ in 2016, and was therefore up 1.1 % 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 % over a period of 15 years from 14,679 PJ (2001) to 13,383 PJ (2016), whilst the proportion of renewables in PEC has quadrupled at the same time from 427 PJ (2001) to 1,689 PJ (2016 (Fig. 2-11). Each of the renewable energy resources made different contributions to this growth (Fig. 2-11). 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.

3 ENERGY RESOURCES WORLD-WIDE

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" renewable energy 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 absolute volumes of all energy resources consumed in recent years has grown to reach new record levels in 2016, also in the case of crude oil and natural gas, to satisfy the world's energy demand.

A rise in the global population numbers, combined with an increase 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. The growth in energy consumption is in the meantime being covered to an equal degree by renewables and fossil energy resources. 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).

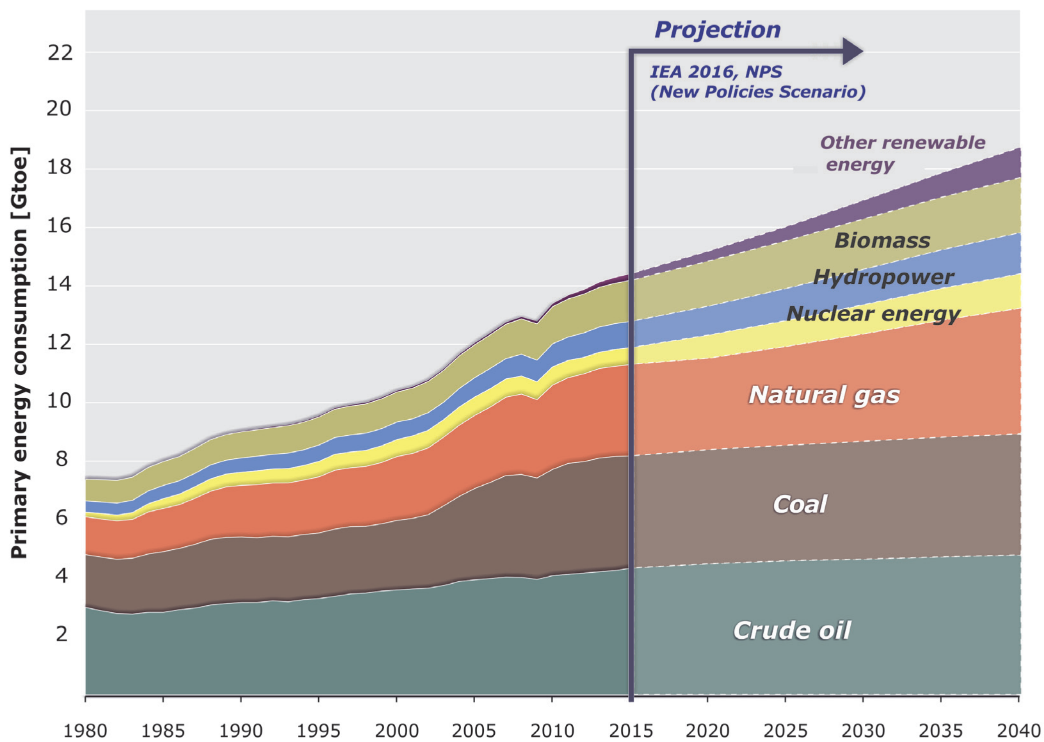

Figure 3-1: Development of global primary energy consumption per energy resource (BP 2017, IEA 2016) and a possible scenario for future developments (New Policies Scenario, IEA 2016) (Hydropower calculated acording to BP 2017).

Following the global review of the reserves situation, a more detailed look is undertaken at individual fossil fuels and energy sources 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 because the reduction in the geothermal energy available below the surface of the earth is negligible in relation to human timescales. It will therefore be looked at in its own special chapter.

3.1 Global reserves situation

Table 2 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, non-conventional potential is presented as far as possible. These include the resources and reserves from tight rocks (shale oil), bitumen (oil sand), extra-heavy oil and oil shale, and as well as tight gas, shale gas and coal seam gas. 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 550,690 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 0.3 % compared to the previous year (BGR 2016b). There was growth in the resources of conventional crude oil (plus 0.6 %), as well as for oil shale because of re-evaluations. Thanks to an improvement in the database, the extractable resources from oil shales can be shown at a country level for the first time (Tab. A-9 in the Appendix). Lower resources for extra-heavy oil, conventional natural gas, shale gas and uranium are primarily attributable to re-evaluations or, in the case of shale gas, an improvement in the database. A comparison of all energy resources shows that coal continues to dominate (hard coal and lignite) with a share of 89.1 % (Fig. 3-2). Trailing well behind in second place are natural gas resources with 5.8 %, which are dominated by non-conventional deposits. The remaining energy resources, including crude oil (3.3 %), 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 2016 corresponded in total to 39,530 EJ, and therefore rose 2.8 % year-on-year. The largest absolute changes are in terms of the extra-heavy oil deposits because re-evaluations have shifted some of the resources in Venezuela into reserves. This led to an almost doubling of the extra-heavy oil reserves (plus 98 %). Other less significant increases were also reported for most other energy resources. Slight declines, such as for shale gas, were largely attributable to production factors. Despite the continued relatively low prices for energy resources in 2016, this had hardly any effect on reserves because they actually rose again slightly overall. In terms of energy content, coal is the dominant energy resource in terms of reserves as well with 54.1 %. Crude oil (conventional and non-conventional) accounts for 25.5 % of total reserves; natural gas 18.9 %; 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 2: 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	171	7,155	524	168	7,028	515
Shale oil	Gt	1,6	69	5,0	60	2,496	183
Oil sand	Gt	26	1,099	118	67	2,785	298
Extra heavy oil	Gt	42	1,752	187	42	1,767	189
Oil shale	Gt	–	–	–	111	4,646	497
Crude oil (total)	Gt	241	10,074	834	448	18,721	1,682
Conventional natural gas	Tcm	190	7,202	404	323	12,290	689
Shale gas	Tcm	5,1	194	11	205	7,805	438
Tight gas	Tcm	–[1]	–[1]	–[1]	63	2,394	134
Coal-bed methane	Tcm	2,0	75	4,2	51	1,950	109
Aquifer gas	Tcm	–	–	–	24	912	51
Gas hydrates	Tcm	–	–	–	184	6,992	392
Natural gas (total)	Tcm	197	7,471	419	851	32,344	1,371
Hard coal	Gtce	608	17,820	1,686	14,966	438,615	41,493
Lignite	Gtce	121	3,554	359	1,776	52,044	5,256
Fossil fuels [total]	–	–	38,918	3,298	–	541,724	49,803
Uranium [2]	Mt	1,2 [4]	612 [4]	–	12 [5]	5,788 [5]	–
Thorium [3]	Mt	–	–	–	6,4	3,178	–
Non-renewable fuels	–	–	39,530	3,298	–	550,690	49,803

– 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

Non-renewable energy resources with an energy content of around 515 EJ were produced in 2016. This is a slight decline of around 1.2 % compared to the previous year (2015: 521 EJ). In terms of energy content, changes in the production mix were affected by a rise in the share of crude oil and nuclear fuels as a result of a rise in production volumes, and the decline in the production of coal (Fig. 3-2). In particular, the lower production of coal in China as the world's largest producer, and the USA as the world's third largest producer, also had an influence on global energy resource production. Crude oil (35.5 %) continues to be the most important resource, ahead of coal (29.8 %), and followed by natural gas (26.7 %), uranium (6.1 %) and lignite (1.9 %).

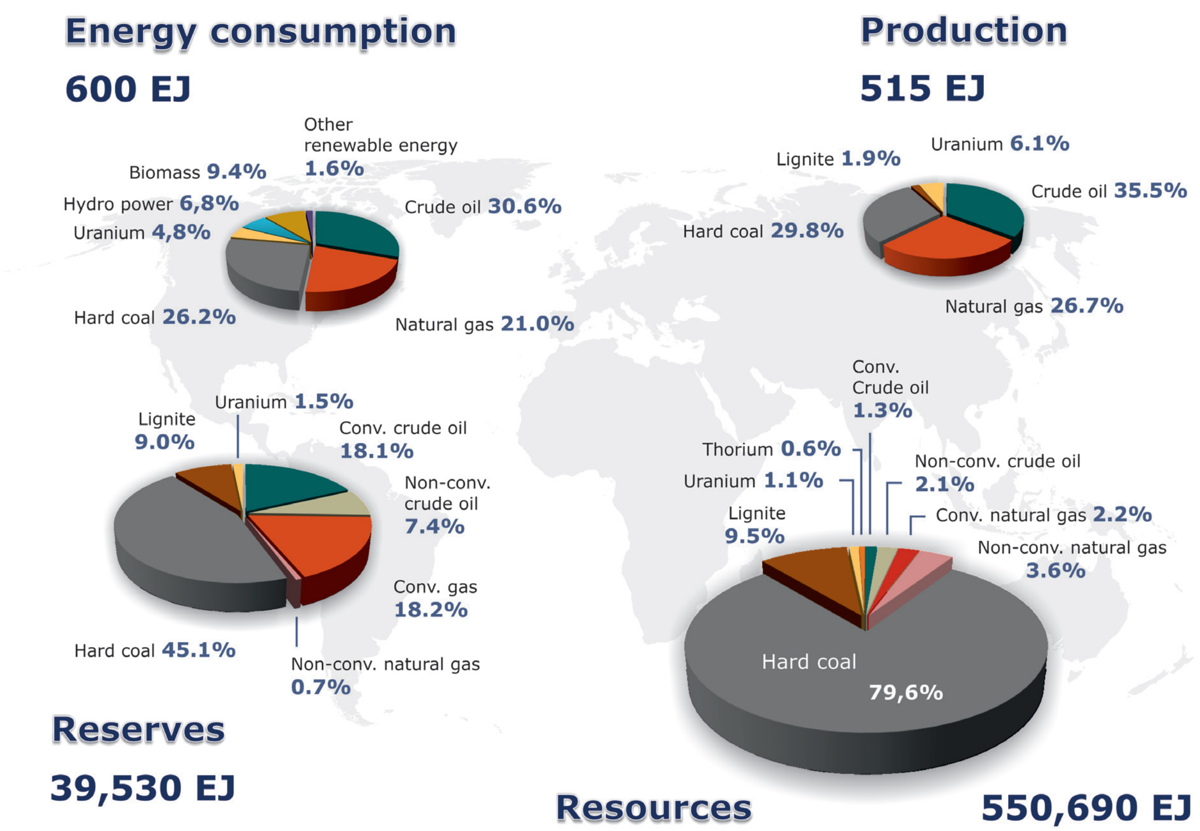

Figure 3-2: Global shares of all energies and energy resources in terms of consumption (IEA 2017b, efficiency of hydropower calculated after BP 2017) as well as the non-renewable energy resources in terms of production, reserves and resources for the end of 2016.

Energy consumption world-wide was around 600 EJ in 2016 and represents the total amount of primary energy used world-wide. Because biomass is fully reported for the first time thanks to the change in the database, it is not possible to make a direct comparison with the previous year's figure and the relative proportions. Fossil energy resources clearly dominate in the world-wide energy mix and are led by crude oil with 30.6 %, coal (26.2 %) and natural gas (21 %). Nuclear power has a share of 4.8 % of global PEC. Of the renewable energy resources, biomass dominates with 9.4 %, followed by hydropower (6.4 %). The remaining renewables, including solar power and windpower, have a global share of 1.6 % (IEA 2017b).

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 relatively low resources. 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 unbroken and adequate supplies of energy resources for many years, the associated 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 world‘s most important energy resource. Its share of global primary energy consumption was 30.6 %. Global crude oil production rose by 0.6 % to an all-time high of 4,374 Mt (2015: 4,346 Mt).

Total crude oil resources (conventional and non-conventional) rose to 448 Gt (plus 26 %), marking a significant rise. This is largely attributable to a re-evaluation of oil shale resources thanks to an improved database. The resources extractable from oil shale are visualised for the first time at a country level (Tab. A-9 in the Appendix). In addition to being combusted directly to generate power, oil shale can also be thermally treated to extract distillate oil. Distillate oil is currently being extracted in significant quantities from oil shale in Estonia, China and Brazil. Figures are also available for the first time estimating the conventional crude oil resources in North Korea.

Conventional crude oil reserves have declined slightly world-wide by 0.2 % to 171.1 Gt. Among the non-conventional crude oil reserves, there was a considerable rise to 69.8 Gt (plus 62 %). This is primarily attributable to a re-evaluation of the extra-heavy oil reserves in Venezuela. The shale oil reserves have also risen during the reporting year. This is due to an improvement in the database with respect to the subdivision of the US-American crude oil reserves into conventional and non-conventional crude oil (shale oil). The largest share of total crude oil reserves at around 110 Gt (45 %) is located in the Middle East, followed by Latin America at 51 Gt (21 %), and North America with 34.7 Gt (14 %) (Fig. 3-3). Although it is one of the largest consumers of petroleum products, Europe‘s share of total reserves is very low at only 1.8 Gt (about 1 %). Venezuela, Saudi Arabia and Canada alone, the three countries with the highest crude oil reserves, have nearly 46 % of total world-wide reserves.

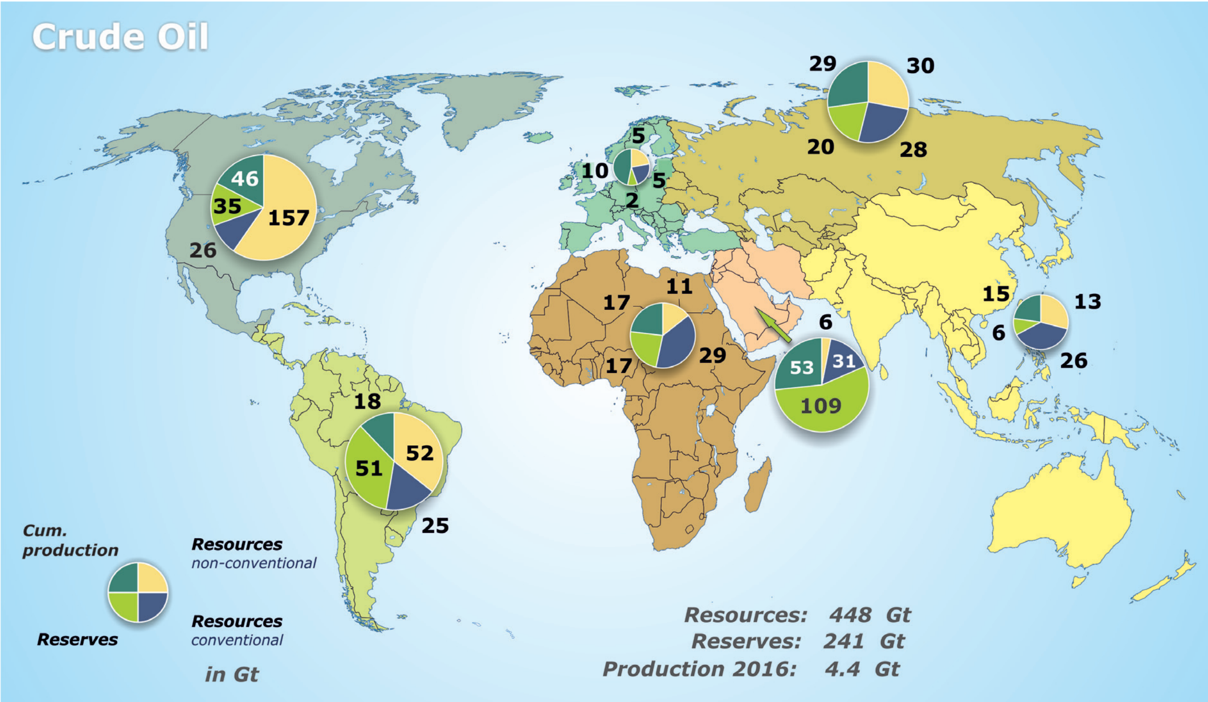

Figure 3-3: Total potential of crude oil 2016: regional distribution.

The countries with the highest production were Saudi Arabia and the Russian Federation as in the previous year, which both reported increases in production, as well as the USA, which dropped down to third place because of lower shale oil production in the reporting year. Saudi Arabia boosted its production by 4 % to 589.1 Mt, and thus produced more crude oil than any country in history. Iraq (plus 11 %), and Iran (plus 18 %) also reported considerable increases in production. Thanks to their large conventional crude oil reserves, both of these countries still have major potential to increase their crude oil production levels. However, the extent to which this potential can be realised largely depends on the further economic and geopolitical development in these countries. The OPEC countries increased their production overall by more than 3 %. The share of OPEC countries in global production therefore rose to 43.1 %. The largest declines in production amongst the important oil producing countries were in China (minus 7 %), Venezuela (minus 10 %), and Nigeria (minus 13 %). The lower crude oil prices combined with the lower crude oil production levels gave rise to serious economic problems in Venezuela and Nigeria in particular, because both countries are highly dependent on revenues from the exports of crude oil and petroleum products.

Crude oil was produced in 102 countries in total in the reporting year. However, crude oil production is very irregularly distributed, and concentrated in a relatively small number of countries and/or regions. The 15 largest crude oil producing countries alone covered more than 80 % of global crude oil production. Although the production of crude oil from non-conventional deposits is rising, conventional crude oil production – with a current share of around 86 per cent of total production – will continue to be the main source of supplies of liquid hydrocarbons in the long term as well. The global rise in crude oil production in the reporting year was primarily attributable to the increase in condensate production (NGL) – which is a by-product of natural gas production, but which is counted alongside crude oil production – as well as a slight rise in the production of conventional crude oil.

The production of non-conventional crude oil at a Larger scale has previously been limited to the USA (shale oil), Canada (oil sand, shale oil), and Venezuela (extra-heavy oil). The decline in crude oil prices had the most significant impact on the development of non-conventional deposits because these are usually associated with higher production and development costs[2] than conventional crude oil fields. The initial reaction in the USA and Canada to the lower crude oil prices was a significant reduction in shale oil drilling activity. Combined with the rapid decline in production typical for shale oil wells (Wachtmeister et al. 2017), this led to a drop in shale oil production in both countries. However, the number of shale oil wells drilled during the course of the reporting year has again grown considerably thanks to the consolidation of the crude oil prices since the middle of 2016, and major cost reductions in the shale oil industry in the USA – although still not at the same level seen prior to the collapse in crude oil prices at the end of 2014. These developments came along in parallel to technological advantages which have enabled much higher initial production rates and recovery rates (EIA 2017a). Therefore there has been a rapid rise again in US-American shale oil production since autumn 2016. Another significant rise in US-American oil shale production is therefore expected in 2017. It remains to be seen, however, to what extent the technological advances can also compensate for the higher production declines in shale oil production wells in the long term.

Despite considerable savings in further expansion of Canadian oil sand projects, and the negative impact on production caused by forest fires around Fort McMurray in Alberta in the middle of 2016 – an important centre for the oil sand industry in Canada – oil sand production actually rose to 140 Mt (plus 2 %). Canadian oil sand production has therefore almost quadrupled since the turn of the millennium, and now accounts for around 3 % of global production.

Venezuela boasts the world‘s largest crude oil reserves (47 Gt). However, around 90 % of these reserves are in sulphur-rich heavy and extra-heavy oil which is expensive to produce and process. The rise in the reserves of Venezuelan extra-heavy crude oil in the reporting year is due to an increase in the recovery rate of Venezuelan extra-heavy oil deposits to 21 %, as well as a change in the conversion factor from barrels to tonnes to better reflect the higher density of extra-heavy oil compared to conventional crude oil (see conversion factors in the Appendix). The increase in the recovery factor is a result of technological advances in production technology (more powerful production pumps) as well as the development of reservoirs (directional drilling, high-resolution 3D seismic surveys). Although the size of the crude oil reserves in Venezuela are similar to those in Saudi Arabia (35 Gt), the amount of crude oil produced in the South American country is much lower for reasons attributable to production engineering aspects. Because extra-heavy oil cannot be exported because of its low quality, it has to be treated by being mixed together with lighter crude oil types. The production of extra-heavy oil in Venezuela stagnated in 2016 at 59 Mt, to match the same level as the previous year (PDVSA 2017). The country has great difficulty in maintaining its production of extra-heavy oil at the current level because it has not made the necessary high level of investments in production and processing plants in recent years.

2 Applies only to a certain extent to shale oil

Year-on-year, the global consumption of petroleum products has risen moderately by 0.8 % to 4,387 Mt. As the world‘s most important traded commodity, crude oil consumption is a strong indicator of economic development. The relatively low prices for crude oil gave rise to higher consumption particularly in the transport sector. The strongest growth in petroleum consumption was reported in the major regions Austral-Asia (plus 2.5 %) and the CIS (plus 2.8 %). In contrast, consumption sank considerably in Africa (minus 4.9 %) and Latin America (minus 6 %). There were only minor differences in Europe, North America and the Middle East. As in the previous year, three quarters of the petroleum was used by the 20 leading consuming countries. However, only five of these countries (Saudi Arabia, Russian Federation, Canada, Mexico, Iran) are able to cover their own needs from domestic production, and in addition, to export crude oil. With a calculated domestic supply of lower than 5 %, Germany, Japan, South Korea, France and Spain are particularly dependent on crude oil imports. Around 12 % of consumption in the European Union is covered by domestic production.

Of the crude oil produced in 2016, around half was traded across borders. Transport was mainly by oil tanker or pipeline, and to a lesser extent also by rail or by road tanker. 2,228 Mt of crude oil were exported world-wide, a rise of almost 6 % compared to the previous year. The two leading exporting countries for crude oil, Saudi Arabia and the Russian Federation, covered around 29 % of all crude oil exports (Fig. 3-4). Global refinery capacities rose to 4,838 Mt, with the strongest growth reported in the Austral-Asian region with 1,626 Mt (plus 3 %), and the Middle East with 471 Mt (plus 1.7 %).

The most significant importing region was Austral-Asia with a share of 50 %. Africa had the lowest share of imported crude oil at 0.3 %. The largest crude oil importer is still the USA with 393 Mt (plus 6 %). The countries in second and third position are China and India respectively whose imports rose to 379 Mt (plus 12 %) and 216 Mt (plus 9 %) respectively.

There are various reference types for different qualities of crude oil which are largely traded in a standard way on global markets, with the exception of minor price surcharges or discounts. The annual average price in 2016 of the Brent crude oil reference type („North Sea oil“) was 43.55 USD per barrel (bbl) crude oil. This was almost 17 % down year-on-year (52.32 USD/bbl). The decline in crude oil prices which started in the middle of 2014 therefore continued. After reaching a low at the end of January (Brent 26.01 USD/bbl), crude oil prices began to climb again. Crude oil prices rose continuously to 50.59 USD/bbl in the first half of the year because of expectations that the oversupply of the market which had existed since 2014 would reverse by the end of 2016. This development was supported by the continuous decline in shale oil production in the USA, as well as unexpected shut-downs in production in Canada, not to mention discussions between OPEC countries and some non-OPEC countries about regulating production levels. However, the decline in the oversupply of the market for crude oil began to diminish in the middle of the year, which means that there was no further rise in the prices. The price in December stuck at over 50 USD/bbl when OPEC countries and some other important production countries agreed to limit production in the first half of 2017. The price of crude oil reached its peak in 2016 in December when it nudged slightly over 53.29 USD/bbl.

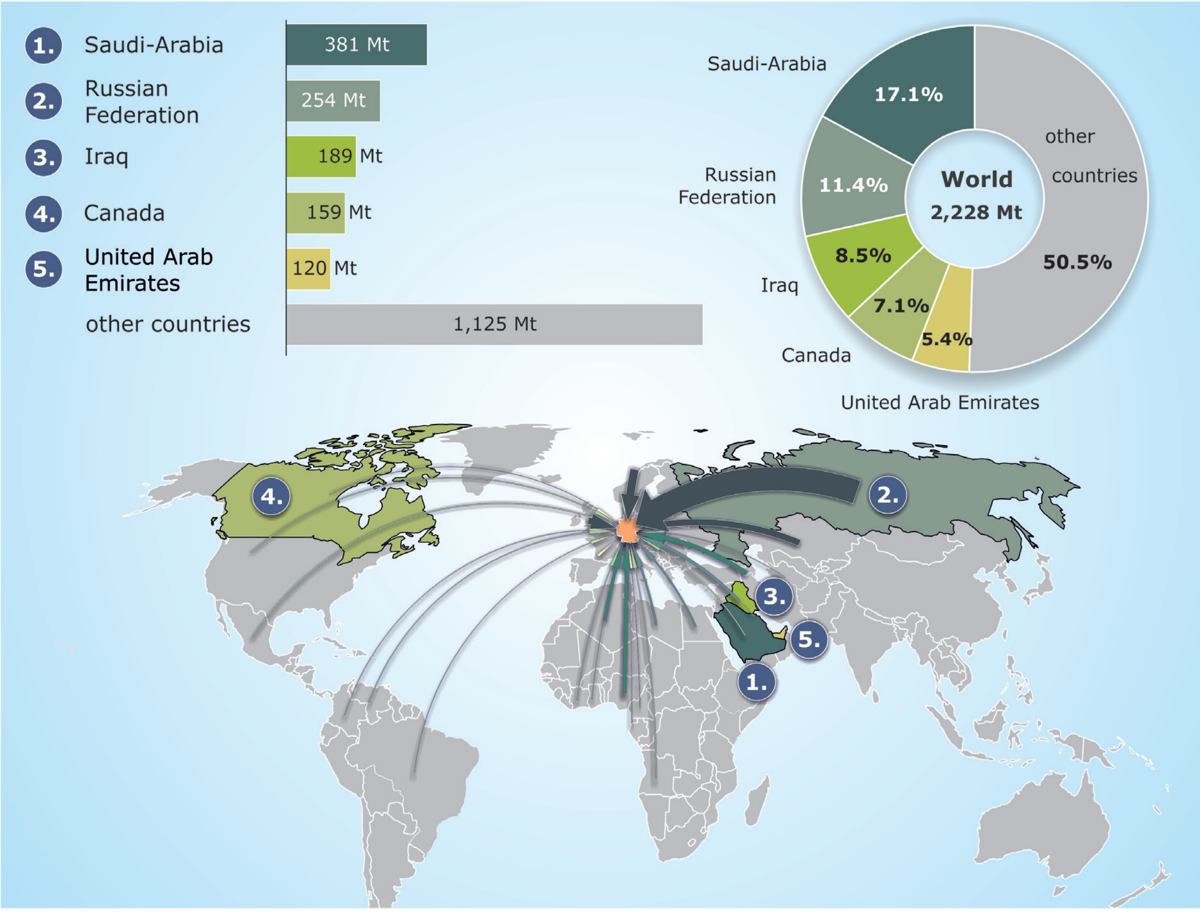

Figure 3-4: The largest crude oil exporting countries and Germany's most important crude oil suppliers in 2016.

The US-American reference oil type West Texas Intermediate (WTI) reflected the trend in Brent prices with only minor differences. The crude oil price sank on average from 48.66 USD/bbl the previous year to 43.14 USD/bbl in 2016. The third price indicator for crude oil is the OPEC basket price comprising 13 selected crude oil types from OPEC member countries. This declined to an annual average of 40.76 USD/bbl (49.49 USD/bbl in 2015).

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).

Development of investment and reserves in the crude oil sector

The considerable decline in crude oil prices since the third quarter 2014 led to a major drop in investment in the upstream sector, giving rise to a slump of over thirty per cent in over two years (Fig. 3-5). Numerous exploration and development projects, and especially expensive deep sea and oil sand projects, were suspended or postponed for an indefinite period of time. A rise in investments is thought probable in 2017 because of the stabilisation of the crude oil prices (OGJ 2017a).

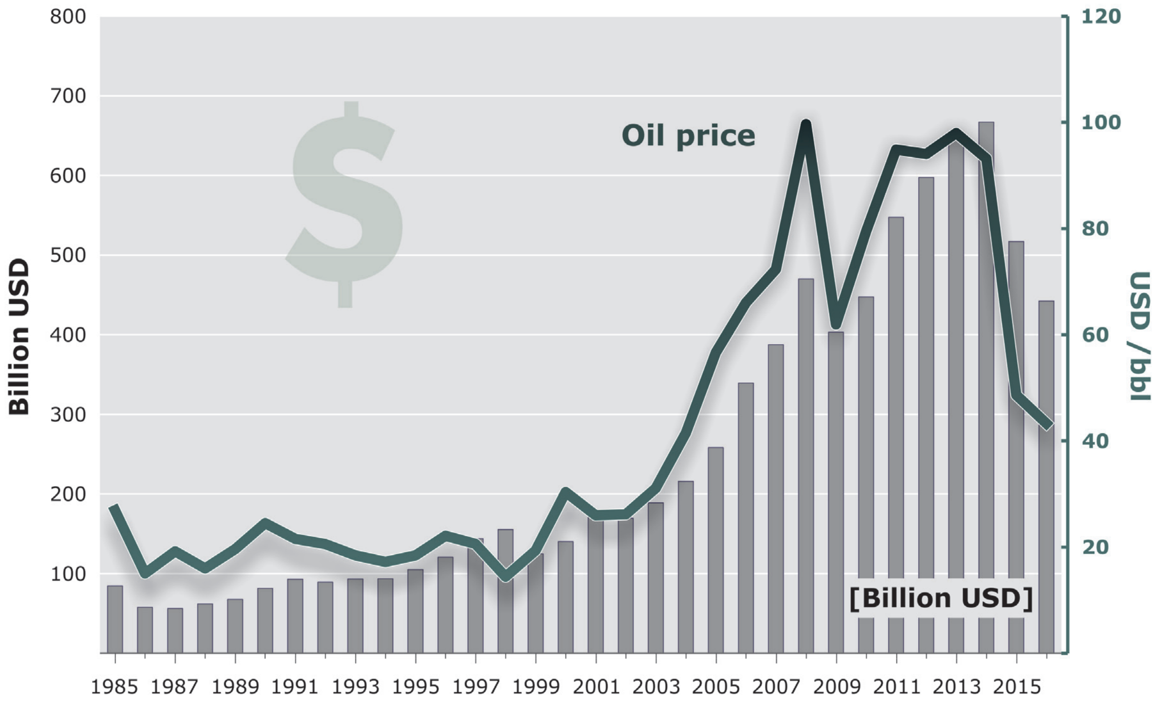

Figure 3-5: Investments in the upstream sector and changing WTI crude oil prices over time (after Barclays Research 2017, EIA 2017b).

Discoveries of new fields in the last two years have declined because of savings in the upstream sector, and reached a level in the reporting year which had not been seen for over seven decades (IEA 2017c). Although the oil production volumes since the middle of the 1980s have been continuously higher than the new discoveries with a few exceptions, there has nevertheless been an almost continuous rise in conventional oil reserves (Fig. 3-6). Most of the growth in reserves is due to so-called „reserves growth" in already developed oil fields. In other words, after the discovery of a field and its development, crude oil reserves have generally been rated higher over the course of the years (they "grow").

The (too) low figures for oil reserves reflects the fact that only those figures can be reported which can be declared as reserves at that particular point in time and according to the information available. If the reserves were defined according to the regulations stipulated by the US-American SEC (Securities and Exchange Commission), and as used by publically quoted companies in the USA, this would mean that only „proved reserves" would be stipulated in principle. When taking into consideration the uncertainties associated with estimating reserves, this means that one can assume with a probability of 90 % that the actual reserves are higher than the specified values. The reserves are therefore systematically estimated too low in most cases (biased). Parts of the fields defined as resources can be transferred to reserves by re-evaluations based on continuing exploration, improved production technologies or a sustained period of higher crude oil prices. This process, which increases the total reserves of a field during the development activities, slows down, however, as the degree of exploration and development increases. At a global level, this means that conventional reserves can increase further in the medium term even though the number of new discoveries is lower than the actual level of crude oil production.

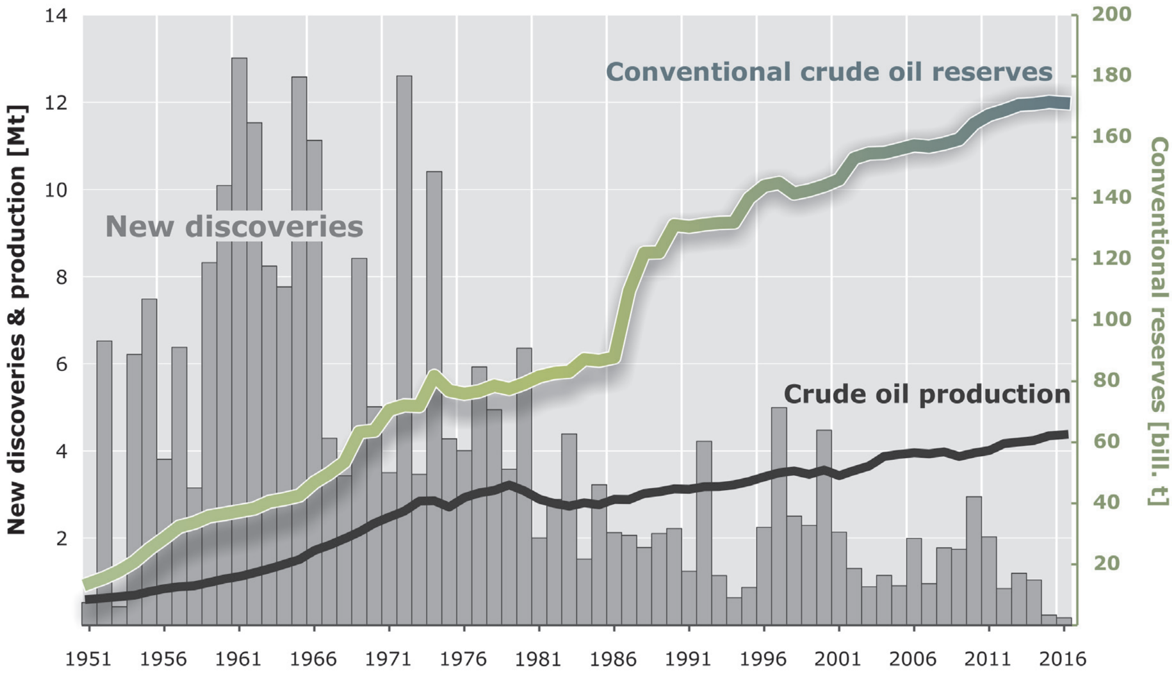

Figure 3-6: New discoveries (after Wood Mackenzie 2017), crude oil production and reserves between 1951 and 2016.

3.3 Natural gas

With respect to its proportion of global primary energy consumption, natural gas is the third most important energy resource behind crude oil and coal. Despite the comprehensive global supplies and decreasing prices, natural gas consumption world-wide only rose by around 1.4 %, and therefore failed to match the previous year's rise of 2.3 %. Nevertheless, a rise in global natural gas consumption is expected in the medium to long term.

Global resources in the range of 851 tcm are assumed when aquifer gas and natural gas from gas hydrates are included (Tab. 2). Of the developed non-conventional natural gas deposits with commercial production, the relatively well understood shale gas resources dominate with 205 tcm, followed by tight gas with 63 tcm and coal bed methane (CBM) with 51 tcm (Tab. A-16 in the Appendix). Hardly any current, country-specific and reliable estimates on the technically producible resources of natural gas in tight sandstones and carbonates (tight gas) are available. It can, however, be assumed in principle that tight gas is present particularly in the Palaeozoic horizons of most of the world's basins with gas prospectivity. Against this background, the global resources of 63 tcm are thought to be significantly undervalued.

The country with easily the largest conventional and non-conventional **natural gas resources** is the Russian Federation, followed by China, the USA, Canada and Australia (Tab. A-16 in the Appendix). The most comprehensive conventional natural gas resources in the world are thought to be in the Russian Federation, followed by the USA, China and Saudi Arabia. The natural gas resources of conventional and non-conventional deposits are estimated at 643 tcm overall (previous year: 652 tcm) (Fig. 3-7). The decline is attributable to a re-evaluation of the shale gas resources in South Africa, China and the Ukraine in particular, as well as in various European countries.

So far, there are mainly only global estimates available on the resources of aquifer gas and natural gas in gas hydrates, and only a few detailed regional studies. According to our current understanding, there may be 24 tcm of natural gas in aquifers and 184 tcm of natural gas in gas hydrates. It is still uncertain when this potential can be put to commercial use. With respect to gas hydrates, a few countries have, however, been involved in research projects for many years with the aim of developing domestic offshore gas hydrate deposits as potential energy sources. For instance, China conducted a 60-day test operation in 2017 in the Shenhu region of the South China Sea producing more than 300,000 m^3 of natural gas with a high degree of purity from gas hydrates at a depth of 1,266 metres below water level (water depth around 1,240 m). The maximum production rate was apparently 35,000 m^3 per day.

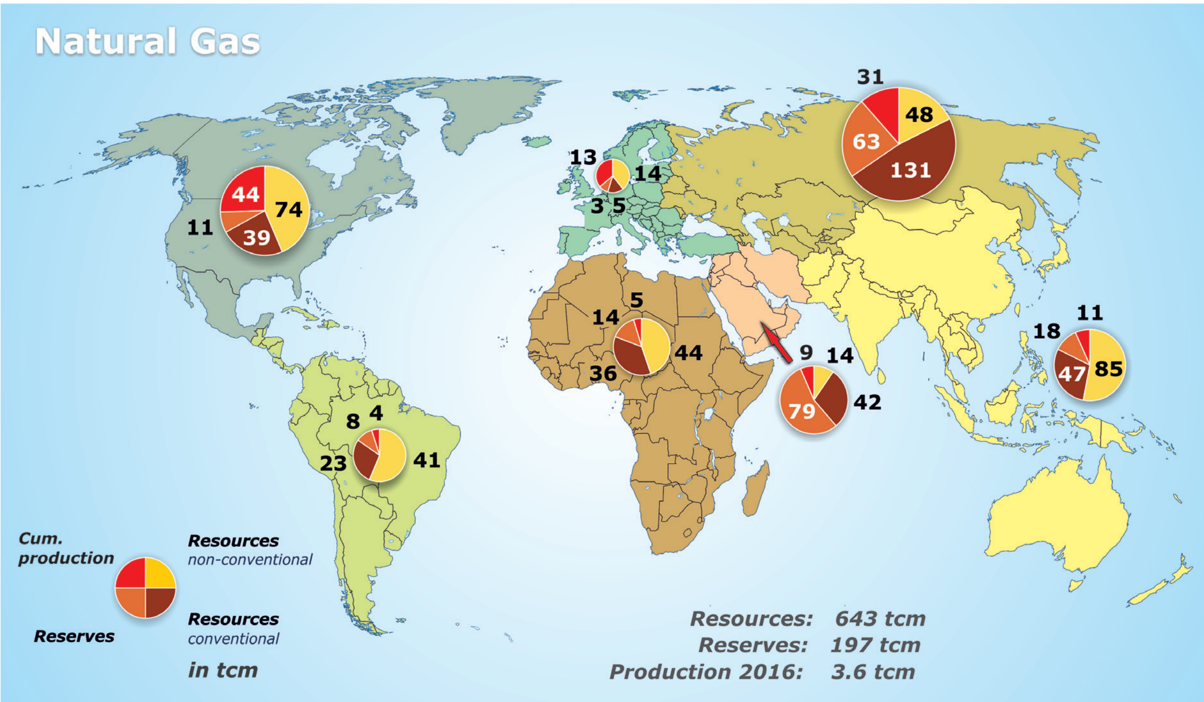

Figure 3-7: Total natural gas potential 2016 (excluding aquifer gas and gas hydrates): regional distribution.

The global **natural gas reserves** have only declined marginally year-on-year and were again estimated at 196.6 tcm at the end of 2016 (Fig. 3-7). When the annual production of around 3,620 bcm in 2016 is taken into consideration, the above figure reveals that production overall was compensated for by increases in reserves.

On a global scale, the share of non-conventional reserves is relatively low, and set to remain so for the foreseeable future (Tab. A-17 in the Appendix). However, tight gas reserves are usually not reported separately so that precise analysis as part of global reporting is not possible. Estimates for the USA assume that tight gas reserves account for more than 20 % of the remaining reserves. Significant shale gas reserves are currently only reported in the USA. Here, they totalled almost 5 tcm and account for around 57 % of the total reserves in the country. About half of global natural gas reserves (almost 54 %) are in the Russian Federation, Iran and Qatar (Tab. A-17 in the Appendix), and are almost all in conventional deposits. 81 % of the global reserves are located in OPEC and CIS countries. Most of the onshore reserves are located in the CIS, and particularly in the Russian Federation.

The Middle East has the most offshore reserves world-wide, and the biggest share of these reserves is located in the world‘s largest natural gas field: North Dome/South Pars (Qatar/Iran) in the Arabian Gulf. The mega-giant North Dome/South Pars field extends over an enormous area covering 9,700 km^2 of the Arabian Gulf, which corresponds to around half of the area of the state of Rheinland-Pfalz in Germany. Water depths are up to 70 m. The reservoir lies at depths of between 2,750 m to 3,200 m below sea level. The mega-giant field is estimated to have originally contained almost twice as much producible gas as the world‘s second largest natural gas field, Galkynysh in Eastern Turkmenistan (Tab. 3). Compared to the Zohr field discovered offshore Egypt in 2015, and which is the largest natural gas field ever discovered in the Mediterranean, North Dome/South Pars still holds almost fifty times as much in its remaining reserves and resources (Tab. 3). In addition to the enormous volumes of natural gas, the field also contains considerable quantities of natural gas condensate (MEI 2016), which is included in its oil production figures. Because of the relatively moderate production rates at present, and the huge remaining reserves, the overall field will be of major economic and geostrategic significance in future as well.

Global **natural gas production** in 2016 rose by a modest 1.3 % to around 3,620 bcm. This is a lower rise than the previous year‘s figure of 2.6 %, which is largely attributable to the fact that the natural gas production in the USA declined for the first time in many years, and was down around 1.6 %. This is mainly attributable to the lower demand for the generation of heat, and unattractive market prices at times.

In regional terms, the largest percentage increases in production were reported from Austral-Asia (5.5 %), and the Middle East (3.8 %). Production in the European Union declined again, although it only dropped by 2.5 % in the reporting period compared to minus 9.4 % the previous year. This is mainly due to the continued throttling of production from the huge Groningen natural gas field in the Netherlands.

Table 3: 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** [Tcm}	Remaining Reserves** [Tcm]	Yearly Production* [bcm]
1	North Dome South Pars	Qatar Iran	Offshore	1971 1990	38	35,8	255
2	Galkynysh	Turkmenistan	Onshore	1970 2006	21	20,5	40
3	Urengoy	Russian Federation	Onshore	1966	9,5	2,5	77
4	Yamburg	Russian Federation	Onshore	1969	6,2	1,5	60
5	Shtokman	Russian Federation	Offshore	1988	3,8	3,8	(not developed)
	Hassi R'Mel	Algeria	Onshore	1956	2,8	< 0,5	50
	Groningen	Netherlands	Onshore	1959	2,8	0,6	27
	Zohr	Egypt	Offshore	2015	0,7	0,7	(not developed)
	Snøhvit	Norway	Offshore	1984	0,224	0,182	6
	Salzwedel	Germany	Onshore	1968	0,2	0,002	0,4

*predominantly estimated; **all estimated, partly including resources

The USA is still the world's largest natural gas producer ahead of the Russian Federation and Iran (Tab. A-18 in the Appendix), and was able to cover almost all of its natural gas consumption from domestic production. Shale gas production as well as natural gas produced from shale oil production accounted for around 60 % of the natural gas produced in the USA in 2016 (EIA 2017c), followed by the production of natural gas from tight gas sandstones with a share of around 23 % (OGJ 2017b). Commercial shale gas production during the reporting year, in addition to the USA, was only reported from Canada, China and Argentina, albeit at much lower levels.

The highest volumetric growth in natural gas production occurred in Iran with 18.5 bcm (10 %), and Australia with 18.3 bcm (26.2 %). Australia was able to almost double its production of coal bed methane (CBM). The next highest volumetric growth rates are reported from Algeria with 10.9 bcm (13.2 %) and the United Arab Emirates with 6.1 bcm (10.9 %). Domestic production rose by 3.7 bcm (2.7 %) in China. Although production from conventional natural gas deposits declined in China, shale gas production increased year-on-year by around 52 % to 7.9 bcm (XINHUANET 2017).

The Russian Federation and the USA together produced around 1.4 tcm in 2016. This corresponds to almost 39 % of global natural gas production.

After many years of low growth, **natural gas consumption** in 2015 had risen world-wide by almost 2.3 %. However, in 2016 the rise dropped to around 1.4 % year-on-year, to around 3,610 bcm (Tab. A-19 in the Appendix). Although natural gas consumption rose more or less strongly in many regions around the world, natural gas demand in Latin America and the Confederation of Independent States declined. In the Russian Federation in particular, there was a strong decrease of more than 5 %, but it still remained the second largest natural gas consumer in the world, well behind the USA though, whose natural gas demand only increased marginally compared to 2015 (Tab. A-19 in the Appendix). The USA and the Russian Federation accounted for around a third of global demand in 2016.

The strong growth in natural gas consumption in the EU continued further with a rise of 6 %, partially due to the increasing competitiveness of natural gas compared to coal. The growth in imported natural gas was almost all via pipelines from Algeria and the Russian Federation. Consumption also rose in the Middle East (plus 5.2 %) and Austral-Asia (plus 4.3 %). China‘s natural gas consumption rose significantly by 6.8 %, due in large part to the improved natural gas infrastructure.

Around 1,086 bcm of natural gas, and thus 30 % of global natural gas production (3,620 bcm) was traded across borders during the reporting year, of which 346.6 bcm (32 %) in the form of liquefied natural gas (LNG). The world‘s biggest LNG exporting country in 2016 was again Qatar which exported 104.4 bcm, followed by Australia with 56.8 bcm, and Malaysia with 32.1 bcm (BP 2017a). The increased supplies available from Australia were absorbed by the stronger demand in Asia and the Middle East (EEK 2017a).

Global trade in natural gas has grown further overall compared to the previous year. The global trade in LNG with a rise of around 6.5 %, grew more than pipeline gas. The largest share of the growth in LNG exports was accounted for by Australia, which has significantly boosted its LNG exports and could become the world‘s largest exporter of liquefied natural gas in the medium term. The USA exported around 4 bcm of its shale gas production in the form of liquefied natural gas during the course of the year from the Sabine Pass Terminal which was commissioned in 2016. The world‘s largest importer of LNG at 108.5 bcm continues to be Japan which sources its supplies from a large number of countries. Around 63 % came from Southeast Asia and Australia (27 %).

Europe accounted for around 45 % of global natural gas imports (Fig. 3-8). Germany‘s share of 112 bcm alone accounted for 23 %, or nearly one quarter of total European imports. At a global level, this meant that Germany was also the largest importer in 2016 (Fig. 3-8), and is also one of the largest consumers in the world with a consumption of around 101.5 bcm (Tab. A-19 in the Appendix). The Federal Republic of Germany has major natural gas storage capacities at a global level. At the end of 2016, the maximum usable working gas volumes in these storages totalled 24.2 bcm (LBEG 2017), which corresponds to around one quarter of annual consumption.

Germany exclusively imports all of its gas via pipelines, whereas Japan as the world‘s second largest natural gas importer has to import all of its natural gas in liquefied form. Thanks to the domestic production of shale gas, the world‘s third largest importer, the USA, has been able to slash its imports by almost 35 % since 2007, even though consumption rose around 20 % over the same time period.

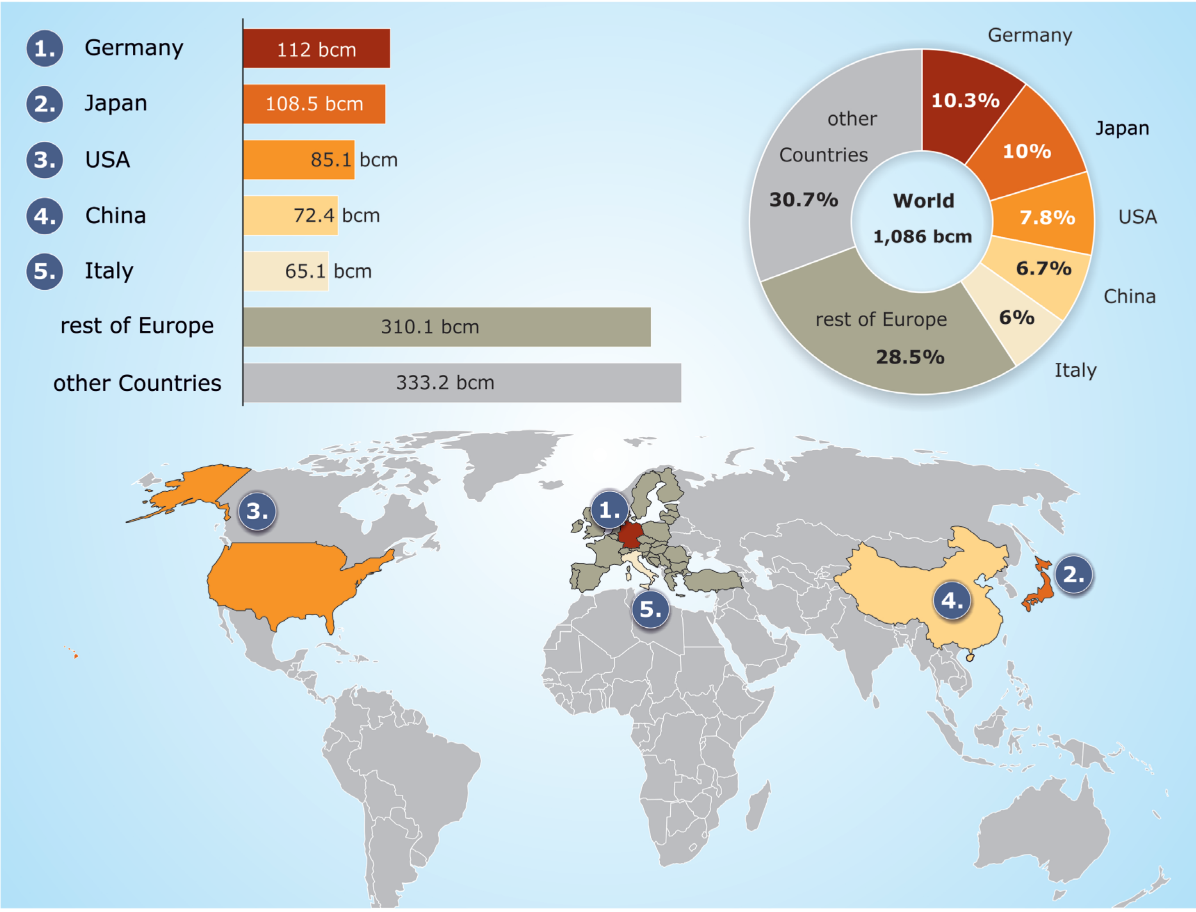

Figure 3-8: The biggest natural gas importers in 2016.

Although supra-regional natural gas markets exist around the world, the global trade in LNG is leading to increasing harmonisation. Closer connections between the various gas markets caused by the generous availability of LNG, has led to a further convergence in global prices. Natural gas continued to be cheap in the USA in 2016 because of the large volumes available on the supply side. The average natural gas price (Henry Hub spot price) in the USA was 2.46 USD/million BTU (previous year: 2.6 USD/million BTU). Natural gas imported into Germany cost on average 4.93 USD/million BTU (BP 2017a). The prices for LNG imported to Japan averaged 6.94 USD/million BTU, and are therefore now only around three times as high as in the USA. Overall, the trend of falling prices against the background of relatively cheap crude oil continued further in 2016.

With its growing supply grid, Europe is connected to a large part of the global natural gas reserves, either via pipelines or LNG import terminals. The European natural gas market therefore basically finds itself in a relatively comfortable position, although geopolitical risks are still a key factor affecting natural gas supplies.

In Europe, there are currently 25 large LNG import terminals, of which 23 are in the EU, and 2 in Turkey (King & Spalding LLP 2016). These terminals are in Belgium, France, Greece, the UK, Italy, Lithuania, the Netherlands, Poland, Portugal, Spain and Turkey. The total regasification capacity in the 25 European terminals was 216 bcm in 2016. This corresponds to around 40 % of the natural gas consumption in the region. 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

Of all the fossil fuels, coal is the energy resource with easily the largest global reserves and resources. With a share of 26.2 % of global PEC, coal was the second most important energy resource in 2016 behind crude oil. Coal accounted for a share of 38.3 % of global power generation in 2015, and thus more than any other fuel (IEA 2017c).

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. Because of the relatively high energy content, hard coal is cheaper to transport and is traded world-wide. Lignite on the other hand (energy content < 16,500 kJ/kg) is primarily used close to the deposits because of the lower energy and higher water contents, and is mostly used to generate electricity.

Total coal resources (total of reserves and resources) did not change significantly year-on-year. Reported global coal reserves at the end of 2016 totalled 1,032 Gt, of which 715.6 Gt hard coal and 316.5 Gt lignite. Compared to the previous study (BGR 2016b), differences in the reserves figures primarily affected hard coal reserves (plus 0.5 %), and this was largely attributable to exploration activities and re-evaluations of deposits in India, Indonesia and China.

Global coal production declined again year-on-year, and thus for the third time in the new millennium, and totalled around 7,281 Mt in 2016. This corresponds to a reduction of 6.1 % compared to the previous year. Of this, 6,291 Mt were hard coal (minus 6.7 %), although the decline is almost completely attributable to a reduction in the production of steam coal (IEA 2017a). The remaining 990 Mt (minus 2.1 %) were accounted for by lignite.

Coalfields and their production are spread out even more strongly than conventional crude oil and natural gas resources amongst a very 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 hard coal and lignite.

Hard coal

The regional distribution of hard coal reserves and resources, and the estimated cumulative production since 1950 are shown in Figure 3-9. The Austral-Asia region has the largest remaining hard coal potential with 7,532 Gt, followed by North America with 6,871 Gt, and the CIS with around 3,003 Gt. The world‘s largest hard coal reserves are in the United States of America with 221 Gt

(30.9 % global share). This is followed by the People‘s Republic of China with around 128 Gt (17.9 %), ahead of India with around 93 Gt (13 %). The ranking is then followed by the Russian Federation (9.7 %), Australia (9.5 %), and the Ukraine (4.5 %). The volumes (reserves) of subsidised production producible in Germany until the end of 2018 amount to around 8 Mt hard coal. In terms of resources, the USA alone with 6,458 Gt accounts for over 36.5 % of global hard coal resources, followed by China (30.1 %), and the Russian Federation (15 %).

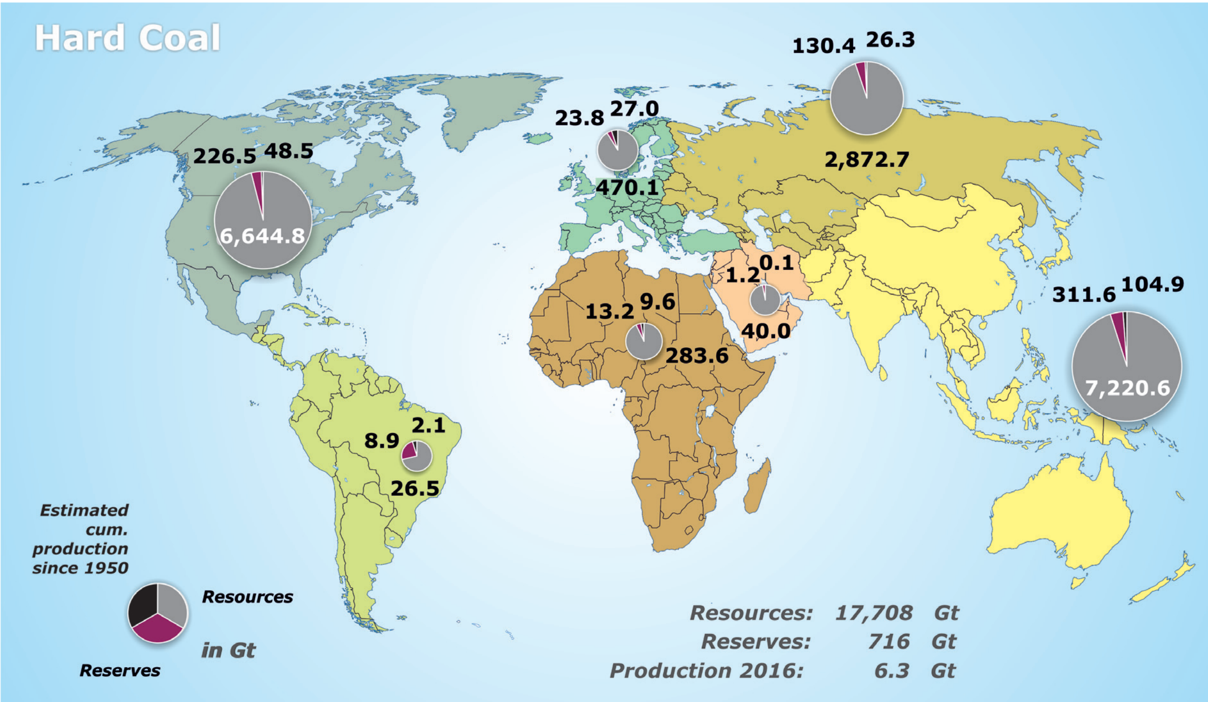

Figure 3-9: Total hard coal potential in 2016 (18,424 Gt): regional distribution.

The three largest hard coal producers in 2016 were China with a share of 49.3 % (3,103 Mt), India (10.5 %) and the USA (9.4 %). The USA therefore fell down the ranking to third place behind India in 2016. Whilst India boosted its production by 3.7 %, production in China (minus 9.4 %) and the USA (minus 20.6 %) dropped significantly. With respect to the European Union (EU-28), the share of global hard coal production is 1.4 %, corresponding to a production of only 87 Mt – and thus around 12 Mt lower than the previous year.

Around 20 % of the hard coal produced world-wide in 2016 amounting to 1,290 Mt was traded, of which 1,115 Mt was transported by sea (VDKI 2017a). The global trading volumes of hard coal therefore rose year-on-year by around 2.6 %. Australia dominated the hard coal world market with exports totalling 392 Mt (30.3 %), followed by Indonesia (28.6 %) and the Russian Federation (12.8 %).

The largest hard coal importers were China, India and Japan, with a combined volume of around 636 Mt (49.8 %). China increased its imports year-on-year in 2016 significantly by around 25 % from 204 Mt to 256 Mt. This means that around one fifth of global hard coal imports in 2016 were accounted for by China. With imports of around 191 Mt in 2016, India imported slightly less hard coal than the previous year (200 Mt). Japan‘s imports of around 190 Mt were almost identical to the previous year (191 Mt). As in previous years, Asia dominates the global hard coal import market (Fig. 3-10) with a current share of around 74 %. At 164 Mt – and thus around 30 Mt or 16 % lower than the previous year – only around one eighth of global hard coal imports were accounted for by the European Union (EU-28), which covered around 59 % of its hard coal demand in this way in 2016.

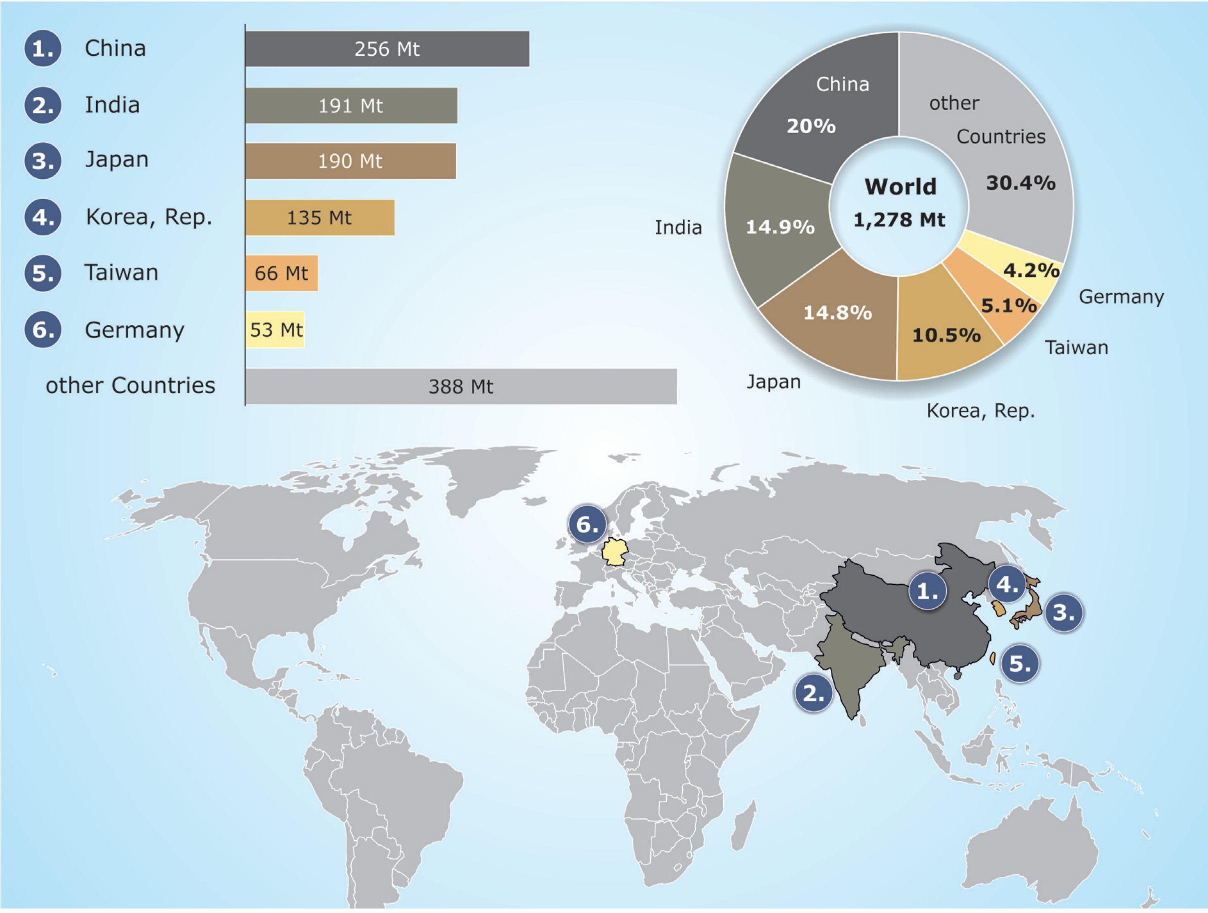

Figure 3-10: The largest hard coal importing countries in 2016.

There are many reasons for the decline in European hard coal imports, which occurred in parallel to a decline in hard coal production (Fig. 3-11). A fuel switch from hard coal to natural gas for power generation has been increasingly observed since the middle of 2016 as a consequence of the high hard coal prices (Fig. 3-12) and relatively favourable natural gas prices in Germany and other countries in Europe (Hecking et al. 2017). The push to expand renewable energy has also led to a reduction in European hard coal (import) demand. However, the main reason for the significant reduction in the last five years is the introduction of a minimum CO_2 price in the United Kingdom (Scottish government 2016) in addition to the costs for a CO_2 certificate from the European Emissions Trading System, which reduces the competitiveness of hard coal as an energy resource. British imports declined from 49.4 Mt (2013) to 8.5 Mt (2016) since the system was implemented in 2013. There are also minimum CO_2 prices in other European countries, albeit with differences in how they are applied to different sectors (World Bank 2016). The highest minimum CO_2 price at the moment of 120 €/t CO_2 in Sweden affects all of the sectors not covered by the EU Emissions Trading System (primarily heavy industry, heat/power plants and power generation) (Raab 2017). The Netherlands plans to implement a minimum CO_2 price in 2020 (S&P Global Platts 2017a), and France supports the implementation of an EU-wide minimum CO_2 price (S&P Global Platts 2017b).

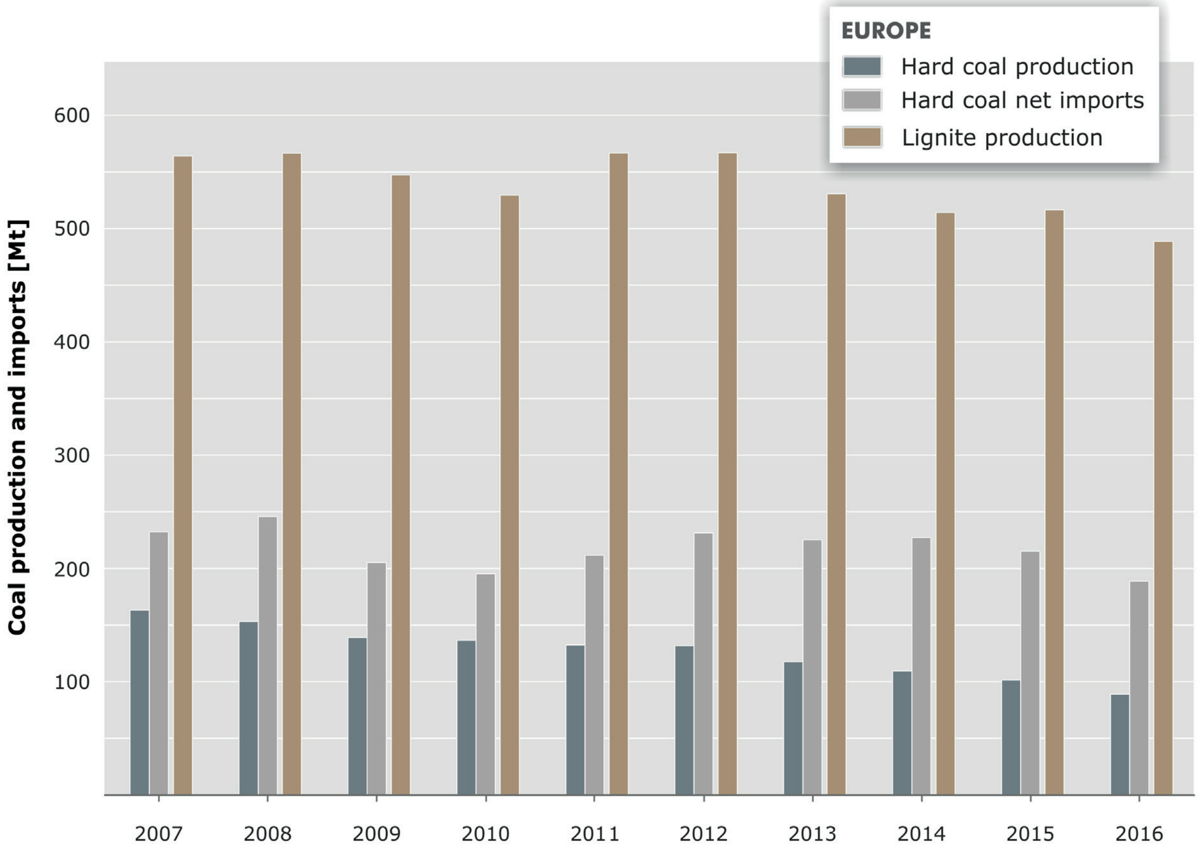

Figure 3-11: Development of European coal production and imports since 2007.

The dependency of the EU-28 on imports of fossil fuels has risen almost continuously since the middle of the 1990s. Dependency on imports in 2015 was 88.4 % for crude oil, 69.1 % for natural gas, and 64.1 % for hard coal (EC 2017). The dependency on hard coal imports as well is likely to increase further with the EU-wide closure of non-competitive hard coal mines at the end of 2018 which have been granted shut-down grants by the EU (EC 2010). However, against the background of the announced withdrawal from coal-fired power generation by various European countries including Italy and the UK in 2025, as well as the Netherlands, Ireland, Finland, France and Portugal in 2030, (Argus 2017), it appears likely that the consumption of hard coal in the EU will decline in the next few decades, and therefore also the need for imports. This will probably be accompanied by a further increase in the EU‘s dependency on imports of natural gas, because at least some of the closed coal power plant capacities will need to be replaced by natural gas power plants. In the light of the continuous decline in natural gas production in EU countries, lignite will be the only fossil fuel in Europe which does not depend on any imports, and which is produced in large quantities compared to the rest of the world (European share is 489 Mt or 49.4 % of global production).

The North-west European annual average spot prices for steam coal (port of Amsterdam, Rotterdam or Antwerp; cif ARA), increased from 67.45 USD/tce in 2015 to around 68.53 USD/tce in 2016, an increase of around 1 USD/tce (plus 1.6 %) (VDKI 2017b). Driven mainly by increases in prices in the Asian (Chinese) coal market, prices rose up to around 100 USD/tce in December 2016. The prices then continued to remain at a relatively high level until autumn 2017 (Fig. 3-12).

The price of coking coal boomed in 2016 after dropping for five years, and continued to be very volatile in 2017 as well (Fig. 3-12). Whilst the spot price for high quality Australian coking coal was still at around 77 USD/t in January 2016, this jumped suddenly from the summer to 311xUSD/t (day spot price) by mid November 2016. This climb in prices was primarily due to the consequences of production cuts in China as well as in the USA. The spot price for high quality Australian coking coal then halved by the beginning of spring 2017, before jumping again to 290 USD/t (day spot price) by the middle of April 2017 because of production and transport outages as a consequence of cyclone Debbie in Australia. By the start of summer 2017, the price dropped down again to just under 150 USD/t before rising again to the 200 USD/t mark in August and September 2017 because of a shortage in the supply of Australian coking coal (IHS markit 2017, VDKI 2017a).

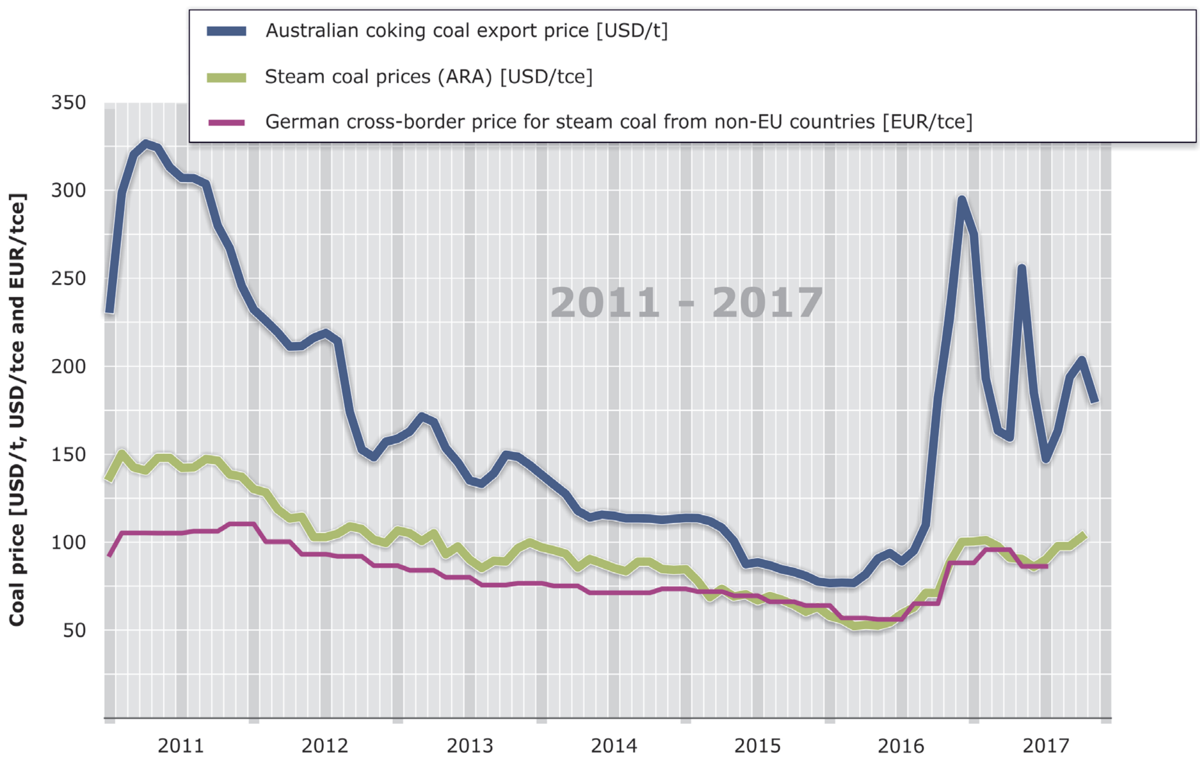

Figure 3-12: Development of Australian (prime hard coking) export prices for coking coal as well as North-west European and German steam coal import prices from December 2010 to October 2017 (BAFA 2017c, IHS markit 2017, VDKI 2017b).

The rise in the world market prices for hard coal from summer 2016 ended the global wave of mine closures with high production costs that had continued over a period of several years. The US-American coal sector in particular experienced major cut-backs (BGR 2016b), and hard coal production in the USA dropped again in 2016 by another 20 %. The reason for the production cuts associated with the decline in hard coal consumption were the growing competition from cheap domestic natural gas (shale gas) on the one hand, as well as more stringent environmental regulations for coal-fired power plants such as the Mercury and Air Toxics Standards (EPA 2016) or the Clean Power Plan (White House 2015) on the other hand. However, the US Environmental Protection Agency announced in October 2017 that it would be annulling the Clean Power Plan (The New York Times 2017).

The preliminary estimates for 2017 indicate a significant expansion in US-American hard coal production in the possible order of around 10 % compared to 2016 (EIA 2017d). This rise in US production is only due in small part to higher hard coal consumption in the USA compared to the previous year (EIA 2017e). The main reason is the US coal industry‘s reputation as a swing supplier which boosted its hard coal exports year-on-year by 68 % to 62.4 Mt in response to the rise in world hard coal market prices in the first three quarters of 2017 (S&P Global Platts 2017c).

China reduced its hard coal production for the third year in succession in 2016, this time by around 9 % compared to the previous year. The significant cut-back in production is primarily attributable to political stipulations to reduce the current overcapacities in the Chinese coal sector. To achieve its objective of cutting annual production in 2016 by more than 250 Mt (China Coal Resource 2016a), the Chinese government stipulated in April 2016, alongside other measures, the reduction in the number of working days in Chinese coal mines from 330 to 276 a year (China Coal Resource 2016b). After only a few months, this gave rise to a considerable rise in coal prices in China, as well as on the world market (Fig. 3-12), so that the rule stipulating the reduction in working days was first loosened from the autumn, and subsequently completely abandoned.

China has been pushing ahead with the restructuring of its coal sector for many years now, primarily aimed at closing small mines with low production capacities (< 90 kt/a), and relatively many (fatal) accidents. According to China Coal Resource (2017a), there were 9,598 coal mines in China at the end of 2015 of which almost half had low production capacities of less than 90 kilo tonnes per year. Around 2,000 mines were closed in 2016 (China Coal Resource 2017b), and another 1,000 mines in 2017 (China Coal Resource 2017c). This gave rise to an associated decline in production capacity of 290 Mt in 2016, and the planned reduction of production capacities by another 150 Mt in 2017, of which 128 Mt had already been closed by the end of July 2017 (China Coal Resource 2017d). Despite the current wave of closures, new modern coal mines are in the planning stage or in development, or already existing mines are being modernised and their production capacities expanded. The China National Coal Association put the figure for Chinese production capacity in November 2017 at 3.9 Gt/a. In addition, mines with 1.2 Gt to 1.3 Gt coal production capacities are still under development or in the modernisation phase (China Coal Resource 2017e).

Coal as part of the Chinese energy mix

The main driver of the significant expansion of Chinese coal production since the beginning of the new millennium, as well as coal imports in recent years, is the growing demand for energy, and therefore also for electricity. Chinese power consumption rose between 2010 to 2016 by around 41 % or 1,720 terawatt hours (TWh) to 5,920 TWh. This went hand-in-hand with the expansion of power generation capacities which grew over the same time period by around 72 % to 1,604 GW. The Chinese power mix is primarily based on coal (943 GW), followed by hydropower (332 GW) and windpower (149 GW), as well as photovoltaics (77 GW), natural gas (70 GW) and nuclear power (34 GW). The four latter power sources boasted the highest relative growth rates in recent years in terms of the expansion of generation capacities. Combined, the additional generation capacities for windpower (plus 119 GW), photovoltaics (plus 77 GW) and for natural gas (plus 61 GW) and nuclear power (plus 23 GW) totalled 280 GW. It was therefore slightly below the additional coal-fired generation capacity of 291 GW. Hydropower increased its capacity by 116 GW.

Power generation rose between 2010 and 2016 by around 42 % from 4,228 TWh to 5,990 TWh (Fig. 3-13). Although power generation from coal rose from 3,224 TWh to 3,906 TWh over this period, the (relative) proportion of coal in the power mix (Fig. 3-13) dropped from around 76 % (2010) to around 65 % (2016).This is attributable on the one hand to the expansion of other generation capacities (renewables, nuclear power, natural gas), as well as a reduction in the full load hours of thermal/coal power plants by around a fifth. Despite the reduction of the proportion of coal in recent years, coal still dominates Chinese power generation, accounting for almost two thirds, followed in 2016 by hydropower (19.7 %), windpower (4 %), nuclear power (3.6 %), others (3.3 %), natural gas (3.1 %) and photovoltaics (1.1 %) (after Energy Brainpool 2017). Coal will therefore continue to play a key role in the Chinese energy mix in the long term as well.

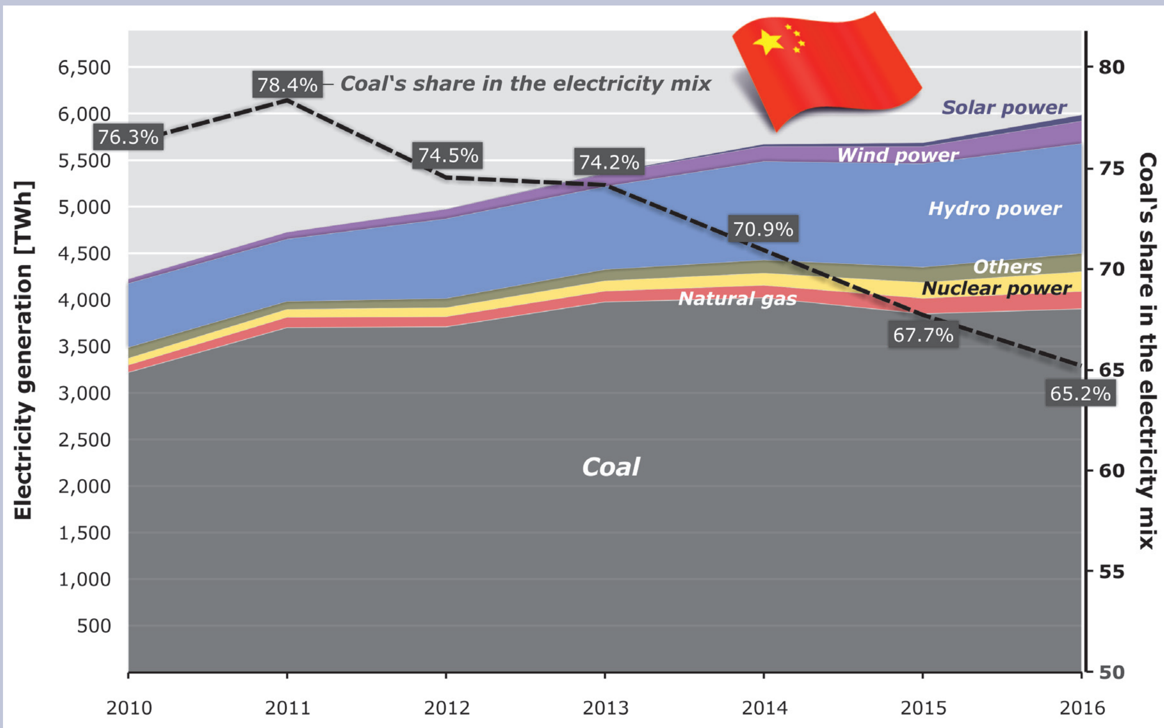

Figure 3-13: *Development of Chinese power generation and the proportion of coal in the power mix (after Energy Brainpool 2017).*

Despite the mine closures planned in the next few years, the production capacity of the Chinese coal sector will probably rise again by 2020 to exceed 4 Gt/a.

Various regulations and measures were adopted in China in recent years to control coal production with the aim of stabilising the inner-Chinese steam coal prices in the 80 USD/t to 90 USD/t range. Against the background of the regulated power price for the power generation sector, this level of prices is acceptable and enables most coal producers to achieve an adequate profit margin. Restructuring of the Chinese coal sector therefore has a significant influence on the world coal market and its prices (IEA 2017b). After a year-on-year reduction in its coal imports in 2015 to around 204 Mt, imports of coal to China in 2016 rose to around 256 Mt. According to preliminary estimates, Chinese coal production (plus 5 %) as well as Chinese coal imports (plus 10 %) will probably be higher in 2017 than in the previous year.

Of the three largest coal producing countries, only India succeeded in increasing its (hard) coal production in 2016, with a rise of 3.7 % to 663 Mt. Earlier, in spring 2015, the Indian government had presented ambitious plans to boost coal production. These plans included a production target of 1.5 Gt (total coal) by 2020, of which the major proportion of the production target accounting for around 1 Gt was to be achieved by expanding production by the state coal producer Coal India Limited (CIL) (CIL 2015, IEA 2015a, EIA 2015). In the 2016 financial year (April 2015 to March 2016), CIL achieved its highest ever growth in production with a rise of 8.9 % to 539 Mt. This production came from 413 mines – 176 open cast mines, 207 deep mines, and 30 opencast/deep mine complexes – whereby with a total of 505 Mt, most of the production is generated by opencast mines. The planned production by CIL for the 2017 financial year was 599 Mt (CIL 2017a), but with an actual production of 543 Mt, only 90.8 % of the planned target was actually reached (CIL 2017b). CIL‘s target production for the 2018 financial year is around 600 Mt (China Coal Resource 2017f), however, preliminary estimates indicate that only 278 Mt were produced in the first seven months of the financial year (CIL 2017c). Although India was able to expand its production in recent years and overtake the USA in 2016 as the second largest producer of hard coal, the Indian government‘s production target of 1.5 Gt in 2020 is considered to be unachievable.

Lignite

With around 1,519 Gt, North America has the largest remaining lignite potential in the world, followed by Austral-Asia (1,414 Gt) and the CIS (1,389 Gt, including sub-bituminous coal) (Fig. 3-14). Of the 317 Gt lignite reserves known world-wide in 2016, more than a quarter with 90.7 Gt (including sub-bituminous coal) are located in the Russian Federation (28.7 % global share), followed by Australia (24.2 %), Germany (11.4 %), the USA (9.5 %) and Turkey (3.5 %). With around 1,368 Gt (30.9 % world share), the USA has the world‘s largest lignite resources, ahead of the Russian Federation (29.1 %, including sub-bituminous coal) and Australia (9.1 %). 11 of the total of 35 producing countries accounted for almost 82 % of global lignite production in 2016 totalling 990 Mt.

Global lignite production declined by 2.1 % year-on-year and therefore dropped below 1 Gt for the first time since 2009. Domestic production in Germany sank by around 3.7 % compared to the previous year, but with a share of 17.3 % (172 Mt) was again the largest lignite producer ahead of China (14.1 %) and the Russian Federation (7.2 %).

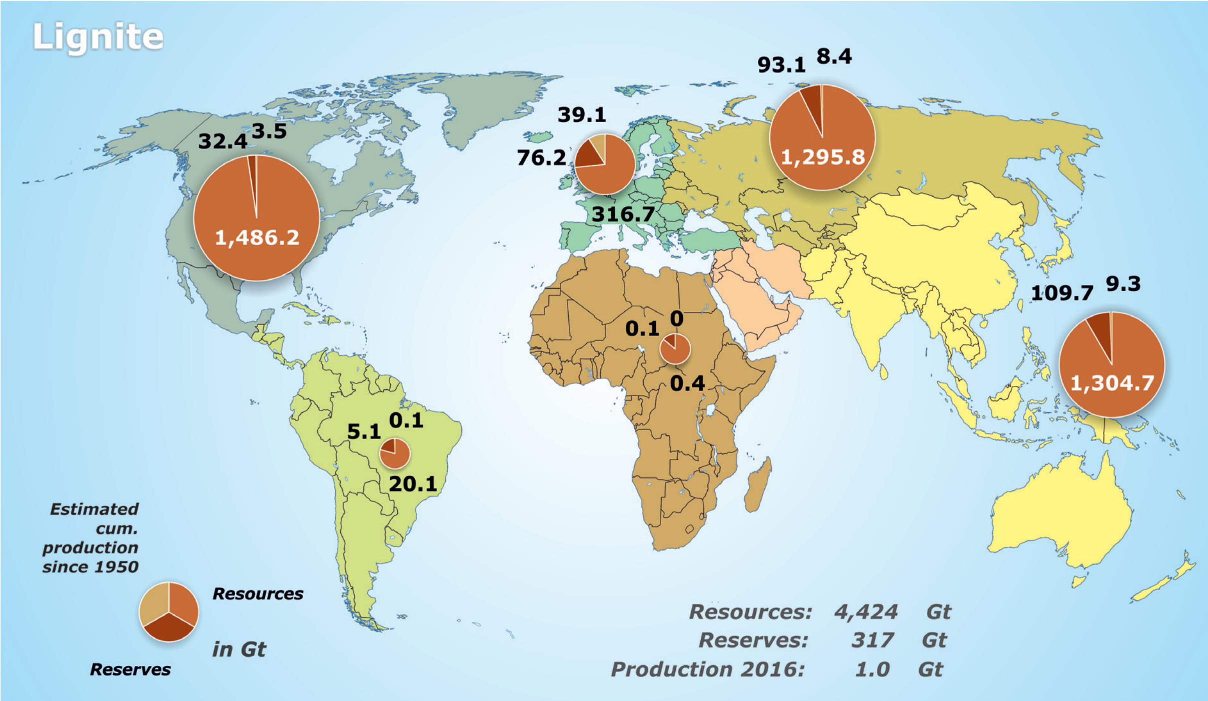

Figure 3-14: Total lignite potential 2016 (4,739 Gt): regional distribution.

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. 9 GW_e of newly installed nuclear power capacity was added world-wide in 2016. This is the highest expansion for 25 years. Six new nuclear reactors went online in China alone. 128 reactors are operating currently in Asia alone, and another 39 are under construction. A moderate increase in uranium demand is also expected in the coming decades in the Latin America and Africa regions (IAEA 2016a, IAEA 2017b, OECD-NEA/IAEA 2016).

Global uranium resources[3] are very extensive at 11.6 Mt, although they declined significantly compared to the previous year with a drop of 2,162 kt. In the recent past, declines in the uranium resource figures were primarily attributable to changes in the disclosures made by some countries. In 2016 as well, the total reduction is due to the drop in the bulk of the resources in one country. There were already signs in 2015 that the USA will no longer publish any figures on its inferred resources in future (BGR 2016b). The resources in the USA in this cost category (inferred resources < 260 USD/kg U) thus fell in 2016 alone by 2,131 kt compared to the previous year. There were already significant reductions in US-American resources and reserves in 2015 following a revision of the uranium resources in the USA. Numerous investigations and projects are currently being undertaken by the US Geological Survey ((USGS) in the USA (USGS 2007, USURA 2017a, USURA 2017b), the results of which will flow into the re-evaluation of American resources in the next few years. According to the initial preliminary results from the USGS, around 72 kt U are classified as potential undiscovered resources in the South Texas region (OECD-NEA/IAEA 2016). The classification and evaluation of US-American uranium reserves have so far been primarily based on investigations carried out in the 1980s, which are no longer adequate for validation according to today‘s criteria. This led to a reduction in the uranium resources in the USA within two years from 2,564 kt in 2014 to 121 kt in 2016 (minus 95 %). Argentina, Brazil, Iran, India, and Vietnam also stopped providing data on speculative resources for the first time in 2013. Major production countries such as Australia, the Russian Federation, and South Africa also followed suit. Given these reporting uncertainties, the resource figures presented in this study must be considered conservative.

With the exception of the disclosure-related reduction in the US-American resources, the size of global uranium resources has largely remained unchanged compared to the previous year. Although increases as a result of exploration activities and re-evaluations in recent years are low as a consequence of the continuing recession in the uranium market, rises have been reported in China, Greenland, Peru, Spain, and Uzbekistan. The resources in South Africa increased significantly by 403 kt U, and are primarily a result of an upgrading of former speculative resources. Resources

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

from Mauretania were published for the first time in 2016. Reductions in resources were reported for Australia, Canada, and Kazakhstan, as well as the disclosure-related reductions in the USA. The three most important uranium production countries in the world are Kazakhstan, Canada and Australia (Tab. A-39 in the Appendix), and they regularly review the size of their resources and reserves.

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 2016 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.

Analogous to the uranium resources, there were reductions in the uranium reserves compared to the previous year. The transfer of reserves into higher cost categories and/or re-evaluations, as well as production-related reductions in reserves, affected Canada and Kazakhstan in particular. Only as far back as 2015, both of these countries had initially increased their reserves as a result of exploration successes in recent years, but these were revised again in 2016 (OECD-NEA/IAEA 2016). Reserves were significantly increased in Niger (plus 2.8 kt U), Peru (plus 12.6 kt U), and South Africa (plus 55 kt U). Inferred resources here were transferred into the secured reserves as a result of a re-evaluation. Global uranium reserves in the cost category < 80 USD/Kg U totalled 1.2 Mt (2015: 1.3 Mt). Around 93 % of the reserves are located in only 10 countries, with Canada in first place, followed by Kazakhstan and South Africa. According to the current database, these three countries account for half of the global uranium reserves (Fig. 3-15).

Global uranium production rose by 1,916 t U in 2016 to 62,413 t U (plus 3 %). This was largely due to a considerable boost in Australian production, as well as another rise in production in Kazakhstan. The Chinese-owned Husab mine went into production in Namibia at the end of 2016, and could develop into one of the world‘s largest uranium mines in future. The mine which was developed in only three years could produce up to 5,500 t U per year. Canada also boosted its production year-on-year by 714 t U. The largest individual mine continued to be the McArthur River mine in Canada (6,945 t U, 11 % of global production), followed by Cigar Lake, Canada (6,666 t U, 11 %), Tortkuduk and Myunkum, Kazakhstan (4,002 t U, 6 %), Olympic Dam, Australia (3,233 t U, 5 %), and Inkai, Kazakhstan (2,291 t U, 4 %). Some mines continue to be forced to limit their production because of the relatively low spot market prices available for several years now (e.g. Rössing, Namibia). Some mines have even be forced to shut down (e.g. Kayelekera, Malawi).

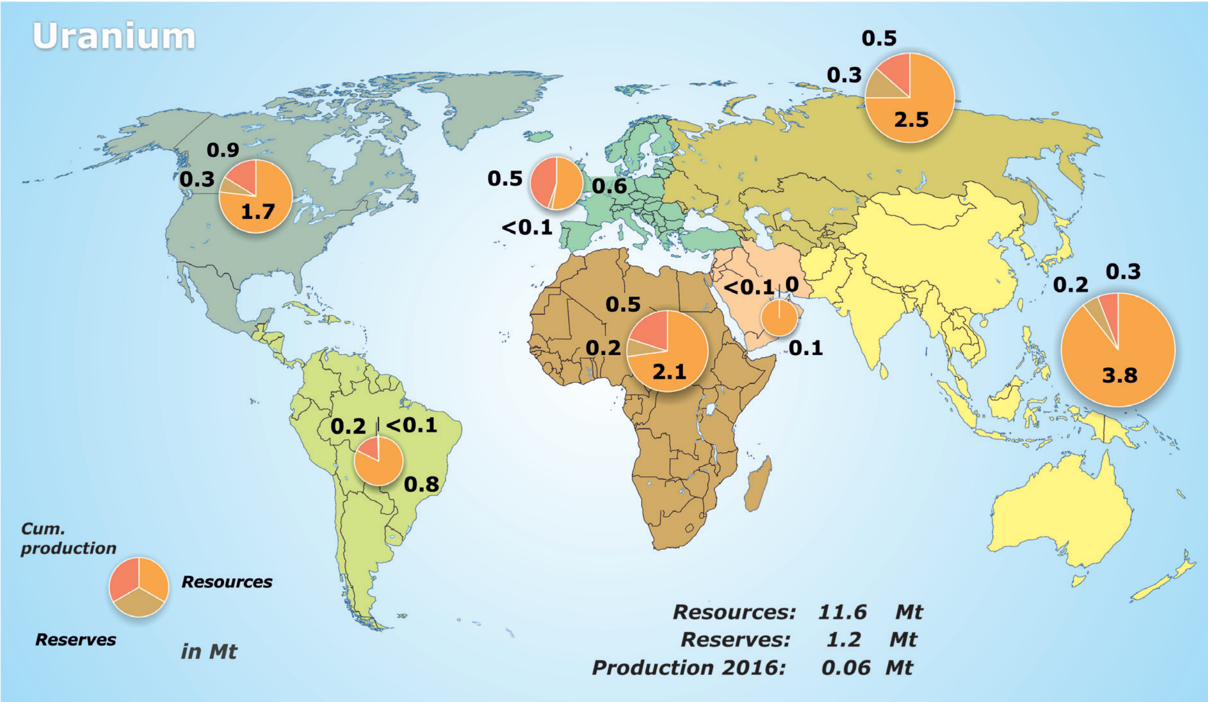

Figure 3-15: Total uranium potential 2016: regional distribution.

Around 88 % of global production was again generated by only six countries (Fig. 3-16). The largest producing country was again Kazakhstan. With 24,575 t U, the country boosted its production again (2015: 23,800 t U), and therefore accounted alone for nearly 40 % of global uranium production. The annual production in Kazakhstan has risen more than fivefold in the last ten years. Canada, Australia, Niger, Namibia and the Russian Federation together accounted for another 49 % of global production. As in previous years, uranium production is concentrated in only a few major companies. In 2016, around 83 % of global production came from only nine mining companies. Over half of the uranium produced world-wide came from only three companies: Kazatomprom (Kazakhstan) with a 21 % global share; Cameco (Canada) with 17 % and Areva (France) with 13 %.

Uranium consumption is concentrated in a small number of countries. More than half of the global uranium demand is accounted for by three countries: the USA, France and the Russian Federation. Global demand for uranium in 2016 was 63,404 t U (2015: 66,880 t U), and has thus declined significantly by around 3,476 t U year-on-year. Reductions were primarily due to Japan, India and China (Tab. A-39 in the Appendix), but, with the exception of Japan, probably do not represent any declining trend. A growing demand for uranium is expected in the coming years in China and India. Uranium demand in Germany reduced considerably with the shut-down of eight nuclear power plants in 2011, and was only 1,689 t U in 2016 (Chapter 2.2). The decommissioning of the Grafenrheinfeld nuclear power plant in June 2015 reduced the calculated annual reactor demand in Germany by around 200 t U.

Uranium is primarily traded world-wide on the basis of long-term supply contracts. Uranium supplies to EU member countries in 2016 totalled 14,325 t U (minus 1,665 t U or a drop of 10.4 %). The

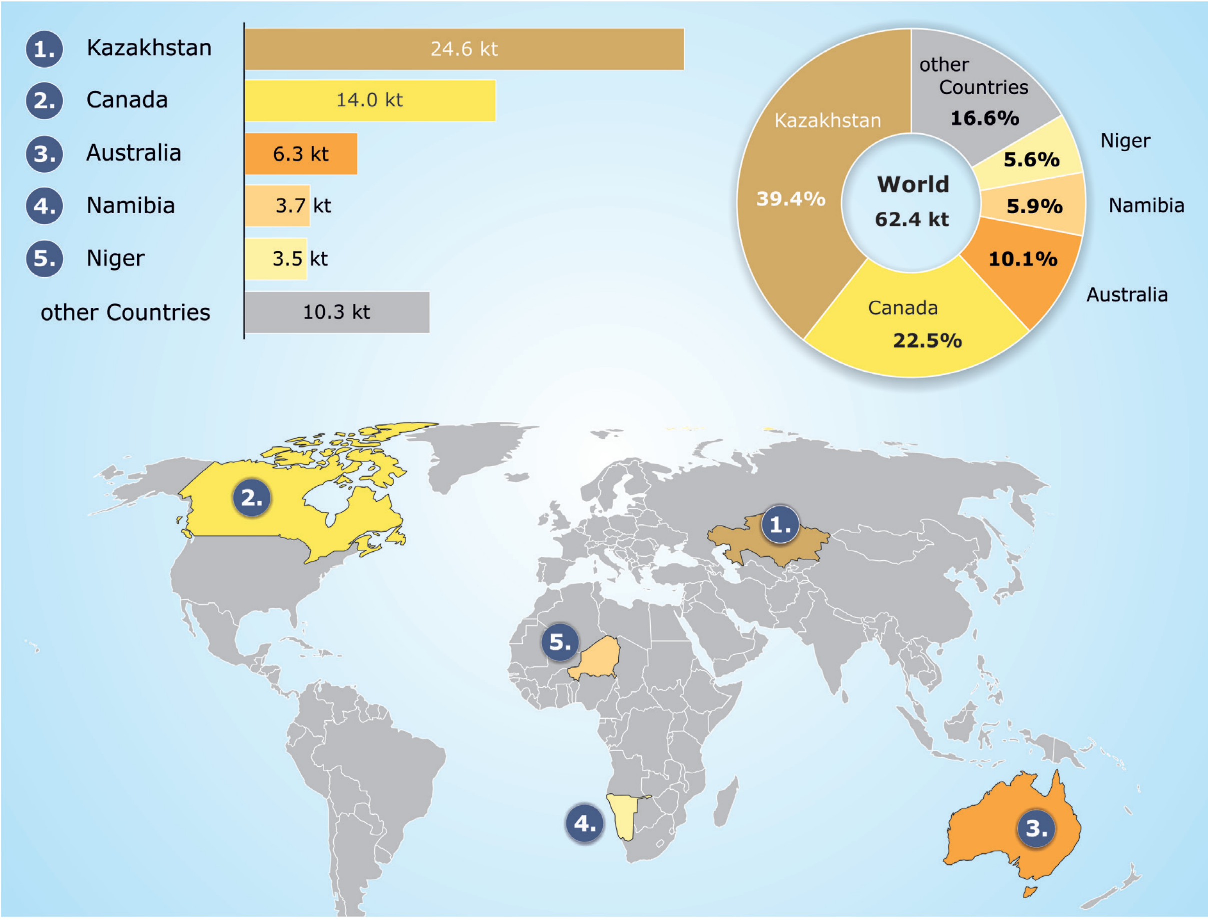

Figure 3-16: The biggest uranium producing countries 2016.

share of supplies arising from spot market contracts was only 3 % (European Union 2017). The uranium market continues to be characterised by relatively low spot market prices, which jeopardise the profitability of various mines and exploration projects. The trend of falling uranium prices which has continued since 2011 (as at January 2011: 188 USD/kg U), initiated by the consequences of the reactor accident in Fukushima and the associated shut-down of 48 reactors in Japan and 8 reactors in Germany, has now continued into its fifth year. As a result, spot market prices during the course of 2016 declined from 90.2 USD/kg U to 52.7 USD/kg U, and were thus around 130 USD/kg U lower than in 2011. The spot market reached a 12-year low of 46.80 USD/kg U in November 2016. No end to the decline in prices is foreseeable in the short term even though the spot market price remained relatively stable with an average price of 59 USD/kg U in the first half of 2017.

Although the uranium price only accounts for a small proportion of the power generation costs (around 14 % of total costs; WNA 2017a), it is crucial for the development of new exploration and mining projects. Investments have either been stopped or reduced in many exploration projects. The number of projects which have either been shelved or continued after delays is on the increase. Despite the rise in production costs, many uranium producers still profit from existing long-term contracts which usually contain a higher guaranteed price.

Growing demand is expected world-wide in the medium to long term even though not as strongly as forecast only a few years ago (IAEA 2017a). The growing energy demand in Asia in particular will probably give rise to an increasing demand for uranium. And uranium will also continue to be in demand as a fuel in Europe in the long term despite the expected long-term decline in demand due to Germany‘s withdrawal from nuclear power production, and the shelving of the expansion plans in Italy, Switzerland, and Belgium. Other countries such as Finland, France, Romania, Sweden, Slovakia, Slovenia, Spain, Czechia, Hungary, and the United Kingdom, still rely on nuclear power as an important part of their national energy mixes. Poland is planning to construct its first nuclear power plant by 2025. And the first two reactors in Turkey are also to be built by 2023 with the help of the Russian Federation and France.

61 nuclear power plants in 15 countries were under construction at the end of 2016 including in China (21), the Russian Federation (7), India (5), USA (4), United Arab Emirates (4), Pakistan (3), South Korea (3), Japan (2), Slovakia (2), Taiwan (2), Ukraine (2), Belorussia (2), Argentina (1), Brazil (1), Finland (1), and France (1). Another 125 nuclear power plants world-wide are in the planning or authorisation phases. Nuclear power plants were decommissioned in the Russian Federation (1) as well as in the USA (1). 160 reactors have been decommissioned world-wide since the use of nuclear reactors began (as at: January 2017). Of these, 15 reactors (including research reactors and prototypes) have been completely dismantled (WNA 2017b). In Europe, four decommissioning projects have been completely finished, of which three alone in Germany (BfS 2015). New power plants were commissioned in China (six) as well as one each in India, Pakistan, the Russian Federation and the USA. The 448 nuclear power plants operating in 2016, with a total net capacity of 391 GW_e (IAEA 2017b), consumed around 66,404 t natural uranium. Most of this (62,895 t) came from mine production.

The world mine production of uranium in the last five years lay between 58,395 and 62,413 t U, compared to an annual consumption of over 63,000 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 were 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). 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 world-wide 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 reduction in some 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 (opencast mining, conventional 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 48 %. The average production costs using this method are below 80 USD/kg U (as at: 2016).

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 2015.

3.6 Deep geothermal energy

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

In the first three quarters of 2016, 44 new geothermal power plants with a total capacity of more than 1,560 MW_e were constructed world-wide in 23 of the 24 countries generating geothermal electricity (GEA 2016). Of these, plants were commissioned with an estimated total installed capacity of 900 MW_e. This is the highest growth in the last ten years (IRENA 2017a). The main growth was concentrated in the three countries Kenya, Turkey and Indonesia. Depending on the source of the data, the figures given for the size of the growth vary between 29 MW_e and 518 MW_e for Kenya, and 95 MW_e to 205 MW_e for Indonesia (Tab. 4). Different figures are also given for the global increase in installed capacity, although IRENA gives a higher growth figure than BP and REN21. However, if one looks more closely at the data for the amount of power generated geothermally world-wide, it reveals a different picture: REN21 (2017) quotes a power production figure of 78 TWh_e. This corresponds to a growth of 4 % (3 TWh_e) compared to the previous year. IRENA reports 81 TWh_e, a growth of 6 % year-on-year (76 TWh_e). The differences in the data sets are probably due to factors such as the time of the surveys, the nature of the data gathering, construction delays and production outages.

Independent of the data set used, the proportion of geothermally generated power world-wide when compared to total electricity production still remains very low at around 0.3 %.With a share of more than three quarters, most of the electricity generated world-wide continues to come from non-renewable energy resources (REN21 2017).

No complete set of up-to-date data is currently available for individual countries world-wide for 2016. Figure 3-17 provides an overview of the countries which use deep geothermal energy for power production. The data is largely based on information from 2015.

Table 4: Comparison of published data on installed geothermal capacity (MW_e) for 2016.

Data Source	Kenia Increase (Total)	Indonesia Increase (Total)	Turkey Increase (Total)	World Increase (Total)
REN21 (2017)	29 MW_e (600 MW_e)	205 MW_e (1,600 MW_e)	197 MW_e (800 MW_e)	447 MW_e (13,500 MW_e)
IRENA (2017a)	518 MW_e (1,116 MW_e)	95 MW_e (1,534 MW_e)	197 MW_e (821 MW_e)	890 MW_e) (12,647 MW_e)
BP (2017)	71 MW_e (676 MW_e)	189 MW_e (1,590 MW_e)	151 MW_e (775 MW_e)	439 MW_e (13,438 MW_e)

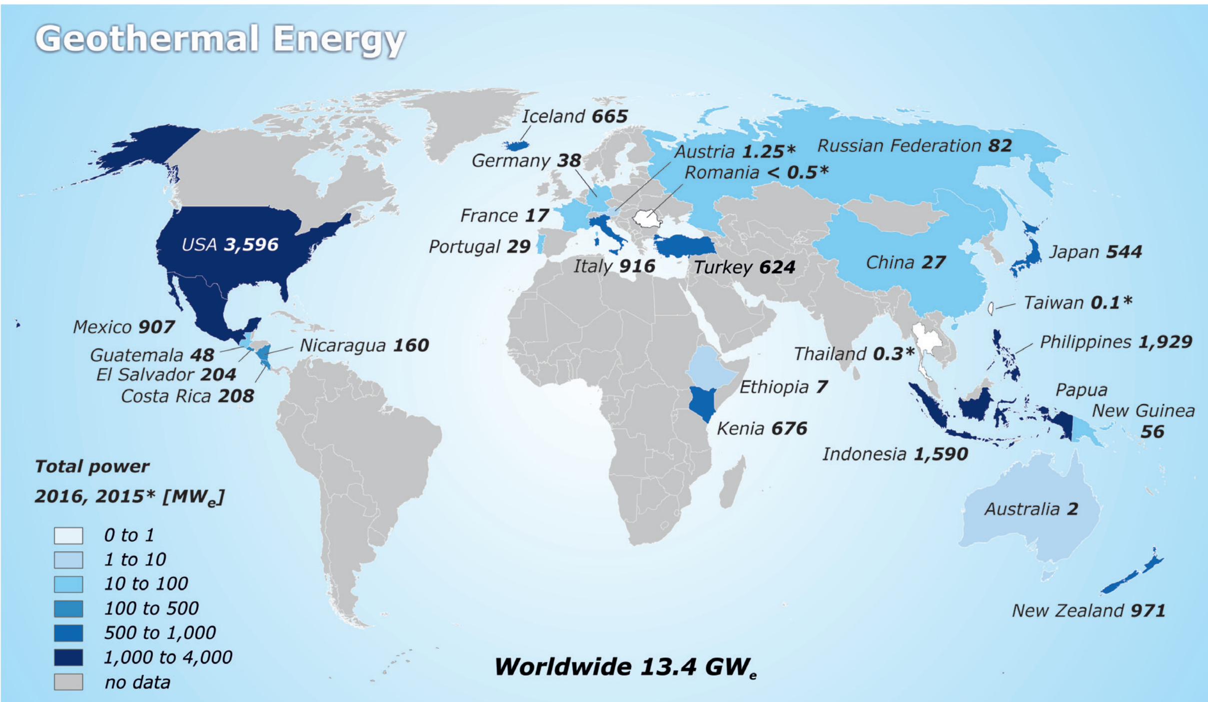

Figure 3-17: Countries using deep geothermal energy for the generation of electricity. Data from 2015 was used in some cases because of the limited data available for 2016.

The leading country in geothermal power production continues to be the USA (3.6 GW_e), and particularly California, followed as in the past by the Philippines (1.9 GW_e) and Indonesia (1.6 GW_e). This ranking could change in the next few years because from 2018 Indonesia will reach an installed capacity of more than 2,020 MW_e with the additional capacities from the Sarulla and Karaha power plants (Indonesia Investments 2017). The Indonesian government is expecting a growth of 3.4 GW_e by 2021 (EEK 2017b). This would be a major step forwards in the diversification of the energy sector in Indonesia because the power sector is currently dominated by coal which accounts for more than half of the electricity generated. Problems with the power transmission system, and the failure to expand renewables in the past, meant that 23 million people in Indonesia were still without access to electricity in 2016 (ADB 2017).

Changes are also under way in Europe in the European energy sector. The proportion of renewables has grown amongst the EU member states. Electricity supplies are moving away from a centralised, supply-based system with only a few large providers, to a more decentralised and broader-based infrastructure (EEA 2017). The National Renewable Energy Action Plans (NREAP) of the EU member countries also include the expansion of geothermal energy. The proportion of end energy consumption in the EU is to grow to almost 11,000 GWh by 2020 (corresponding to 943 ktoe). Achieving this goal requires a growth of around 70 % based on the capacity of around 6,200 GWh in 2015. The biggest expansion is currently taking place outside of the EU-28 in Turkey. EGEC (2017) estimates that the installed capacity in Europe will grow from the present day 2.5 GW_e, to 3 GW_e by 2020.

In terms of heat utilisation as well, no comprehensive country data are currently available for 2016. Globally, new capacities of 1.3 GW_{th} were added globally for thermal use (without heat pumps). The total installed capacity grew in 2016 to 23 GW_{th}. The generated heat totalled 79 TWh_{th} (REN21 2017), a growth of more than 6 %. This means that the steady growth in geothermally used heat continued into 2016. The largest user is China, followed by Turkey, Japan and Iceland (REN21 2017). More than 260 thermal plants were in operation in Europe in 2016 (REN21 2017). The installed capacity was 4 GW_{th}. The leading countries here are France, the Netherlands, Germany and Hungary. However, the growth still falls well short of the expansion targets defined by the EU member countries in their NREAP. The EU‘s expansion target for thermally generated heat is almost 31 TWh (corresponding to 2,646 ktoe) by 2020. This would require an annual growth rate of 25 % between 2014 and 2020.

Tables A-40 to A-42 in the Appendix provide an overview of the available country-specific installed capacity (electrical and thermal), consumption (electrical) and the technical potential (resources) of deep geothermal energy.

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 specific 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?

AUSTRALIA

Dr. Sven Teske
Research Director
Institute for Sustainable Futures, University of Sydney
https://www.ufs.edu.au

(1) While Australia has excellent geothermal resources, they are mostly located a long way from either the power grid, or from large industrial customers which could buy the power they produce. It is estimated that one per cent of the geothermal energy shallower than five kilometres and hotter than 150°C could supply Australia's total energy requirements for 26,000 years (based on 2004-05 figures).

(2) There was a huge interest in geothermal energy – especially power generation – in Australia in early 2000. Due to a number of failures – mostly related to drilling and financing – the support cooled down significantly.

ARENA's (Australian Renewable Energy Agency) international geothermal expert group found that utility-scale generation from geothermal projects was not expected to be commercially viable by 2020. The technology was only expected to become competitive with traditional fossil fuel power generation by 2030 with the help of a high carbon price and in the most favourable scenario for cost reductions.

(3) The actual resources are far away from the demand centers. Australia has excellent solar and wind resources. Therefore geothermal energy is economically not viable for the majority of the energy projects.

(4) Ok. There is not much of a debate about geothermal energy at all. The failures of the past left the energy experts in Australia extremly critical to geothermal energy.

GERMANY

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Leibniz-Institut für Angewandte Geophysik (LIAG)
https://www.geotis.de; http://www.geothermie.de.

(1) *Geothermal reservoirs with the potential for economic use in Germany should have a permeability of at least 500 mD, a porosity of over 20 %, and a minimum thickness of 20 m (Rockel et al. 1997). These conditions can be met in three main regions. In the eastern part of the North German Basin, the most suitable horizons are considered to be the sandstones of the Rhaetic, Lias, Dogger, Lower Cretaceous and Middle Bunter Sandstone; whilst the Upper Muschelkalk and Bunter Sandstone are considered to be suitable for geothermal applications in the Upper Rhine Graben. Most of today's geothermal projects are being realised in the South German Molasse Basin and targeted in the eastern part on the Malm (Upper Jurassic) as the most promising formation for successful geothermal use. Suitable conditions in the western part of the basin are found in the Upper Jurassic and Upper Muschelkalk formations.*

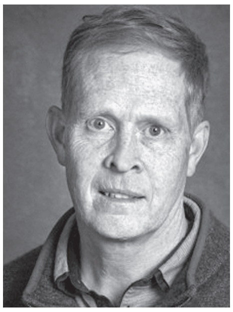
(2) *The installed geothermal heat capacity has trebled in the last 10 years. The installed electrical capacity has grown even more strongly by a factor of 10 over the same time period. It can be assumed that this trend will continue given the many advantages associated with geothermal energy. Geothermal energy can provide base load power because of its complete independence of daily or seasonal rhythms, which gives it a clear edge over solar power and windpower. In addition, the operation of geothermal energy plants produces no greenhouse gases and also boasts a very low footprint. Against the background of the fact that 54 % of German primary energy consumption is used for the generation of heat, it becomes clear that geothermal energy can make a major contribution to the energy transition. In addition, geothermal energy can be used for a range of applications (district heating, heating greenhouses, breweries, fish farming, swimming pools, etc.); ideally, the applications can be configured as a cascade.*

(3) *One of the major challenges facing deep geothermal energy projects in Germany is the high cost of drilling wells. In addition, given the comprehensive exploration required, there is always the risk of wells being unprospective. This is why a great deal of research is carried out to develop alternative drilling technologies to make drilling faster and cheaper.*

There is also a current worry that the Location Selection Act – which regulates the search for an underground repository for nuclear waste – will considerably delay approval procedures for new geothermal projects. This is because official verification is required for every planned drilling project with a depth of more than 100 m that the well will not penetrate a potential host rock for a nuclear repository. If a drilling location is rejected as a nuclear repository location in line with exclusion criteria such as active faults or volcanic activity, one still has to apply for additional authorisation from the new Federal Nuclear Disposal Safety Agency (BFE).

(4) *In principle, the aforementioned advantages mean that geothermal energy in Germany is considered a prudent alternative to other forms of energy. However, some negative examples (e.g. induced seismicity) mean that there are also some biases, which are often exacerbated by a lack of understanding and disinformation. It is therefore important to gain the acceptance of the general public by providing information and clarifying any risks. The general public should be involved over the whole project time period, and all of the project phases need to be transparently communicated. When this is undertaken, one can also gain the support of the general public for projects, as clearly seen in the case of the public approval for projects in the Munich area.*

CALIFORNIA



Dr. Patrick Dobson

Lead, Geothermal systems Program
Lawrence Berkeley National Laboratory
https://eesa.lbl.gov/programs/geothermal-systems

(1) *There are a wide range of geothermal systems in CA — with different geological and geophysical characteristics.*

(2) *California is the largest producer of geothermal energy in the USA. It has abundant undeveloped resources still remaining (particularly in the Salton Sea region, South California), but threre has been little new development taking place in the state due to the low costs of solar and wind power. California has a high renewable portfolio standard (see http://energy.ca.gov/portfolio/), but this has not spurred on geothermal development due to its higher cost.*

(3) *There are abundant undeveloped geothermal resources in the USA. There are a number of barriers to deploying these resources — these include economic (cost of geothermal power generation is generally higher than wind or solar, resources can be far away from markets and transmission lines), regulatory (it is often difficult and time consuming to obtain permits from a myriad of different agencies, which vary from state to state (see https://openei.org/wiki/Rapis/Geothermal), the cost of financing geothermal projects is high, due to the exploration risks associated with geothermal systems, there may be environmental challenges (geothermal systems are often near or in protected forests and parks), there can be sociétal challenges (microseismicity, water use, impacts on surface thermal features, gas discharges, etc.), and there can be technical challenges (for example, in the utilization of EGS resources — resource characterization, resource sustainability, etc.).*

(4) *Public acceptance is mixed — most people are not very aware of geothermal energy in general. There is some opposition in certain communities that fear impact on local water supplies and water quality or creation of microseismicity resulting from geothermal activities.*

3.7 Renewable energy resources

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[4] and China on 3 September 2016, as well as the European Union (including Germany), Canada and Nepal on 5 October 2016 (UNFCCC 2016), 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 2017). 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 17.4 % of global primary energy consumption in 2016 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 70 % 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 1.6 % of global primary energy consumption. However, their expansion has enjoyed the highest growth rates in recent years.

As in the previous year, the new power generation capacities installed around the world primarily involved the expansion of renewable energy. Its share in 2016 amounted to around 62 % (2015: 77 %). This means that the annual addition of renewable energy exceeds the new installed capacities of fossil energy resources for power generation. One of the reasons for this is the establishment of political conditions in many countries which favour the expansion of renewable energy resources. Another factor is the technology cost which, in the case of solar and windpower, has dropped considerably in recent years (FS-UNEP 2017), and have led to the improved competitiveness of renewables. The installation of new capacities in the power sector in 2016 was significant for photovoltaics in particular. Around 43 % of the new installed capacity for renewables was accounted for by the addition of photovoltaic capacities of 71 GW. Half of this alone was installed in China. In terms of windpower and hydropower, additional capacities of 51 GW and 35 GW respectively were added in 2016.

Despite the immense increase in the installation of renewables, investments in new projects declined in 2016 by around 23 % to USD 242 billion (REN21 2016). This is mainly due to the shift in investments in the Chinese market where around a third of global capital systems were involved in renewables. Chinese investment in new projects reduced from around USD 115 billion in 2015 to USD 78 billion in 2016. This is due to the assumption in China that domestic energy demand will slow down in future, and the concentration of its investment activity in the existing grid to use its potential as comprehensively as possible (FS-UNEP 2017).

4 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.

A second reason for the slump in investments is the consequences 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 was around 2,008 GW (Fig. 3-18). By comparison, around 421 GW (gross) was globally available in 2016 from nuclear power. The main pillar of renewable energy for power generation accounting for around 1,246 GW of installed capacity (around 62 %) is hydropower, followed by windpower (467 GW; 23 %) and photovoltaics (291 GW; 15 %). With over a quarter of the total globally installed capacity (546 GW) China leads the world in renewables. Hydropower alone in China accounts for 334 GW, plus another 149 GW of windpower. Another 442 GW of renewables are installed in the USA (215 GW), Brazil (123 GW), and Germany (105 GW). These four countries account for almost half of the globally installed capacities for renewables (Tab. A-44 in the Appendix).

In terms of photovoltaics, Germany with over 41 GW installed capacity for power generation is one of the top three countries dominating the market world-wide. New capacities of 1.4 GW were added in 2016. The market leader is still China with over 77 GW installed capacity (2016: an additional 34 GW), followed by Japan with 42 GW. Record additional capacity was installed in the USA in 2016 with 11 GW of new capacity. These four countries account for over 65 % of the globally available capacities for solar power. The globally installed capacity for photovoltaic power generation rose by 32 % year-on-year to 291 GW (2015: 220 GW).

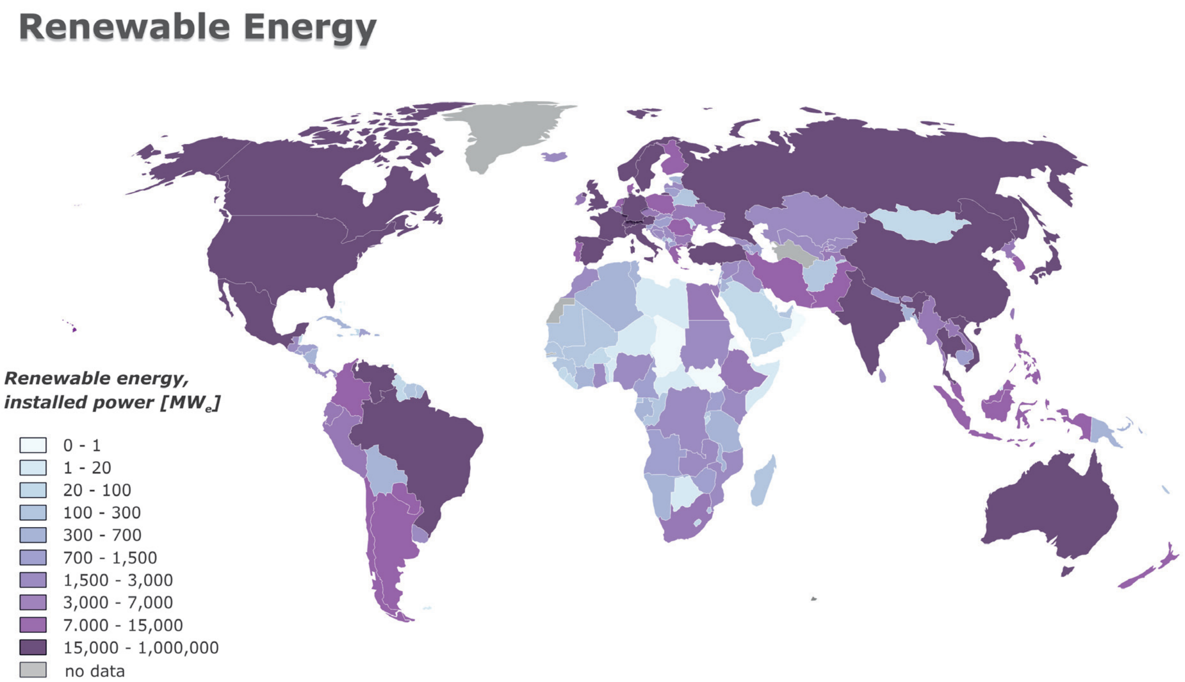


Figure 3-18: Total potential of the installed capacity of renewables for power generation (2,008 GW); regional distribution (IRENA 2017b).

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 24.5 % (2015: 23.7 %), hydropower is the dominant renewable accounting for around 16.6 % of this figure (around 70 % of power generation from renewables). Windpower (4 %), biomass (2 %) and photovoltaics (1.5 %) together accounted for 7.5 % of power generation in 2016 (REN21 2016). 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 (77 billion kWh; 12 % of the German power mix) and biomass (51.6 billion kWh; 8 % of the German power mix) (Chapter 2.2.).

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 (263.1 Mtoe), the USA (143 Mtoe), Brazil (105.9 Mtoe), and Canada (97 Mtoe). Over half of the power production generated by renewables world-wide took place in these four countries (Fig. 3-19).

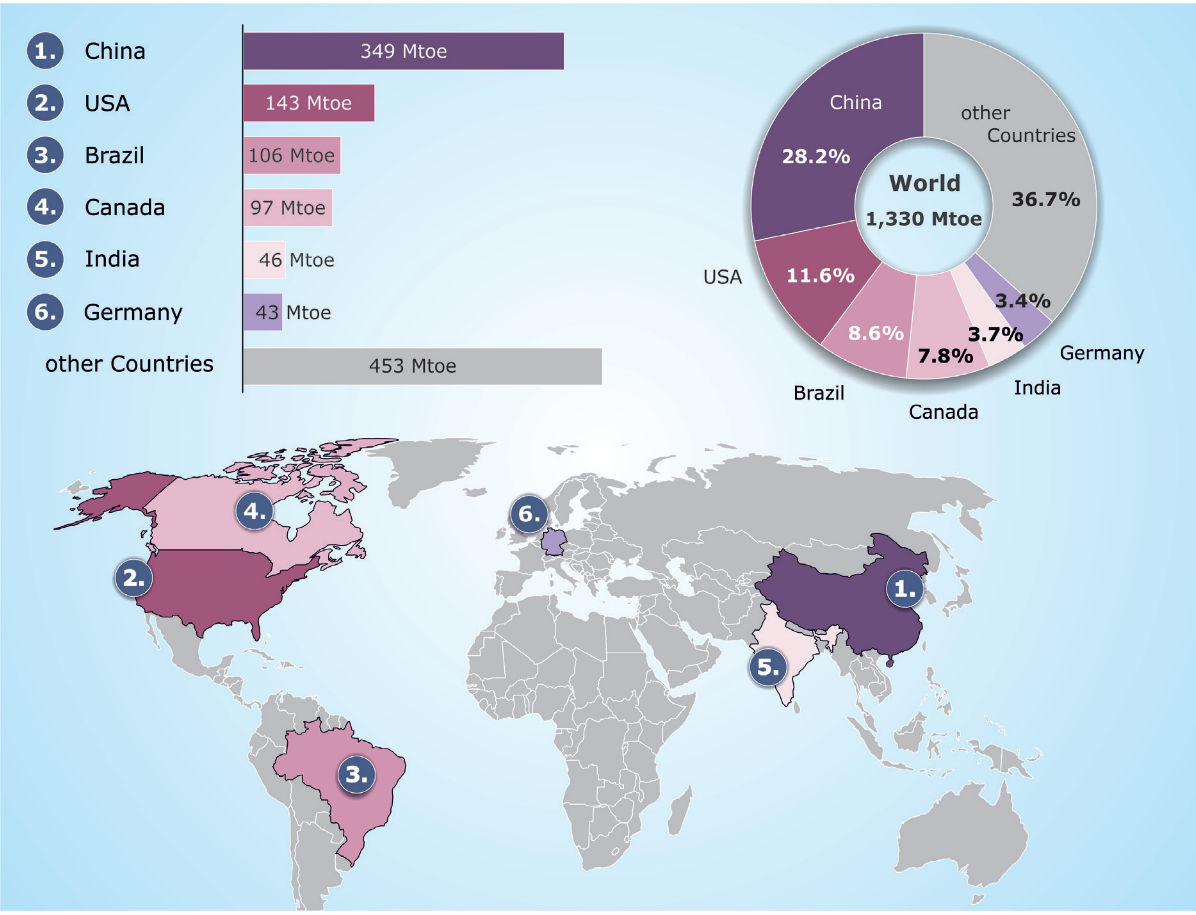


Figure 3-19: The biggest users of renewable energy resources for electricity generation 2016.

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, Ireland, Portugal, and Uruguay is covered by windpower (REN21 2016). 100 % of Iceland‘s electricity needs are covered by renewables (72.6 % hydropower; 27.3 % geothermal energy; 0.1 % windpower) (IEA 2017e). Around 29 % of the demand for electricity in Germany in 2016 was covered by renewables (2015: 32 %) (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 generation sector. Biofuels currently account for 0.8 % of global end energy consumption. Global production in the last 12 years has increased several times over from around 30 billion litres (2004) to around 135 billion litres (2016) (REN21 2016), and a further rise is expected. The leading producers are the USA and Brazil. Over 70 % of ethanol fuels and biodiesel are sourced from these two countries. The production of wood pellets for generating heat rose from around 4 Mt in 2004 to around 24 Mt (2014). 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 14.1 Mt in 2015 (AEBIOM 2016). Demand in Europe as well as in Asia has grown considerably in recent years (IEA 2015b) and can no longer be covered by domestic production. Today‘s biggest exporter is North America. Around 5.76 Mt of wood pellets were exported from North America to Europe in 2015 (AEBIOM 2016). The domestic demand in Germany alone is estimated to be 2 Mt/a (2006: 470 kt) (DEPL 2016), 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 TOPICS)

4.1 Lithium – A key resource for the energy and mobility transition

Thanks to its special properties, lithium is one of the key resources for the energy and mobility transition. The use of lithium-ion batteries for energy storage is particularly important. Batteries of this kind already play a crucial role in smartphones, laptops and tablets, which are currently the most important areas of application. Other areas of application including ceramics, glass ceramics, lubricants, glass and polymers, also play a very important role in the lithium market (Fig. 4-1). Lithium is also used in the castings industry, in air conditioning, in non-rechargeable batteries (button cells), aluminium production, and in the pharmaceutical and chemical industries.

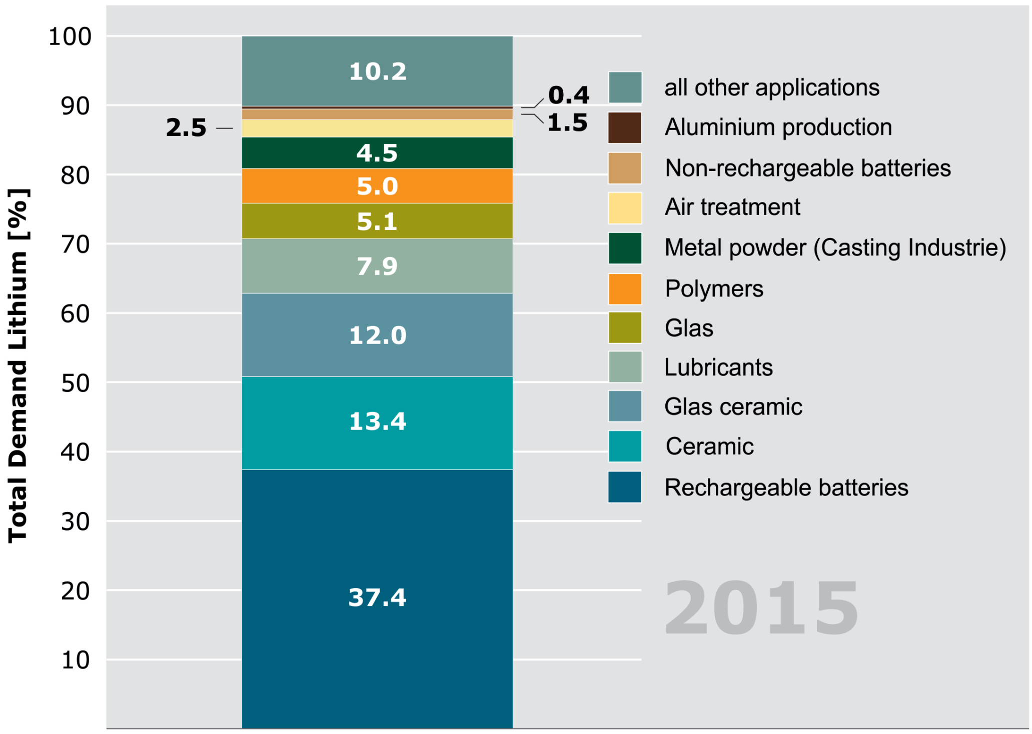


Figure 4-1: Areas of application of lithium in 2015 (Roskill 2016, USGS 2016).

The storage of renewables in PV-coupled batteries for instance, as well as the predictions for the boom in electromobility, will become increasingly important, and will be a strong engine of growth for the lithium market in coming years. According to a DERA estimate, the proportion of rechargeable batteries in the overall demand will rise from approx. 37.4 % in 2015 to 60 % to 76 % in 2025. It is therefore crucial to analyse these demand-driven commodities markets to be able to implement timely avoidance strategies to safeguard commodity supplies, as well as to hedge against possible price rises. The following report is an extract from the current DERA study on the resource risk assessment of lithium (DERA 2017a).

Lithium is currently extracted from two primary sources: brines and hard rock deposits – each account for around 50 % of the market. Brines containing lithium are primarily extracted and processed in South America in the triangle formed by the three countries of Chile (e.g. Salar de Atacama), Argentina (e.g. Salar del Hombre Muerto) and Bolivia (Salar de Uyuni) (Fig. 4-2). Other deposits are located in the USA (Silver Peak, Clayton Valley) as well as in China (Tibet, Quinghai province). However, for various reasons, the deposits in Bolivia and their enormous potential have not been exploited to date, although work has been undertaken in this direction.

Figure 4-2: Solar evaporation pond operated by Albermale (Rockwood Lithium Ltda.) in the Salar de Atacama (Chile) (BGR 2016).

Around 33,011 t lithium (Li-content) was produced world-wide in 2015. The supply here is determined by only two countries. The largest producing country was Australia with a market share of around 40 %, followed by Chile with a market share of around 36 %. Argentina followed in third place with a market share of around 11 %.

The global reserves of lithium are estimated to be around 14.5 million t Li-content by USGS (2017). Most of these reserves are in Chile (51.8 %). Other reserves are located in China (22.1 %), Argentina (13.8 %) and Australia (11.1 %). Reports of a geological shortage of lithium are therefore unjustified.

An important factor to understand the lithium market is a consideration of the global trading structures on the basis of the net exports of the producing countries. The brines primarily extracted in South America are further processed on site to lithium carbonate and/or lithium hydroxide. These intermediate products are then primarily exported to China, South Korea and Japan, and reprocessed to produce cathode material which is then used in lithium-ion batteries. Mineral concentrates containing lithium are exported from Australia to China where it is further processed into battery intermediate products. In addition, lithium concentrates are also exported to Europe for the glass and glass ceramic industries.

The pricing of lithium is very intransparent because lithium products have not been traded in international commodity exchanges in the past. At present, prices are negotiated bilaterally between the producers and the consumers, and are dependent on the quality of the produced product. However, small quantities of lithium products are also traded freely on the spot market, although these prices are much higher than the prices in long-term supply contracts. The price for lithium carbonate has risen considerably since the beginning of 2016. The annual average price in 2016 was approx. 7,460 USD/t and therefore around 13 % higher than the level in 2015. The price for lithium carbonate in April 2017 had already risen to approx. 13,000 USD/t (Fig. 4-3).

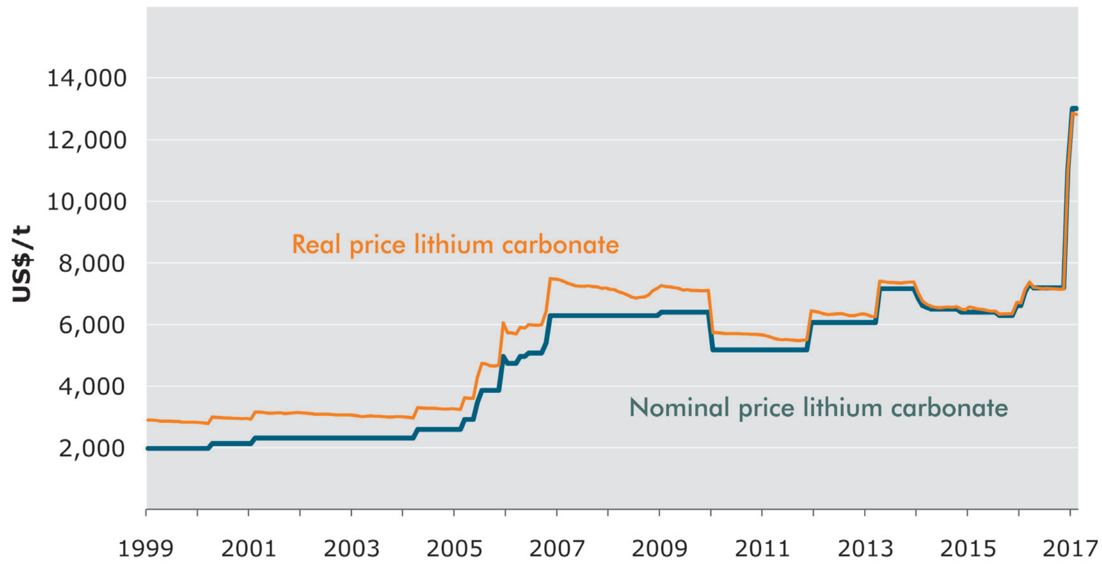


Figure 4-3: Development of nominal and real prices for lithium carbonate (01/1999 to 02/2017). The data has been deflated with the consumer price index CPI (Ø 2016 = 100) (DERA 2017b).

These massive price rises are primarily attributable to the rise in demand and the forecasts for each of the different applications. Total demand for lithium in 2015 was around 33,300 t Li-content. The greatest proportion was accounted for by the applications: rechargeable batteries, ceramics/glass ceramics and lubricants. These applications accounted for around 71 % of total demand in 2015. A massive rise in demand is expected up to 2025. Depending on the extent to which electromobility penetrates the market, the total demand in 2025 is forecast to be between approx. 67,500 t Li-content to 111,000 t Li-content. Compared to 2015, this corresponds to a rise of two or three times. Depending on the forecast, the proportion of this total demand used for rechargeable batteries will be between 60 % to 76 %.

Lithium supplies which are currently determined by Chile and Australia will shift by 2025 in favour of Australia, Argentina and Canada according to a DERA assessment. Chile's share of the lithium market according to this forecast will drop from the current level of almost 36 % to below 17 %. According to the information currently available, new projects in Australia and Argentina, as well as planned expansions in Australian capacity are the most important factors in the lithium production forecast for 2025. Around 67 % of the additional production capacities planned for 2025 will be implemented in these two countries.

DERA modelled two supply scenarios up to 2025 to assess the future market cover, which is an important indicator for price and supply risks. These two supply scenarios were coupled to three demand scenarios. Depending on the scenario, the oversupply in 2025 could be as high as 52,600 t Li-content. Oversupplies of this size usually lead to the delayed implementation of individual projects or the scaling of production to counteract a slump in price. Only one scenario gives a deficit of approx. 22,700 t Li-content. Such a situation could, however, give rise to considerable price and supply risks.

The supplies of lithium from the secondary sector have so far been insignificant in terms of overall supply. Because of the dissipated distribution in the end products, and the specifications for product quality, lithium recovery is currently not economically realisable. However, the recycling of lithium-ion batteries is possible and the relevant large-scale industrial processes are available. If electromobility really takes off in the markets, recycling and the recovery of the lithium in batteries – taking into consideration the potential service lives – could in future be an important component in the resource cycle. The primary objective should be to achieve a closed cycle.

4.2 Underground coal gasification: background, potential and risks

Coal is primarily used for power generation and for the production of pig iron in the form of coke. However, also alternative ways of using coal have been world-wide discussed, tested for many decades and partially industrially implemented . The aim of these alternative uses is to increase the economic efficiency and to use coal more sustainably – for instance, by reducing the greenhouse gas emissions and the impact on the environment – and therefore to open up additional potential for coal. One of the options here is underground coal gasification (UCG), also known as in situ coal gasification. The following section discusses the background to this technology, current developments world-wide, as well as the risks associated with this application.

History and current status

The principles of underground coal gasification were first described in 1868 (Siemens 1868), and the first industrial scale plants were realised in the Krutova mine (near Moscow) in the former Soviet Union in the early 1930s. Synthesis gas for research purposes and use in gas power plants was produced in the former USSR as part of a national programme to establish underground coal gasification in various coal mines. Other major research and national programmes – primarily in the middle of the last century – were realised in the United Kingdom, Australia and the USA, but underground coal gasification has also been tested in the past in China, Poland, Belgium, the former Czechoslovakia, Japan, Italy, and Morocco (Burton et al. 2007; Gregg and Edgar 1978; Little 1972).

Many of the research projects were undertaken to improve the understanding of the recovery factors and risks of underground coal gasification (e.g. Green 2017). From today‘s point of view, the relevant projects in Europe worth highlighting, which focused on the generation of hydrogen, are the HUGE1 (2007–2010) and HUGE2 (2011–2014) projects, UCG & CO_2 storage project (2010–2012) as well as the Coal2Gas project (2014–2017) (all financed by the EU). Underground coal gasification has not been used in Germany to date, but German research groups participated in larger scientific projects such as the Belgian-German THULIN project and the Coal2Gas project. Another notable project was the CO2Sinus project undertaken in the late 2000s, which investigated the option of CO_2 storage in relation with underground coal gasification.

Underground coal gasification is currently used world-wide in some countries or is being tested (Fig. 4-4). Attention should be drawn to projects on underground coal gasification, which are either planned or have already been implemented in South Africa, Australia, the USA, and China, as well as in Poland, Pakistan, Indonesia, New Zealand, and Bulgaria. The longest commercial application is in Angren (Uzbekistan), where the synthesis gas, which is produced has been used for power generation since 1961.

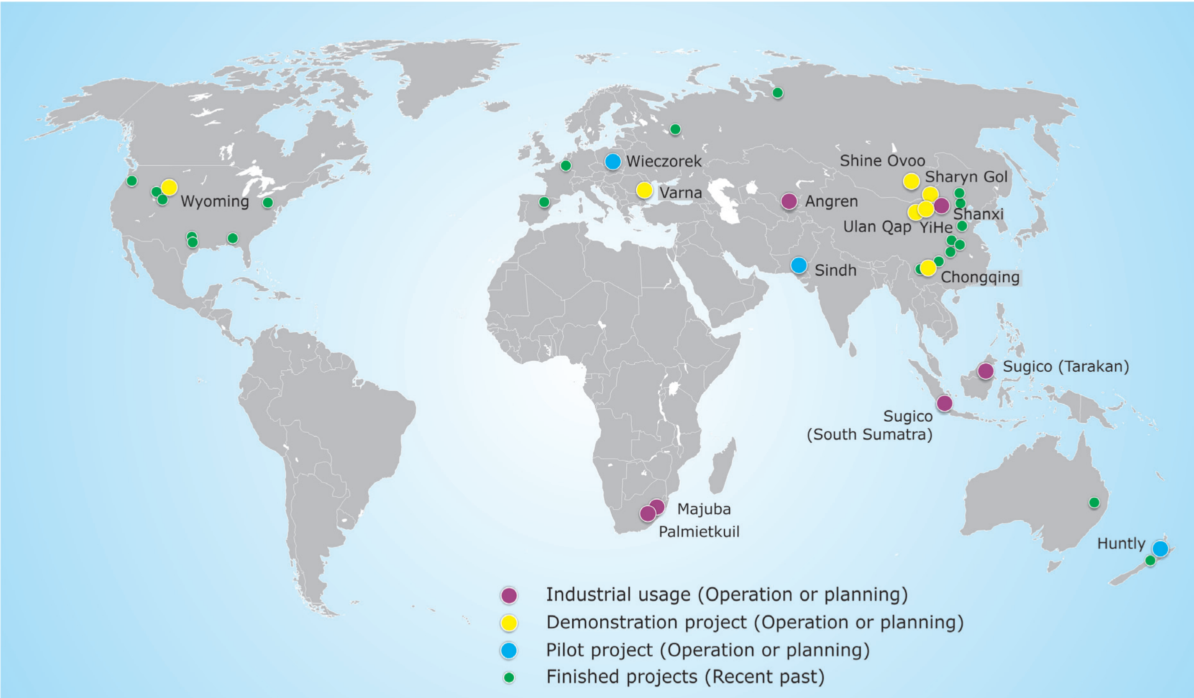


Figure 4-4: Overview of currently ongoing and recently completed projects on underground coal gasification (primarily IEA Clean Coal Centre 2009).

Principle of underground coal gasification

Underground coal gasification involves injection of an oxygen-steam mixture (process gas) underground into a coal seam via an injection well and extraction of the so-called synthesis gas (or syngas) via a second well (Fig. 4-5). The synthesis gas consists of hydrogen and varying proportions of methane, carbon monoxide, ethane, carbon dioxide, nitrogen, and other ancillary gases. Hydrogen, methane, and other hydrocarbons can be used directly or after processing for electrificaton, heat recovery, use in the transport sector or by the chemical industry.

The injection of oxygen-rich process gas induces the self-ignition of the coal. The composition of the synthesis gas can be then controlled via the process gas pressure. A higher methane concentration, for instance, can be achieved by application of a higher reaction pressure, moderate temperatures, and a lower oxygen-water ratio (Grüneberg 2011).

Different process zones are differentiated in underground coal gasification technology (IEA Clean Coal Centre 2009; Grüneberg 2011). The process gas is injected into the so-called "flow and combustion zone". Temperatures of around 900 °C are reached in the combustion zone, giving rise to a synthesis gas, whose composition changes during the next stages of the process. The actual gasification takes place in the reduction zone at temperatures between 600 °C and 900 °C. Minor amounts of oxygen remain in this zone so that heterogeneous reactions can take place, generating carbon dioxide, carbon monoxide, methane, and hydrogen. In the distillation zone, almost completely depleted in oxygen coking (the expulsion of volatile components) and low-temperature carbonization of coal take place at raised temperatures (approx. 200 °C to 600 °C). Pyrolytic decomposition also occurs during this process, which leads to break down of long chain carbon chains into short chain hydrocarbons (as a result of cracking). The last zone is the dry zone, in which the synthesis gas is extracted via withdrawal wells at temperatures of 80 °C to 200 °C (after Grüneberg 2011).

The coal used for underground coal gasification has to satisfy many requirements (Shafirovich et al. 2008). Suitable bituminous coals display contents of < 50 % gaseous and < 55 % moist components. Depending on the depth, the minimum seam thickness is between 0.5 m to 10 m. From a technical point of view, there are basically no depth limits for underground coal gasification, however, from an economic point of view, depth is relevant. The projects displayed in Figure 4-4 use coal seams at depths of approx. 150 m to 1,200 m (averaging to 300 m to 500 m).

In addition to coal's geological properties, other important criteria include hydrogeological and tectonic nature of the surrounding rocks, such as the degree of isolation of deep-seated rocks, the existence of deep saline aquifers, or the structural integrity of the overburden.

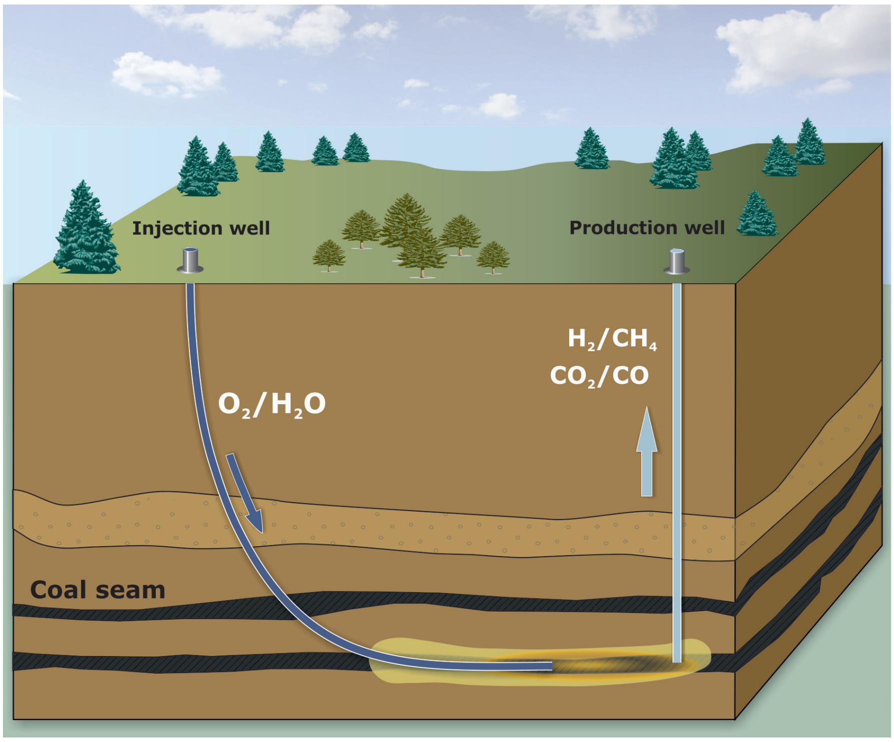


Figure 4-5: Principle of an underground coal gasification (process zones not shown; after Grüneberg 2011).

Opportunities and risks

Underground coal gasification displays a significant potential from the economic point of view. The extracting synthesis gas via underground coal gasification for instance is around 25 % to 50 % cheaper in comparision with surface gasification (Friedmann et al. 2009). In addition, application of the technology reduces the negative impact of classic coal mining (e.g. difficult physical working conditions), and surface area requirements. Synergies with other technologies could also be considered as enhancing opportunities of underground coal gasification. For instance, many projects aim to combine underground coal gasification with the subsequent sequestration of cavities with the separated CO_2 (e.g. Durucan et al. 2014, Green 2017), as in case for instance of the EU-financed demonstration project in Varna (Rumania). The aim of projects of this kind was to reduce locally CO_2 emissions, and thus to increase the acceptance of the technology.

The risks of underground coal gasification are differently evaluated.. The difficulties, which can occur are frequently associated with control and monitoring of the underground process, causes directly or indirectly environmental risks (Grüneberg 2011). Possible impacts include the influence on groundwater by contamination with toxic organic compounds via leaky casings, as well as by release of contaminants via natural paths of upward migration. Other risks are associated with surface subsidence and possible spread of sources of gas and fire.

The importance of such risks is largely determined by the extent of geological exploration and the assessment of geological uncertainties. In addition, the technical configuration of the process path and the casings, as well as an adequate distance between the underground process zone and the usable groundwater are also critical for risk minimisation. One of the predominant concerns is the uncontrolled spread of the coal fire underground – also because difficult to control (shallow) coal fires repeatedly occur around the world (e.g. in China). However, risks of this kind are considered to be low in underground coal gasification for deep-seated underground formations because the process chain is largely controlled by the inflow of process gases, and can thus be stopped when injection is terminated. Nevertheless, the risks still remain, and the technical maturity of underground coal gasification is considered to be lower and the technical risks higher in comparison with the production of coal bed methane (CBM) (IEA Clean Coal Centre 2009).

Overall, the technical challenges appear still high for the implementation of underground coal gasification, and there seems also to be a strong requirement for more research despite the long-term experience already gained in some of the countries. This situation is mainly attributable to the differences in coal deposits regarding coal rank and quality, the surrounding strata and depth, and the associated uniqueness of each coal gasification project. For this reason, this technology was currently banned in Queensland/Australia because of the potential risks and need for additional research, although many pilot projects on underground coal gasification had been run in previous years (Queensland Government/ Department of Natural Resources and Mines 2017). The acceptance of the general public for projects of this kind is considered to be low in most EU countries. In Germany, underground coal gasification is currently not accounted to be a feasible option due to various geological, economic factors (e.g. depth of the coal seams). Nevertheless, the attractiveness of underground coal gasification around the world remains high particularly in countries with large coal deposits, and a glance at the historical developments reveals (e.g. IEA Clean Coal Centre 2009), that the further development of this method and its industrial applications can be expected in some regions in the future.

4.3. Applications for using associated gas – situation analysis in Algeria and Cameroon

Associated gas is a by-product of the production of crude oil, and is frequently either flared off or simply vented off into the atmosphere unflared. Flaring off associated gas is one factor in a complex and controversial interplay between the areas of climate protection, energy efficiency and the production of fossil fuels. 149 bcm of associated gas was flared off world-wide in 2016 (GGFR 2017), therefore preventing any meaningful use. This corresponds to around 4.1 % of the global natural gas production of 3,620 bcm, and exceeds the annual natural gas consumption of Africa – which currently stands at 132 bcm. In addition, flaring as well as venting emits carbon dioxide and methane, two greenhouse gases which play a very significant part in climate change. In addition to carbon dioxide and methane, gas flaring also creates tiny soot particles ("black carbon matter") in the atmosphere which spread around the world and even land in the Arctic (Stohl et al. 2013). Putting associated gas to good use can therefore contribute to climate protection, to implementing sustainability targets in developing countries, and can benefit their economic development.

Options for using associated gas

The potential options for using associated gas depend on a number of variables. The major influencing factors, in addition to the geological and geographical circumstances, are the local energy market, the existence of an appropriate infrastructure, and regulations covering flaring. These factors differ significantly between countries and production sites.

The energy-efficient use of fossil resources is gaining in importance for crude oil producers. As part of the World Bank's Global Gas Flaring Reduction partnership (GGFR), some of the largest crude oil producers are already exchanging information on technological advances in the use of associated gas. Promising developments have arisen in recent years in particular in the utilization of associated gas for electricity generation. Even very small quantities of associted gas can be monetizted without any prior processing, and therefore supply oil production operations directly with energy. Small mobile generators can be installed quite flexible at several production sites one after the other, and can therefore be deployed at short notice and in remote areas. By the means of Mini-LNG or floating LNG plants a so-called virtual pipeline can be created in places where the installation of a pipeline system is economically unfeasible, and enable gas power plants, companies or private households to be supplied with gas. The increasing range of mini and micro GTL plants on the market also enables associated gas to be converted into petrol or diesel. In addition to these innovative application options, there is also the option of re-injecting the gas into the reservoir to enhance oil production, to transport it by pipeline, or to use it as a raw material for the petrochemical industry.

Using associated gas to generate electricity could make a contribution to the electrification of whole regions such as the sub-Saharan region. Deploy natrual gas for power generation would bring many advantages to developing countries since it is considered to be the most climate-friendly fossil resource, and can enable the rapid and safe electrification of urban areas. The production of propane gas from associated gas for cooking is also an interesting option because it would additionally make a contribution to reduce cooking over open coal and wood fires in closed rooms. In addition to reducing greenhouse gas emissions, the use of associated gas therefore also opens up economic and development-policy opportunities. All of the alternatives for its use have advantages and disadvantages, and their suitability varies depending on the production area. In this regard, mini-LNG plants and re-injection are particularly attractive in offshore production areas, whilst generators for power generation and GTL plants are primarily suitable for onshore oil fields.

BGR contracted Carbon Limits to carry out a study analysing the background to gas flaring in Algeria and Cameroon, and to elaborate the potentials of German development co-operation activities in this particular area. The following presents a brief overview of the challenges and opportunities of utilizing associated gas in these two countries on the basis of the already published results of the study.

Case study Algeria

Algeria is Africa‘s largest natural gas producer and its third largest crude oil producer. The country has one of the most extensive natural gas infrastructures on the continent. Natural gas is transported to Spain and Italy via three pipelines, and the country also has four LNG terminals located along the Mediterranean coast. Algeria covered more than 98 % of its energy requirements for power generation with natural gas in 2015 (IEA 2017f), and also uses the gas for re-injection into its reservoirs. The Algerian natural gas sector is under pressure to boost production to satisfy the growing domestic demand and the high demand in Europe for natural gas. At the same time, Algeria flared around 9,100 million m^3 of associated gas in 2016 – more than any other African country. It therefore lies in fifth place in the ranking of countries with the world‘s highest flaring volumes (GGFR 2017). In addition to a few small flares in remote areas in the south-west of the country, the flaring activities are particularly intensive at the Hassi Messaoud and Hassi R‘Mel oil fields, even though both oil production sites are connected to the general natural gas and LPG pipeline grid (Fig. 4-6).

The flaring of natural gas if formally regulated by the Hydrocarbon Law: according to this law, it is illegal to flare associated gas, but possible nevertheless to apply for a flaring permit from the competent regulation authority, the National Agency for the Valorisation of Hydrocarbon Reserves (ALNAFT). This permit precisely defines the volume of natural gas which can be flared off, and can be revised on an individual basis. The law makes no distinction whether the gas is flared off on an excisting or new oil field., i.e. even already existing flares should be converted and the gas used. In addition to regulating the flaring of associated gas, ALNAFT is also responsible for the promotion of investment, monitoring contractual compliance, collecting production royalties, and therefore dealing with a range of potentially counteractive interests.

In addition to the Ministry for Energy and Mining, the state oil company Sonatrach, as the largest producer, also plays a crucial role in the Algerian hydrocarbon sector. The company has a statutory right to a majority shareholding in all oil and gas projects in Algeria.

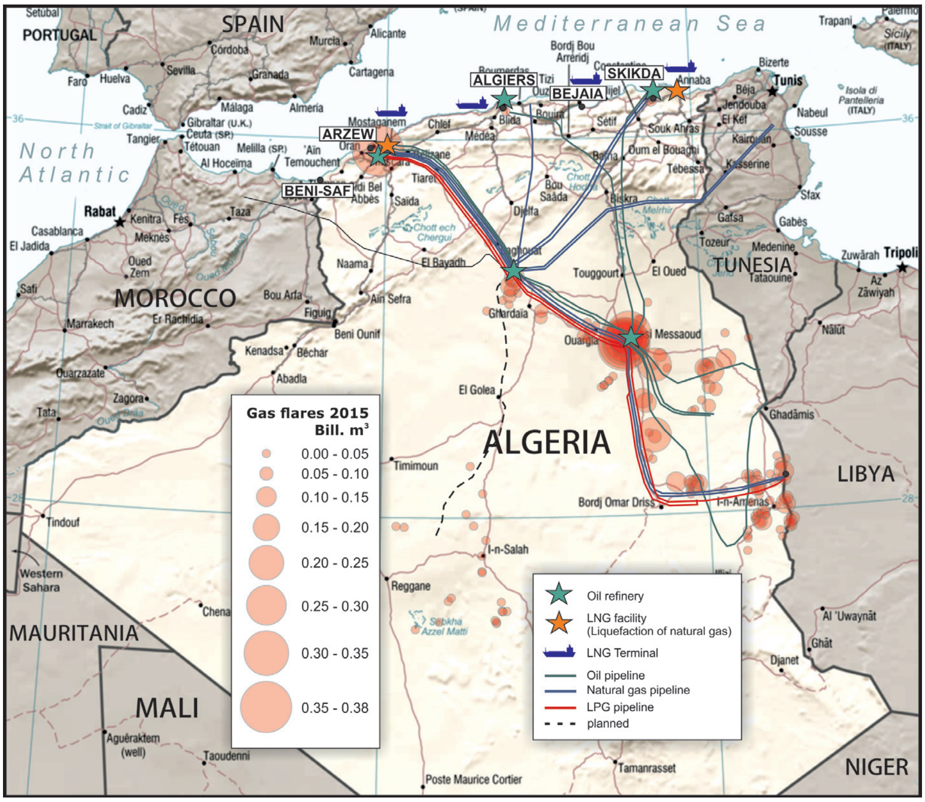


Figure 4-6: Gas flares and infrastructure in the oil and gas sector in Algeria.

In addition, around 80 % of the downstream oil and gas infrastructure is also owned by Sonatrach. This means that third party companies need the permission of Sonatrach to use the infrastructure so that they can utilise the associated gas. In addition to Sonatrach, there are also private companies, such as Anadarko, ENI and BP, active in Algeria. Informal sources indicate that the private companies flare less associated gas than Sonatrach, however, no official figures are published.

The Algerian crude oil sector faces significant challenges concerning the utilization of associated gas. Although the necessary infrastructure exists, the amount of associated gas which was flared off has risen continuously in recent years, even though oil production actually declined. A possible approach for reducing the gas flaring could be priority access for associated gas to the infrastructure, and in particular, also for third parties. A possible solution for the more remote oil fields in the centre of the country could be flexible generators to enable electricity generation for oil production purposes. Moreover, the responsible authority could be strengthend to regulate flaring, particularly because the bulk of the associated gas is flared off by the state-owned company Sonatrach. An additional approach worth considering is strengthening the independence of ALFNAFT with respect to the ministry and Sonatrach , for instance through capacity development in regard to flaring mitigation. When used optimally, associated gas can make an important contribution to covering the growing demand for natural gas in the Algerian market.

Case study Cameroon

Cameroon is in 27th place in the ranking of countries with the highest volume of flared associated gas, and “only” flared off 1,098 million m^3 of natural gas in 2016. However, in terms of flaring intensity[5], Cameroon occupies fourth place in the global ranking (GGFR 2017). In addition, the flaring of associated gas has risen by around a third in Cameroon over the last three years. This is mainly attributable to the rise in oil production. Moreover, there is a very low demand for natural gas in Cameroon itself.

The oil sector in Cameroon is dominated by the Société National de Hydrocarbures (SNH), the state-owned oil company. Although the Ministry for Water Resources and Energy is responsible for regulating the sector, SNH has the right to represent the interests of the state when it comes to the exploration and production of oil reserves. SNH is not an operator itself, but is instead responsible for the transport of oil and gas to industrial users, energy providers and end users, as well as for the export facilities. Crude oil production in Cameroon is in the hands of two private companies: Perenco and Addax.

Most of the natural gas flared off in Cameroon, accounting for over 90 %, is offshore in the Rio del Rey Bay, an extension of the Niger delta (Fig. 4-7). Most of the gas is flared because Cameroon has hardly any natural gas infrastructure. The domestic energy market is dominated by hydropower. Nevertheless, natural gas is seen as an attractive option of satisfying the growing demand for energy in future. However, in the next five years this can be achieved by two already developed natural gas fields. Because of the lack of a natural gas infrastructure, an alternative being considered was the installation of a floating LNG plant (FLNG) which would have enabled the utilisation of the associated gas. Instead though, the current plans are to use these FLNG plants in the south of the country for the further transport of non-associated natural gas. This therefore makes it unlikely that the FLNG plants will help reduce the flaring off of associated gas in Cameroon.

According to a proposed law in 2011, there was an intention to ban the flaring off of associated gas in Cameroon from already existing and new oil production facilities. The exceptions to this law are flaring permits issued by the government for a period of 60 days. According to this law, associated gas is the property of the state. However, preparing a reduction plan for flaring is not one of the pre-conditions for being issued with a production permit. The proposed law also stipulates that violations of the ban on flaring can be penalised in various ways ranging from fines to the suspension of the production permit, all the way to the annulment of the production permit. However, no precise details are available on whether the law has already come into force, for unknown reasons, the law has not yet been applied.

5 Flaring intensity describes the ratio of the amount of flared associated gas to total hydrocarbon production.

Figure: 4-7: Gas flaring and oil infrastructure in Cameroon.

Projects aimed at using the associated gas could not be implemented in the past, such as the construction of a fertiliser plant. Prudent first steps to reduce the flaring could include specifying the legal framework and the mandatory provisions more clearly, and strengthening the independence of the competent regulatory authority. Because Cameroon produces almost exclusively only offshore oil, the re-injection of associated gas is also a feasible alternative to a limited extend in addition to mini-LNG, FLNG and pipeline systems. Constructing a special natural gas infrastructure with a pipeline grid would be associated with large investments, but these could be worthwhile if other natural gas fields lying in the vicinity came under production in future.

Conclusions

As shown by these case studies, tackling gas flaring in developing and emerging countries in particular, is associated with serious challenges. Whilst Algeria produces oil onshore, has a modern natural gas infrastructure and high domestic demand for natural gas, Cameroon has offshore oil production and hardly any of the necessary infrastructure for the transport and marketing of natural gas. Despite the apparent promising conditions in Algeria, neither of the countries has been able to significantly reduce the flaring of associated gas in the past.

This is due in part to the inadequate regulatory and legislative frameworks, as well as the lack of infrastructure or inadequate options for selling the gas on the domestic natural gas market. Reducing the amount of flaring is also associated with investments in most instances, which has not taken place because priorities are placed elsewhere. In addition, the state implementation of flaring bans is increasingly moving into the spotlight in the context of forcing oil producers to reduce the flaring of associated gas.

Nevertheless, the rise in energy efficiency, and the optimised use of fossil fuels within the oil sector make it possible to increasingly reduce production-related emissions. New technologies for instance enable the use of increasingly smaller amounts of associated gas, and thus support more energy-efficient oil production in remote areas as well, or in previously uneconomic situations.

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 this system. There are even countries already today which can 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. For the transition to a low-carbon energy system, which is necessarily a long-term process, it is therefore crucially important that fossil fuels can also continue to be made available in future to the extent that they are actually required.

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 (2017b) 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 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 resources. Non-conventional 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. In addition, oil production is also beginning to drop for technical reasons even though large reserves and resources are still available. 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 treaties.

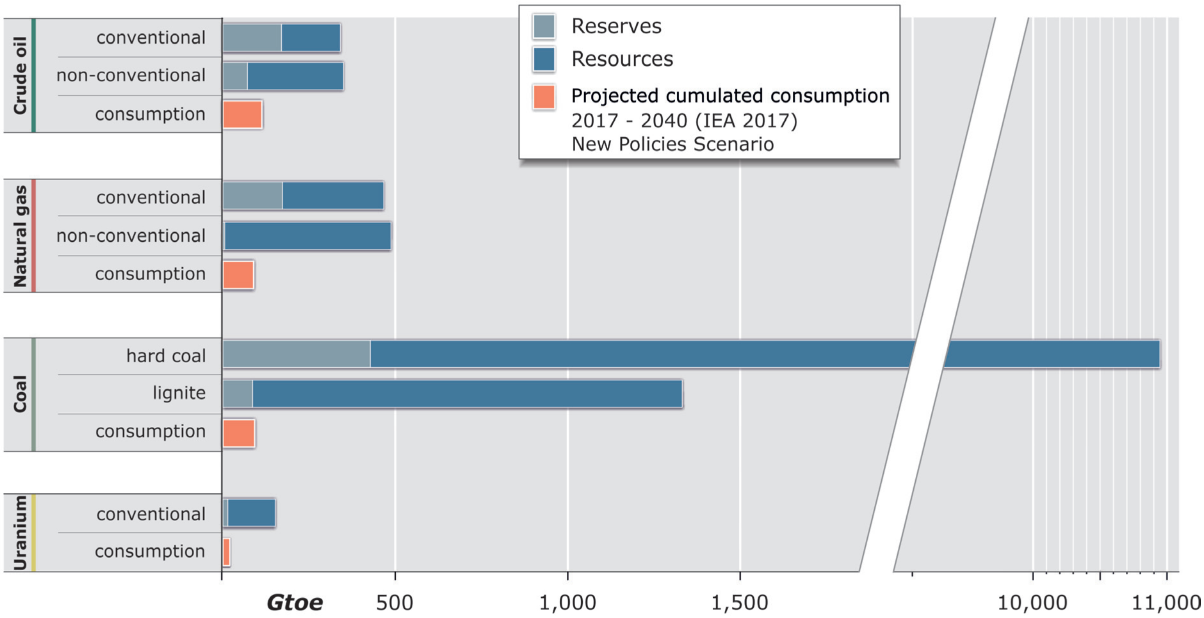


Figure 5-1: Supply situation for non-renewable energy resources end 2016.

5.2 Summary and outlook

Crude oil

Crude oil remains the most important energy resource world-wide. The resources have grown due to a re-evaluation of global oil shale deposits. There was also a rise in crude oil reserves primarily because of a re-evaluation of Venezuelan extra-heavy oil reserves. However, the conventional crude oil reserves which are crucial for global oil supplies have stagnated. New discoveries have declined considerably since 2010. This trend intensified because of the cost savings made by the oil industry since the strong decline in oil prices beginning in 2014. After years of oversupply, supply and demand moved back into balance during the course of 2016. This was accompanied by a stabilisation of crude oil prices by the end of the year. However, the continuing low level of oil prices has negative consequences for national economies which largely depend on the oil sector. Global oil production as well as petroleum consumption rose world-wide to new all-time record highs. From a geological point of view, the supply of crude oil can be maintained for the next few years even in the face of a continued moderate rise in consumption. As one of the largest petroleum consumers in the world in future as well, Europe, and Germany in particular, are confronted by a declining trend in domestic production. Against this background, the significant dependence on crude oil imports therefore remains unchanged because no alternatives have been found to date to replace crude oil in its essential role as an energy resource and basic raw material.

Natural gas

Natural gas was again the third most important global energy resource in 2016 with respect to primary energy demand, behind crude oil and hard coal. Despite the comprehensive global supply and falling prices, global natural gas consumption only rose slightly by almost 1.4 %, and therefore again remained below the average historic growth rates. Nevertheless, a tangible rise in global natural gas consumption is expected in the medium to long term. Because of the high remaining natural gas potential, global supplies of this resource can be maintained for many decades into the future, even in the face of a stronger rise in demand. Global natural gas reserves have hardly changed year-on-year. This means that natural gas production in 2016 was completely compensated for by additions to reserves. The global trade in natural gas increased again in 2016. The close integration of the various natural gas markets due to the generous supplies of LNG (Australia boosted its LNG exports by almost 50 %) has again led to a global convergence in prices. At the same time, the falling natural gas price trend continued into 2016 against the background of relatively cheap crude oil. Germany and Europe with their integrated and growing supply grids are connected to a large proportion of global natural gas reserves via pipelines as well as LNG import terminals, and are therefore in a relatively secure position. Geopolitical risks, however, continue to be one of the key factors affecting natural gas supplies. The total regasification capacities of the 25 European facilities were 216 bcm at the end of 2016. This corresponds to around 40 % of the natural gas consumption in the region in 2016.

Although production in the USA has declined for the first time in many years because of a slightly lower demand, as well as periodic unattractive market prices, a further expansion of production is considered likely in future.

Coal

The global reserves of hard coal and lignite can cover the identifiable demand for many decades from a geological point of view. Global coal production declined during the reporting period for the third year in a row in response to demand, as well as Chinese policy to reduce the existing overcapacities in the Chinese coal sector. Coal production dropped year-on-year by around 6 % and totalled around 7,281 Mt in 2016. Although the global seaborne hard coal trade reduced again by a small amount, it actually grew compared to the previous year because of the rise in cross-border trading. The importance of the Pacific market continued to be very high as in previous years with a share of global hard coal imports of 74 % in Asia, and grew another three percentage points in 2016 compared to 2015. China is easily the world‘s largest producer and consumer of hard coal, and has also been the world‘s largest hard coal importer since 2011, closely followed by India and Japan. In 2016, and therefore much earlier than forecasted, India displaced the USA as the second largest hard coal producer worldwide. This was mainly attributable to cut backs in production in the USA and less so to the rise in Indian production. The expansion of Indian coal production was much too low in recent years to suggest that the Indian government's ambitious production target of 1.5 Gt (total coal) in 2020 can actually be reached.

The consolidation phase in the global coal sector which began in 2012 reached its high point in 2016 against the background of production cut-backs in China and the United States in particular. The decline in global production led to a shortage in late summer 2016, and a tangible rise in prices on the global hard coal market. Some producing countries have already responded to this in 2017 by increasing their hard coal production. According to preliminary estimates, hard coal production around the world could rise by around three per cent to around 6.5 Gt. 2017 was also marked by high coal prices, in which the global hard coal market repeatedly came under additional pressure from events such as extreme weather (cyclone Debbie in Australia, strong rainfall in Colombia) as well as strikes (Australia, South Africa). Although the rise in hard coal prices means that coal producers could again achieve big profits in part for the first time in five quarters, hardly any investment has been made in new coal projects for several years now. And even if a decline in hard coal demand in Europe in particular can be assumed in the next decades, this will probably not lead to any significant drop in global hard coal demand because a significant rise in demand is expected in Southeast Asia in particular (IEA 2017g). Against the background of a stable demand for hard coal around the world, as well as low investments in new coal projects occurring at the same time as the associated depletion of producing coal mines, the relatively high prices of hard coal on the world market are considered to be a medium-term trend, although subject to developments in China.

Nuclear fuels

The global reserves of uranium are very extensive. The current reduction in uranium resources compared to the previous year is primarily due to the absence of the resources in the USA reported as inferred resources. These inferred resources are currently being revised and will again lead to a rise in resource figures in the next few years. From a geological point of view, there will be no shortage in supplies of nuclear fuels in the foreseeable future. Whilst the demand for uranium in Europe and North America will probably decline in future, because a large number of reactors will reach the end of their operating lives by 2030, the demand for uranium is expected to increase in the emerging economies and developing countries in the Asia and Middle East regions. South Korea could, however, be an exception here: the most recent announcements by the South Korean government indicate that the country could withdraw from nuclear energy in the medium term (WNN 2017). 24 reactors are currently operating in South Korea and supply one third of the country's electricity – which makes South Korea the fifth largest consumer of uranium world-wide. The absence of the South Korean reactors would thus have a significant influence on the future demand for uranium, although this could be compensated for by rising demand in other countries. A moderate rise in the demand for uranium is expected in Latin America and Africa in the decades to come.

The uranium market continues to be dominated by relatively low spot market prices, which jeopardise the profitability of various mines and exploration projects because these are becoming increasingly time-consuming and cost intensive to realise. Nevertheless, the expansion of uranium mining in a few countries enabled global mine production to rise again by 3 % compared to the previous year. In future, the Chinese-owned Husab mine which started operations in Namibia in 2016 could develop into the world‘s largest uranium mine. Further increases in production are expected in the medium term in the light of the foreseeable rise in global demand.

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, the 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. The installed capacity in Germany in 2016 rose by around 5 MW_e to around 38 MW_e. The development of deep geothermal energy world-wide 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 2016 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 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 all of the stakeholders involved.

Renewable energy

The proportion of renewables rose further in 2016 especially for power generation. Photovoltaics in particular boasted the largest growth rates world-wide for the first time in terms of the expansion of renewable energy resources. The global installed capacity of renewables for power generation today totals 2,008 GW. Increased investment here has been made in recent years 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 242 billion USD/a. However, global investments in renewable energy declined for the first time since 2013. This is due to the reduction in technology costs on the one hand, but also to a shift in investment policy in China on the other hand. The further expansion in all areas of energy supplies is expected in future associated with the development of new and important markets in Africa, Asia and Latin America. 176 countries have now formulated targets for the expansion of renewables. Investments and the expansion of capacity will further increase the global influence of renewables, particularly in the electricity sector, whilst the influence in the thermal and transport sectors will probably tend to grow rather more moderately 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 17.4 % 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, acceptance).

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APPENDIX

- Tables
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Table A-1: Reserves of non-renewable fuels 2016: 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	79	–	123	–	635	682	13	1,532	3.9
CIS	844	–	2,402	2	3,282	1,354	168	8,052	20.4
Africa	730	–	546	–	309	1	112	1,698	4.3
Middle East	4,558	–	3,016	–	30	–	–	7,605	19.2
Austral-Asia	276	–	604	63	7,638	1,091	102	9,775	24.7
North America	284	1,168	220	204	5,692	383	129	8,080	20.4
Latin America	383	1,751	290	–	232	43	88	2,788	7.1
World	**7,155**	**2,919**	**7,202**	**269**	**17,820**	**3,554**	**612**	**39,530**	**100.0**
OECD	382	1,168	426	246	8,177	1,748	142	12,288	31.1
EU-28	35	–	53	–	612	482	10	1,192	3.0
OPEC	5,407	1,751	3,615	–	59	1	–	10,833	27.4

[1] including tight gas

Table A-2: Ressources of non-renewable fuels 2016: 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	205	202	205	529	12,564	2,958	280	286	17,229	3.2
CIS	1,155	1,245	4,974	1,833	70,292	18,958	1,241	103	99,800	18.4
Africa	1,212	444	1,351	1,679	6,656	4	1,063	264	12,674	2.3
Middle East	1,276	254	1,607	524	1,008	–	57	–	4,726	0.9
Austral-Asia	1,069	813	1,782	3,222	176,700	12,404	1,890	771	198,651	36.6
North America	1,082	6,576	1,493	2,794	166,884	17,547	859	427	197,661	36.4
Latin America	1,028	2,159	879	1,569	686	173	398	466	7,358	1.4
World	**7,028**	**11,694**	**12,290**	**12,150**	**438,615** [2]	**52,044**	**5,788**	**3,178** [3]	**542,786**	**100.0**
OECD	1,363	6,911	2,110	4,322	220,482	24,013	2,016	1,010	262,226	48.3
EU-28	109	155	118	493	12,525	2,688	280	55	16,423	3.0
OPEC	1,889	2,157	1,779	1,717	1,220	3	21	150	8,936	1.6

[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 without country allocation (62 EJ)

Table A-3: Production of non-renewable fuels 2016: Regional distribution [EJ]

Region	Crude oil	Natural gas	Hard coal	Lignite	Uranium	Total	Share [%]
Europe	7.4	9.6	2.4	4.4	0.1	23.9	4.6
CIS	28.7	31.8	11.1	1.2	15.5	88.4	17.2
Africa	15.6	7.9	6.3	–	3.8	33.6	6.5
Middle East	62.7	23.9	< 0.05	–	–	86.7	16.8
Austral-Asia	15.8	21.5	114.5	3.3	4.2	159.3	30.9
North America	36.9	36.5	16.4	0.9	7.6	98.2	19.1
Latin America	15.7	6.4	2.6	< 0.05	< 0.05	24.7	4.8
World	**182.9**	**137.6**	**153.4**	**9.8**	**31.2**	**514.8**	**100.0**
OECD	44.8	49.7	30.7	4.8	10.8	140.8	27.3
EU-28	3.1	5.0	2.3	3.4	0.1	13.9	2.7
OPEC	78.8	27.9	0.1	–	–	106.8	20.7

Table A-4: Consumption of non-renewable fuels 2016: Regional distribution [EJ]

Region	Crude oil	Natural gas	Hard coal	Lignite	Uranium	Total	Share [%]
Europe	27.8	19.8	7.3	4.4	10.3	69.6	13.5
CIS	8.3	22.7	7.5	1.2	4.3	43.9	8.5
Africa	7.9	5.0	4.6	–	0.2	17.6	3.4
Middle East	17.0	19.4	0.4	–	0.1	36.9	7.2
Austral-Asia	64.7	27.3	116.9	3.3	6.5	218.7	42.5
North America	44.2	36.8	14.9	0.9	10.0	106.8	20.8
Latin America	13.5	6.2	1.0	< 0.05	0.3	21.0	4.1
World	**183.4**	**137.2**	**152.6**	**9.8**	**31.7**	**514.6**	**100.0**
OECD	86.7	63.9	32.3	4.8	22.9	210.7	40.9
EU-28	24.9	17.6	6.3	3.3	10.1	62.1	12.1
OPEC	19.2	20.6	0.1	–	0.1	39.9	7.8

– no reserves, resources, production or consumption

Table A-5: Germany: Supply of crude oil 2015/2016 [kt]

Country / Region	2015	2016	[%]	Changes 2015 / 2016	[%]
Russia	32,577	36,048	39.6	3,471	10.7
Norway	12,455	11,111	12.2	-1,344	-10.8
United Kingdom	9,953	9,128	10.0	-825	-8.3
Kazakhstan	6,421	8,409	9.2	1,988	31.0
Azerbaijan	5,316	5,131	5.6	-185	-3.5
Nigeria	6,691	3,810	4.2	-2,881	-43.1
Algeria	3,468	3,254	3.6	-214	-6.2
Iraq	2,392	3,146	3.5	754	31.5
Libya	2,874	1,779	2.0	-1,095	-38.1
Egypt	2,894	1,740	1.9	-1,154	-39.9
Mexico	586	854	0.9	268	45.7
Saudi Arabia	1,195	844	0.9	-351	-29.4
Angola	340	675	0.7	335	98.5
other countries	206	665	0.7	459	222.8
United States	117	608	0.7	491	419.7
Denmark	707	502	0.6	-205	-29.0
Côte d'Ivoire	364	492	0.5	128	35.2
Venezuela	109	408	0.4	299	274.3
Netherlands	362	305	0.3	-57	-15.7
Equatorial Guinea	163	304	0.3	141	86.5
Tunesia	422	284	0.3	-138	-32.7
Italy	219	235	0.3	16	7.3
Colombia	668	228	0.3	-440	-65.9
Brasilia	10	208	0.2	198	1.980.0
Poland	254	203	0.2	-51	-20.1
Ghana	0	202	0.2	202	
Kuwait	192	190	0.2	-2	-1.0
Turkmenistan	0	159	0.2	159	
Estonia	175	59	0.1	-116	-66.3
Cameroon	0	34	0.0	34	
Canada	0	32	0.0	32	
France	4	18	0.0	14	350.0
Sweden	0	16	0.0	16	

continuation of table A-5
[kt]

Country / Region	2015	2016	[%]	Changes 2015 / 2016	[%]
South Africa	2	0	0.0	-2	-100.0
Latvia	15	0	0.0	-15	-100.0
Guatemala	66	0	0.0	-66	-100.0
U. Arab Emirates	9	0	0.0	-9	-100.0
Gabon	49	0	0.0	-49	-100.0
Total imports	**91,275**	**91,081**	**100.0**	**-194**	**-0.2**
OPEC		14,106	15.5		
Middle East	3,788	4,180	4.6	392	10.3
Africa	17,267	12,574	13.8	-4,693	-27.2
CIS	44,314	49,747	54.6	5,433	12.3
Europe	24,144	21,577	23.7	-2,567	-10.6

Data for 2016 are partly preliminary

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

Country of origin	2015	[%]	2016	[%]
Russia	38.8	31.1	n. s.	n. s.
Netherlands	37.1	29.7	n. s.	n. s.
Norway	37.0	29.6	n. s.	n. s.
Others	2.6	2.1	n. s.	n. s.
Domestic production	9.3	7.5	8.6	7.1
Total	**124.8**	**100.0**	**120.6**	**100.0**
re-export	31.4	25.2	19.3	16.0
storage change	2.8	2.2	0.2	0.2
Total consumption	**96.1**	**77.0**	**101.5**	**84.2**

n. s. not specified

Data are partly preliminary
Translating energy units into volume units is based on conversion factors by IEA 2017

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 2017b (original numbers in TJ), LBEG 2017a

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

Country / Region	2012	2013	2014	2015	2016	Changes 2015/2016	[%]
EU	6,704	8,364	11,024	8,248	6,075	-2,173	-26.3
hard coal	4,089	5,891	8,817	6,651	4,286	-2,365	-35.6
coke	2,615	2,473	2,207	1,597	1,789	192	12.0
Non-EU	41,218	44,502	45,182	49,262	49,119	-143	-0.3
hard coal	40,858	44,228	44,854	48,894	48,832	-62	-0.1
coke	360	274	328	368	287	-81	-22.0
Australia	4,451	4,739	5,673	5,737	6,505	768	13.4
hard coal	4,451	4,739	5,673	5,737	6,505	768	13.4
coke	0	0	0	0	0	0	
Indonesia	0	0	0	53	180	127	239.6
hard coal	0	0	0	53	180	127	239.6
coke	0	0	0	0	0	0	
Canada	1,516	1,214	1,462	1,316	1,487	171	13.0
hard coal	1,516	1,214	1,462	1,316	1,487	171	13.0
coke	0	0	0	0	0	0	
Colombia	9,352	9,999	7,381	9,948	10,725	777	7.8
hard coal	9,319	9,974	7,381	9,948	10,649	701	7.0
coke	33	25	0	0	76	76	
Norway	395	680	435	561	636	75	13.4
hard coal	395	680	435	561	636	75	13.4
coke	0	0	0	0	0	0	
Poland	3,971	4,325	4,389	4,096	2,803	-1,293	-31.6
hard coal	2,406	3,008	2,931	3,098	1,521	-1,577	-50.9
coke	1,565	1,317	1,458	998	1,282	284	28.5
CIS	11,546	13,091	13,722	16,724	17,798	1,074	6.4
hard coal	11,227	12,842	13,495	16,528	17,798	1,270	7.7
coke	319	249	227	196	0	-196	-100.0
South Africa	1,972	2,533	5,082	3,400	1,983	-1,417	-41.7
hard coal	1,972	2,533	5,082	3,400	1,983	-1,417	-41.7
coke	0	0	0	0	0	0	
Czech Republic	323	690	659	832	534	-298	-35.8
hard coal	7	365	362	566	392	-174	-30.7
coke	316	325	297	266	142	-124	-46.6

continuation of table A-7
[kt]

Country / Region	2012	2013	2014	2015	2016	Changes 2015/2016	[%]
United States	9,809	12,044	11,099	10,913	9,107	-1,806	-16.5
hard coal	9,809	12,044	11,099	10,913	9,107	-1,806	-16.5
coke	0	0	0	0	0	0	
Venezuela, Bolivarian Republic	112	59	0	0	0	0	
hard coal	111	59	0	0	0	0	
coke	1	0	0	0	0	0	
China	11	8	124	91	129	38	41.8
hard coal	9	8	23	16	11	-5	-31.3
coke	2	0	101	75	118	43	57.3
other Non-EU	2,054	135	204	519	429	-90	-17.3
hard coal	2,049	135	204	422	336	-86	-20.4
coke	5	0	0	97	93	-4	-4.1
total	**47,922**	**52,866**	**56,206**	**57,510**	**55,194**	**-2,316**	**-4.0**
hard coal	44,947	50,119	53,671	55,545	53,118	-2,427	-4.4
coke	2,975	2,747	2,535	1,965	2,076	111	5.6

Table A-8: Crude oil 2016 [Mt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
EUROPE	Albania	1.1	59	28	56	143	84
	Austria	0.8	125	7	10	142	17
	Bosnia & Herzegovina	–	–	–	10	10	10
	Bulgaria	0.2	10	2	34	46	36
	Croatia	0.8	105	10	20	135	30
	Cyprus	–	–	–	35	35	35
	Czech Republic	0.5	13	2	30	45	32
	Denmark	6.9	362	60	187	609	247
	Estonia	0.8	8	–	300	308	300
	Finland	0.5	5	–	–	5	–
	France	0.8	128	10	838	976	848
	Germany	2.4	307	32	240	578	272
	Greece	0.2	17	1	35	53	36
	Hungary	1.1	103	3	20	126	23
	Ireland	–	–	–	245	245	245
	Italy	3.7	201	71	1,545	1,817	1,617
	Lithuania	0.2	5	2	60	66	62
	Malta	–	–	–	5	5	5
	Netherlands	1.9	150	15	455	621	470
	Norway	98.5	3,827	964	2,148	6,938	3,112
	Poland	0.9	66	13	259	338	272
	Romania	3.8	780	82	200	1,062	282
	Serbia	1.0	48	11	220	279	231
	Slovakia	< 0.05	3	–	5	8	5
	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	150	49	980	1,180	1,029
	United Kingdom	47.9	3,714	515	1,643	5,872	2,158
CIS	Armenia	–	–	–	6	6	6
	Azerbaijan	41.0	1,929	952	1,245	4,126	2,197
	Belarus	1.3	142	27	158	327	185
	Georgia	< 0.05	24	5	51	79	55
	Kazakhstan	79.3	1,863	4,082	12,933	18,877	17,015
	Kyrgyzstan	< 0.05	12	5	10	27	15
	Moldova, Republic	–	–	–	10	10	10
	Russia	547.5	23,826	14,898	40,078	78,802	54,976
	Tajikistan	< 0.05	8	2	60	69	62
	Turkmenistan	13.0	575	82	1,700	2,356	1,782
	Ukraine	2.4	371	54	377	801	431
	Uzbekistan	2.7	205	81	800	1,085	881

continuation of table A-8
[Mt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
AFRICA	Algeria	67.8	3,164	1,660	2,375	7,198	4,035
	Angola	87.9	1,734	1,578	5,095	8,408	6,673
	Benin	–	4	1	70	75	71
	Cameroon	4.9	196	27	350	573	377
	Chad	3.9	82	204	2,365	2,651	2,569
	Congo, DR	1.0	48	24	1,980	2,052	2,004
	Congo, Rep.	11.9	396	218	519	1,132	737
	Côte d'Ivoire	0.8	33	14	300	347	314
	Egypt	32.8	1,691	599	2,340	4,629	2,939
	Equatorial Guinea	13.1	248	150	250	648	400
	Eritrea	–	–	–	15	15	15
	Ethiopia	–	–	< 0.5	60	60	60
	Gabon	11.4	570	272	1,400	2,242	1,672
	Gambia	–	–	–	20	20	20
	Ghana	5.0	33	90	210	333	300
	Guinea	–	–	–	150	150	150
	Guinea-Bissau	–	–	–	40	40	40
	Kenya	–	–	–	300	300	300
	Liberia	–	–	–	160	160	160
	Libya	19.4	3,850	6,580	4,750	15,180	11,330
	Madagascar	–	n. s.	n. s.	2,131	2,131	2,131
	Mali	–	–	–	128	128	128
	Mauritania	0.3	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	0.7	n. s.	20	30	50	50
	Nigeria	98.8	4,675	5,096	5,378	15,149	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, Republic of	5.8	–	475	365	840	840
	Sudan	5.1	–	204	365	569	569
	Sudan & South Sudan	10.9	210	679	730	1,620	1,409
	Tanzania	–	–	–	500	500	500
	Togo	–	–	–	70	70	70
	Tunisia	3.0	212	55	300	568	355
	Uganda	–	–	137	300	437	437
	Western Sahara	–	–	–	57	57	57
	Zimbabwe	–	–	–	10	10	10

continuation of table A-8
[Mt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
MIDDLE EAST	Bahrain	10.2	272	17	200	489	217
	Iran	216.4	10,132	21,388	7,200	38,720	28,588
	Iraq	218.9	5,549	20,240	6,320	32,109	26,560
	Israel	0.1	2	2	970	974	972
	Jordan	< 0.05	–	< 0.5	1,912	1,912	1,912
	Kuwait	152.7	6,509	13,810	700	21,018	14,510
	Lebanon	–	–	–	150	150	150
	Oman	49.3	1,539	731	1,540	3,810	2,271
	Palestinian territories	–	–	–	60	60	60
	Qatar	79.4	1,829	3,435	700	5,964	4,135
	Saudi Arabia	589.1	20,926	35,387	11,800	68,113	47,187
	Syrian	1.5	747	340	400	1,487	740
	U. Arab Emirates	182.4	5,020	13,306	4,160	22,486	17,466
	Yemen	1.2	401	393	500	1,294	893
AUSTRAL-ASIA	Afghanistan	–	–	–	296	296	296
	Australia	15.8	1,065	542	4,055	5,662	4,597
	Bangladesh	0.3	4	4	30	38	34
	Brunei	5.9	532	150	160	842	310
	Cambodia	–	–	–	25	25	25
	China	199.7	6,708	3,496	29,001	39,205	32,497
	India	37.1	1,370	621	1,840	3,831	2,461
	Indonesia	41.3	3,474	439	3,572	7,486	4,011
	Japan	0.5	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	32.7	1,160	490	850	2,500	1,340
	Mongolia	1.2	6	35	1,015	1,057	1,050
	Myanmar	0.8	58	19	595	672	614
	New Zealand	1.6	64	10	250	324	260
	Pakistan	5.4	113	48	1,390	1,551	1,438
	Papua New Guinea	2.8	73	22	290	385	312
	Philippines	0.7	19	14	270	303	284
	Sri Lanka	–	–	–	90	90	90
	Taiwan	< 0.05	5	< 0.5	5	10	5
	Thailand	12.8	217	53	452	722	505
	Timor-Leste	2.6	52	53	175	280	228
	Viet Nam	15.9	370	595	600	1,565	1,195
NORTH AMERICA	Canada	218.2	6,106	26,882	57,170	90,158	84,052
	Greenland	–	–	–	3,500	3,500	3,500
	Mexico	121.0	6,669	1,321	4,760	12,751	6,081
	USA	543.0	32,990	6,519	117,768	157,277	124,287

continuation of table A-8
[Mt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
LATIN AMERICA	Argentina	26.3	1,626	326	4,183	6,134	4,508
	Barbados	< 0.05	2	< 0.5	30	33	30
	Belize	0.1	1	1	15	17	16
	Bolivia	3.7	90	29	280	399	309
	Brazil	125.0	2,401	1,719	15,206	19,326	16,925
	Chile	0.2	63	20	330	414	351
	Colombia	44.0	1,339	225	1,790	3,354	2,015
	Cuba	3.2	73	17	1,008	1,098	1,025
	Dominican Rep.	–	–	–	150	150	150
	Ecuador	27.3	826	1,126	107	2,059	1,232
	Falkland Islands	–	–	–	800	800	800
	(French) Guiana	–	–	–	800	800	800
	Guatemala	0.4	22	12	40	74	52
	Guyana	–	–	–	450	450	450
	Haiti	–	–	–	100	100	100
	Panama	–	–	–	122	122	122
	Paraguay	–	–	–	575	575	575
	Peru	6.7	399	167	2,321	2,887	2,488
	Puerto Rico	–	–	–	75	75	75
	Suriname	0.8	15	11	700	727	711
	Trinidad and Tobago	3.7	530	33	67	631	101
	Uruguay	–	–	–	275	275	275
	Venezuela	134.2	10,162	47,385	46,820	104,367	94,205
	World	**4,374.5**	**187,936**	**240,991**	**447,874**	**876,801**	**688,865**
COUNTRY GROUPS	Europe	177.2	10,224	1,897	9,735	21,857	11,632
	CIS	687.2	28,952	20,187	57,428	106,567	77,614
	Africa	373.8	17,172	17,470	39,621	74,264	57,092
	Middle East	1,501.2	52,925	109,048	36,612	198,586	145,660
	Austral-Asia	377.1	15,345	6,596	45,036	66,976	51,632
	North America	882.2	45,765	34,722	183,198	263,686	217,921
	Latin America	375.7	17,551	51,070	76,244	144,865	127,314
ECCONOMIC COUNTRY GPG.	OPEC	1,885.7	74,946	171,262	96,805	343,013	268,066
	OPEC-Gulf	1,438.9	49,965	107,565	30,880	188,410	138,445
	OECD	1,070.7	56,230	37,066	197,923	291,219	234,989
	EU-28	73.5	6,140	845	6,322	13,307	7,167

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

Table A-9: Crude oil resources 2016 [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	46,820	3,000	1,820	–	42,000	–
4	Russia	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	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
	...						
85	Germany	240	20	70	–	–	150
	...						
	other countries [124]	61,278	42,721	11,223	162	86	7,086
	World	**447,874**	**168,121**	**59,710**	**66,635**	**42,261**	**111,147**
	Europe	9,735	4,900	2,181	46	33	2,575
	CIS	57,428	27,635	11,890	12,667	23	5,213
	Africa	39,621	28,994	7,418	276	8	2,926
	Middle East	36,612	30,532	4,134	–	< 0.5	1,946
	Austral-Asia	45,036	25,578	10,207	2,397	121	6,733
	North America	183,198	25,880	15,770	51,237	50	90,261
	Latin America	76,244	24,602	8,110	13	42,025	1,494
	OPEC	96,805	45,200	9,425	173	42,007	–
	OPEC-Gulf	30,880	27,600	3,280	–	–	–
	OECD	197,923	32,602	20,678	51,283	77	93,283
	EU-28	6,322	2,602	1,541	46	27	2,105

[1] crude oil from tight reservoirs

– no resources

Table A-10: Crude oil reserves 2016 [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
1	Venezuela	47,385	5,485	–	–	41,900
2	Saudi Arabia	35,387	35,387	–	–	–
3	Canada	26,882	530	68	26,284	–
4	Iran	21,388	21,388	–	–	–
5	Iraq	20,240	20,240	–	–	–
6	Russia	14,898	14,898	–	–	–
7	Kuwait	13,810	13,810	–	–	–
8	U. Arab Emirates	13,306	13,306	–	–	–
9	Libya	6,580	6,580	–	–	–
10	USA	6,519	4,938	1,578	–	3
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	1,719	1,719	–	–	–
16	Algeria	1,660	1,660	–	–	–
17	Angola	1,578	1,578	–	–	–
18	Mexico	1,321	1,321	–	–	–
19	Ecuador	1,126	1,126	–	–	n. s.
20	Norway	964	964	–	–	–
	...					
58	Germany	32	32	–	–	–
	...					
	other countries [82]	10,090	10,090	–	–	–
	World	**240,991**	**171,158**	**1,646**	**26,284**	**41,903**
	Europe	1,897	1,897	–	–	–
	CIS	20,187	20,187	–	–	–
	Africa	17,470	17,470	–	–	–
	Middle East	109,048	109,048	–	–	–
	Austral-Asia	6,596	6,596	–	–	–
	North America	34,722	6,789	1,646	26,284	3
	Latin America	51,070	9,170	–	–	41,900
	OPEC	171,262	129,362	–	–	41,900
	OPEC-Gulf	107,565	107,565	–	–	–
	OECD	37,066	9,133	1,646	26,284	3
	EU-28	845	845	–	–	–

[1] crude oil from tight reservoirs

n. s. not specified

– no reserves

Table A-11: Crude oil production 2011–2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2011	2012	2013	2014 [Mt]	2015	2016	Share [%] country	Share [%] cumulative
1	Saudi Arabia	525.8	547.0	523.6	530.1	565.3	589.1	13.5	13.5
2	Russia	509.0	517.9	522.6	526.7	533.6	547.5	12.5	26.0
3	USA	352.3	431.2	485.2	519.9	567.2	543.0	12.4	38.4
4	Iraq	134.2	148.1	152.6	160.3	197.0	218.9	5.0	43.4
5	Canada	165.3	179.2	192.4	208.0	215.1	218.2	5.0	48.4
6	Iran	205.8	185.8	177.7	169.2	182.6	216.4	4.9	53.3
7	China	203.6	207.5	208.1	211.4	214.6	199.7	4.6	57.9
8	U. Arab Emirates	138.4	155.0	165.7	167.3	175.5	182.4	4.2	62.1
9	Kuwait	134.3	151.6	164.7	158.1	149.1	152.7	3.5	65.6
10	Venezuela	159.9	155.3	155.0	149.5	148.6	134.2	3.1	68.6
11	Brazil	114.6	108.2	105.0	118.5	125.6	125.0	2.9	71.5
12	Mexico	145.1	144.8	143.5	137.1	128.8	121.0	2.8	74.3
13	Nigeria	120.2	123.8	118.3	120.4	113.0	98.8	2.3	76.5
14	Norway	92.2	87.5	90.2	93.1	94.8	98.5	2.3	78.8
15	Angola	85.2	86.9	87.4	83.0	88.7	87.9	2.0	80.8
16	Qatar	78.5	83.0	84.2	83.5	79.3	79.4	1.8	82.6
17	Kazakhstan	82.4	79.2	83.8	82.1	79.3	79.3	1.8	84.4
18	Algeria	76.5	76.1	72.6	70.6	68.1	67.8	1.6	85.9
19	Oman	42.1	45.8	46.1	46.2	46.6	49.3	1.1	87.1
20	United Kingdom	52.0	44.6	40.6	39.6	45.7	47.9	1.1	88.2
	...								
58	Germany	2.7	2.6	2.6	2.4	2.4	2.4	0.1	99.4
	...								
	other countries [81]	581.0	600.7	575.1	555.7	537.8	515.1	11.8	100.0
	World	**4,001.1**	**4,161.7**	**4,197.1**	**4,232.8**	**4,358.6**	**4,374.5**	**100.0**	
	Europe	178.8	165.0	164.8	168.0	173.7	177.2	4.1	
	CIS	656.8	661.6	671.3	671.8	673.6	687.2	15.7	
	Africa	422.1	461.6	430.5	406.9	396.4	373.8	8.5	
	Middle East	1,296.1	1,343.0	1,333.5	1,332.9	1,409.0	1,501.2	34.3	
	Austral-Asia	389.2	388.5	384.4	387.6	391.9	377.1	8.6	
	North America	662.7	755.2	821.1	865.1	911.1	882.2	20.2	
	Latin America	395.2	386.8	391.5	400.6	402.8	375.7	8.6	
	OPEC	1,719.9	1,823.9	1,789.3	1,760.2	1,825.5	1,885.7	43.1	
	OPEC-Gulf	1,217.0	1,270.6	1,268.4	1,268.5	1,348.7	1,438.9	32.9	
	OECD	859.1	935.2	997.1	1,044.9	1,096.2	1,070.7	24.5	
	EU-28	82.7 [1]	73.4 [1]	70.0	69.9	73.7	73.5	1.7	

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

Table A-12: Oil consumption 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	USA	859.5	19.6	19.6
2	China	578.7	13.2	32.8
3	India	212.7	4.8	37.6
4	Japan	184.5	4.2	41.8
5	Saudi Arabia	159.5	3.6	45.5
6	Russia	148.0	3.4	48.8
7	Brazil	138.8	3.2	52.0
8	Korea, Rep.	122.1	2.8	54.8
9	Germany	109.8	2.5	57.3
10	Canada	100.9	2.3	59.6
11	Mexico	97.0	2.2	61.8
12	Iran	86.6	2.0	63.8
13	France	78.0	1.8	65.6
14	Indonesia	72.6	1.7	67.2
15	Singapore	72.2	1.6	68.9
16	United Kingdom	69.1	1.6	70.4
17	Italy	59.0	1.3	71.8
18	Spain	58.1	1.3	73.1
19	Thailand	54.6	1.2	74.3
20	Australia	47.4	1.1	75.4
	...			
	other countries [179]	1,077.9	24.6	100.0
	World	**4,387.1**	**100.0**	
	Europe	665.7	15.2	
	CIS	197.5	4.5	
	Africa	188.0	4.3	
	Middle East	407.4	9.3	
	Austral-Asia	1,547.4	35.3	
	North America	1,057.5	24.1	
	Latin America	322.0	7.3	
	OPEC	458.8	10.5	
	OPEC-Gulf	363.0	8.3	
	OECD	2,074.2	47.3	
	EU-28	594.6	13.6	

Table A-13: Crude oil export 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	Saudi Arabia	380.8	17.1	17.1
2	Russia	254.2	11.4	28.5
3	Iraq	189.0	8.5	37.0
4	Canada	159.2	7.1	44.1
5	U. Arab Emirates	119.6	5.4	49.5
6	Kuwait	105.8	4.7	54.2
7	Iran	95.5	4.3	58.5
8	Venezuela	90.3	4.1	62.6
9	Nigeria	86.4	3.9	66.5
10	Angola	82.9	3.7	70.2
11	Norway	69.3	3.1	73.3
12	Kazakhstan	68.8	3.1	76.4
13	Mexico	63.3	2.8	79.2
14	Oman	44.1	2.0	81.2
15	Brazil	39.6	1.8	83.0
16	Azerbaijan	35.0	1.6	84.6
17	United Kingdom	35.0	1.6	86.1
18	Algeria	33.2	1.5	87.6
19	Colombia	30.5	1.4	89.0
20	USA	25.8	1.2	90.1
	...			
58	Germany	0.1	< 0.05	100.0
	...			
	other countries [58]	219.5	9.9	100.0
	World	**2,227.8**	**100.0**	
	Europe	109.8	4.9	
	CIS	358.6	16.1	
	Africa	277.4	12.5	
	Middle East	959.8	43.1	
	Austral-Asia	78.7	3.5	
	North America	248.3	11.1	
	Latin America	195.2	8.8	
	OPEC	1,251.9	56.2	
	OPEC-Gulf	915.7	41.1	
	OECD	371.0	16.7	
	EU-28	40.3	1.8	

Table A-14: Crude oil import 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	USA	393.0	17.1	17.1
2	China	378.7	16.5	33.5
3	India	215.7	9.4	42.9
4	Japan	192.7	8.4	51.3
5	Korea, Rep.	147.7	6.4	57.7
6	Germany	91.1	4.0	61.6
7	Spain	64.2	2.8	64.4
8	Italy	61.1	2.7	67.1
9	France	55.3	2.4	69.5
10	Netherlands	54.4	2.4	71.8
11	Singapore	52.8	2.3	74.1
12	United Kingdom	48.9	2.1	76.3
13	Taiwan	44.8	1.9	78.2
14	Thailand	42.3	1.8	80.0
15	Canada	37.8	1.6	81.7
16	Belgium	31.0	1.3	83.0
17	Greece	28.3	1.2	84.3
18	Turkey	25.1	1.1	85.4
19	Poland	24.6	1.1	86.4
20	Sweden	20.0	0.9	87.3
	...			
	other countries [66]	292.6	12.7	100.0
	World	**2,301.9**	**100.0**	
	Europe	597.6	26.0	
	CIS	36.1	1.6	
	Africa	8.0	0.3	
	Middle East	31.3	1.4	
	Austral-Asia	1,150.0	50.0	
	North America	431.4	18.7	
	Latin America	47.5	2.1	
	OECD	1,380.5	60.0	
	EU-28	564.5	24.5	

Table A-15: Natural gas 2016 [bcm]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
EUROPE	Albania	0.1	8	1	50	59	51
	Austria	1.3	100	9	244	354	253
	Belgium	–	–	–	85	85	85
	Bulgaria	0.2	8	6	575	589	581
	Croatia	1.6	75	25	50	150	75
	Cyprus	–	–	–	250	250	250
	Czech Republic	0.3	16	7	181	204	188
	Denmark	4.5	191	17	236	445	253
	France	0.1	229	9	3,984	4,222	3,993
	Germany	9.0	1,038	70	1,360	2,468	1,430
	Greece	< 0.05	1	1	10	12	11
	Hungary	1.8	232	8	158	399	166
	Ireland	3.0	59	10	50	119	60
	Italy	5.3	761	35	405	1,200	439
	Lithuania	–	–	–	14	14	14
	Malta	–	–	–	10	10	10
	Netherlands	47.4	3,618	697	666	4,981	1,363
	Norway	121.2	2,224	1,782	2,010	6,016	3,792
	Poland	4.3	269	91	1,244	1,604	1,335
	Portugal	–	–	–	148	148	148
	Romania	9.9	1,318	103	1,142	2,563	1,245
	Serbia	0.6	34	48	10	92	58
	Slovakia	0.1	26	4	10	40	14
	Slovenia	< 0.05	n. s.	1	30	31	31
	Spain	0.1	12	3	653	668	656
	Sweden	–	–	–	48	48	48
	Turkey	0.4	15	5	1,153	1,173	1,158
	United Kingdom	42.0	2,581	297	4,540	7,418	4,837
CIS	Armenia	–	–	–	18	18	18
	Azerbaijan	17.5	596	1,148	1,800	3,545	2,948
	Belarus	0.2	13	3	10	26	13
	Georgia	< 0.05	3	8	102	113	110
	Kazakhstan	22.0	578	1,907	4,179	6,664	6,086
	Kyrgyzstan	< 0.05	7	6	20	33	26
	Moldova, Republic	–	–	–	20	20	20
	Russia	640.7	22,966	47,777	152,050	222,793	199,827
	Tajikistan	< 0.05	9	6	20	34	26
	Turkmenistan	77.0	2,713	9,870	15,000	27,583	24,870
	Ukraine	17.9	2,040	952	4,495	7,487	5,447
	Uzbekistan	62.8	2,375	1,585	1,400	5,360	2,985
	Algeria	93.2	2,483	4,501	26,720	33,704	31,221
	Angola	1.9	25	308	1,200	1,533	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	0.4	n. s.	135	200	335	335
	Chad	–	–	–	1,455	1,455	1,455
	Congo, DR	n. s.	n. s.	1	10	11	11
	Congo, Rep.	0.2	n. s.	91	200	291	291
	Côte d'Ivoire	1.9	32	28	400	460	428
	Egypt	41.8	911	2,086	10,830	13,827	12,916
	Equatorial Guinea	6.2	61	37	150	248	187
	Eritrea	–	–	–	29	29	29
	Ethiopia	–	–	–	176	176	176
	Gabon	0.4	6	25	600	632	625
	Gambia	–	–	–	25	25	25
	Ghana	n. s.	n. s.	23	300	323	323
	Guinea	–	–	–	200	200	200
	Guinea-Bissau	–	–	–	50	50	50
	Kenya	–	–	–	333	333	333
	Liberia	–	–	–	200	200	200
	Libya	10.1	330	1,505	4,650	6,484	6,155
	Madagascar	–	–	–	4,700	4,700	4,700
	Mauritania	n. s.	n. s.	28	500	528	528
	Morocco	0.1	3	1	2,220	2,224	2,221
	Mozambique	4.6	42	127	5,500	5,669	5,627
	Namibia	–	–	–	350	350	350
	Niger	–	–	–	250	250	250
	Nigeria	41.2	577	5,284	3,200	9,061	8,484
	Rwanda	n. s.	n. s.	1	50	51	51
	São Tomé and Príncipe	–	–	–	100	100	100
	Senegal	–	–	–	200	200	200
	Seychelles	–	–	–	600	600	600
	Sierra Leone	–	–	–	300	300	300
	Somalia	–	–	–	261	261	261
	South Africa	1.3	46	8	9,080	9,134	9,088
	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	2.6	58	65	750	873	815
	Uganda	–	–	–	100	100	100
	Western Sahara	–	–	–	50	50	50
	Zimbabwe	–	–	–	10	10	10
	Westsahara	–	–	–	50	50	50

continuation of table A-15
[bcm]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
MIDDLE EAST	Bahrain	15.5	311	163	200	674	363
	Iran	202.4	2,766	33,721	10,000	46,487	43,721
	Iraq	7.2	140	3,694	4,000	7,834	7,694
	Israel	9.3	49	156	2,000	2,205	2,156
	Jordan	0.1	5	6	350	361	356
	Kuwait	17.1	369	1,783	500	2,652	2,283
	Lebanon	–	–	–	850	850	850
	Oman	34.7	474	705	3,015	4,194	3,720
	Palestinian territories	–	–	–	380	380	380
	Qatar	165.4	1,772	24,073	2,000	27,844	26,073
	Saudi Arabia	109.4	2,005	8,427	24,664	35,096	33,091
	Syrian	3.9	145	285	300	730	585
	U. Arab Emirates	61.9	1,322	6,091	7,315	14,728	13,406
	Yemen	2.5	52	266	500	818	766
AUSTRAL-ASIA	Afghanistan	0.2	58	50	400	508	450
	Australia	88.2	1,244	3,205	35,085	39,534	38,290
	Bangladesh	27.5	401	205	800	1,406	1,005
	Brunei	11.2	434	258	200	892	458
	Cambodia	–	–	–	50	50	50
	China	141.9	1,777	5,191	64,900	71,868	70,091
	India	27.6	818	1,227	7,039	9,084	8,266
	Indonesia	74.0	2,224	2,773	9,980	14,977	12,753
	Japan	2.9	141	21	10	172	31
	Korea, Rep.	0.2	n. s.	7	50	57	57
	Laos	–	–	–	10	10	10
	Malaysia	73.8	1,404	2,190	1,900	5,494	4,090
	Mongolia	–	–	–	133	133	133
	Myanmar	17.1	218	637	2,000	2,855	2,637
	New Zealand	5.1	171	36	353	560	389
	Pakistan	41.5	922	542	4,570	6,034	5,112
	Papua New Guinea	0.1	4	210	1,000	1,214	1,210
	Philippines	3.9	47	98	502	647	600
	Sri Lanka	–	–	–	300	300	300
	Taiwan	0.3	52	6	5	63	11
	Thailand	38.6	652	207	740	1,599	947
	Timor-Leste	n. s.	n. s.	88	300	388	388
	Viet Nam	10.7	122	617	1,355	2,094	1,972
NORTH AMERICA	Canada	157.1	6,306	2,171	37,901	46,379	40,072
	Greenland	–	–	–	3,900	3,900	3,900
	Mexico	47.2	1,708	270	17,770	19,748	18,040
	USA	755.8	35,806	8,714	53,246	97,766	61,960

continuation of table A-15
[bcm]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
LATIN AMERICA	Argentina	38.3	1,214	325	23,710	25,249	24,035
	Barbados	n. s.	n. s.	< 0.5	100	100	100
	Belize	–	–	–	10	10	10
	Bolivia	19.7	304	280	1,620	2,204	1,900
	Brazil	23.8	336	392	18,446	19,173	18,837
	Chile	1.2	111	40	1,745	1,896	1,785
	Colombia	11.4	281	123	2,282	2,686	2,405
	Cuba	1.2	17	71	400	488	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	14.0	143	399	2,550	3,091	2,949
	Puerto Rico	–	–	–	30	30	30
	Suriname	–	–	–	350	350	350
	Trinidad and Tobago	34.5	704	300	500	1,504	800
	Uruguay	–	–	–	828	828	828
	Venezuela	22.9	1,163	5,702	7,130	13,995	12,832
	World	**3,619.8**	**116,886**	**196,605**	**643,157**	**956,648**	**839,762**
COUNTRY GROUPS	Europe	253.2	12,815	3,229	19,316	35,361	22,545
	CIS	838.1	31,300	63,262	179,114	273,676	242,375
	Africa	206.7	4,572	14,377	79,739	98,688	94,116
	Middle East	629.4	9,410	79,370	56,074	144,854	135,444
	Austral-Asia	564.8	10,689	17,569	131,682	159,939	149,250
	North America	960.1	43,820	11,155	112,817	167,793	123,973
	Latin America	167.5	4,280	7,643	64,416	76,339	72,059
ECONOMIC COUNTRY GRP.	OPEC	733.6	12,965	95,125	91,999	200,089	187,124
	OPEC-Gulf	563.4	8,374	77,789	48,479	134,642	126,267
	OECD	1,307.7	56,907	17,667	169,275	243,848	186,941
	EU-28	130.9	10,534	1,393	16,093	28,021	17,486

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

Table A-16: Natural gas resources 2016 [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	Russia	152,050	110,000	20,000	9,500	12,550
2	China	64,900	20,000	12,000	22,000	10,900
3	USA	53,246	23,000	8,500	17,276	4,470
4	Canada	37,901	10,100	7,500	16,230	4,071
5	Australia	35,085	8,864	8,000	12,380	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	17,770	2,300	–	15,440	30
11	Turkmenistan	15,000	15,000	–	–	–
12	Egypt	10,830	8,000	–	2,830	–
13	Iran	10,000	10,000	–	–	–
14	Indonesia	9,980	5,500	–	1,300	3,180
15	South Africa	9,080	1,000	–	7,510	570
16	U. Arab Emirates	7,315	1,500	–	5,815	–
17	Venezuela	7,130	2,400	–	4,730	–
18	India	7,039	2,000	–	2,720	2,319
19	Mozambique	5,500	5,500	–	–	–
20	Madagascar	4,700	4,700	–	–	–
	...					
48	Germany	1,360	20	90	800	450
	...					
	other countries [124]	100,732	60,839	1,417	31,538	6,938
	World	**643,157**	**323,423**	**63,007**	**205,403**	**51,325**
	Europe	19,316	5,387	312	12,416	1,201
	CIS	179,114	130,888	20,000	11,274	16,952
	Africa	79,739	35,544	5,500	37,285	1,410
	Middle East	56,074	42,280	750	13,044	–
	Austral-Asia	131,682	46,889	20,200	41,620	22,973
	North America	112,817	39,300	16,000	48,946	8,571
	Latin America	64,416	23,135	245	40,818	218
	OPEC	91,999	46,820	5,500	39,679	–
	OPEC-Gulf	48,479	37,000	–	11,479	–
	OECD	169,275	55,531	24,547	73,637	15,560
	EU-28	16,093	3,117	312	11,746	918

– no resources / not specified

Table A-17: Natural gas reserves 2016 [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	Russia	47,777	47,734	–	43
2	Iran	33,721	33,721	–	–
3	Qatar	24,073	24,073	–	–
4	Turkmenistan	9,870	9,870	–	–
5	USA	8,714	3,386	4,973	354
6	Saudi Arabia	8,427	8,427	–	–
7	U. Arab Emirates	6,091	6,091	–	–
8	Venezuela	5,702	5,702	–	–
9	Nigeria	5,284	5,284	–	–
10	China	5,191	4,734	122	334
11	Algeria	4,501	4,501	–	–
12	Iraq	3,694	3,694	–	–
13	Australia	3,205	2,113	–	1,092
14	Indonesia	2,773	2,773	–	–
15	Malaysia	2,190	2,190	–	–
16	Canada	2,171	2,122	n. s.	49
17	Egypt	2,086	2,086	–	–
18	Kazakhstan	1,907	1,907	–	–
19	Kuwait	1,783	1,783	–	–
20	Norway	1,782	1,782	–	–
	...				
57	Germany	70	70	–	–
	...				
	other countries [76]	15,593	15,480	< 0.5	113
	World	**196,605**	**189,524**	**5,096**	**1,985**
	Europe	3,229	3,229	–	–
	CIS	63,262	63,219	–	43
	Africa	14,377	14,377	–	–
	Middle East	79,370	79,370	–	–
	Austral-Asia	17,569	15,907	122	1,539
	North America	11,155	5,778	4,973	404
	Latin America	7,643	7,643	–	–
	OPEC	95,125	95,125	–	–
	OPEC-Gulf	77,789	77,789	–	–
	OECD	17,667	11,197	4,973	1,496
	EU-28	1,393	1,393	–	–

[1] including tight gas
[2] partly data status 2015

n. s. not specified
– no reserves

Table A-18: Natural gas production 2011–2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2011	2012	2013	2014	2015	2016	Share [%] country	Share [%] cumulative
				[bcm]					
1	USA	650.9	681.5	687.2	729.1	768.1	755.8	20.9	20.9
2	Russia	629.5	609.7	627.6	610.1	636.0	640.7	17.7	38.6
3	Iran	151.8	158.2	159.1	172.6	183.9	202.4	5.6	44.2
4	Qatar	146.8	157.0	158.5	160.0	171.3	165.4	4.6	48.7
5	Canada	160.5	156.5	154.8	161.3	154.8	157.1	4.3	53.1
6	China	103.1	110.7	119.3	132.8	138.2	141.9	3.9	57.0
7	Norway	101.4	114.8	107.1	108.8	121.3	121.2	3.3	60.4
8	Saudi Arabia	92.3	95.2	103.0	108.2	106.4	109.4	3.0	63.4
9	Algeria	78.0	81.5	79.6	79.7	82.3	93.2	2.6	65.9
10	Australia	45.4	48.8	50.1	55.3	69.9	88.2	2.4	68.4
11	Turkmenistan	59.5	64.4	62.3	69.3	80.2	77.0	2.1	70.5
12	Indonesia	91.7	76.7	70.4	71.8	72.7	74.0	2.0	72.6
13	Malaysia	61.8	63.0	69.1	66.4	68.2	73.8	2.0	74.6
14	Uzbekistan	58.8	57.7	58.7	59.3	58.8	62.8	1.7	76.3
15	U. Arab Emirates	51.7	51.7	56.0	55.6	55.8	61.9	1.7	78.0
16	Netherlands	80.6	80.1	84.5	66.3	51.2	47.4	1.3	79.3
17	Mexico	52.5	47.0	45.8	44.8	46.0	47.2	1.3	80.7
18	United Kingdom	43.0	41.1	38.5	38.7	41.3	42.0	1.2	81.8
19	Egypt	61.3	60.9	56.1	48.7	44.3	41.8	1.2	83.0
20	Pakistan	38.5	41.3	38.6	42.0	40.0	41.5	1.1	84.1
	...								
44	Germany	13.3	12.1	11.1	10.5	9.7	9.0	0.2	98.0
	...								
	other countries [69]	564.4	578.6	583.6	592.6	573.3	566.1	15.6	100.0
	World	**3,336.7**	**3,388.5**	**3,421.0**	**3,483.9**	**3,573.7**	**3,619.8**	**100.0**	
	Europe	278.2	286.8	276.3	258.2	256.5	253.2	7.0	
	CIS	811.4	795.9	817.1	807.6	832.5	838.1	23.2	
	Africa	197.6	210.5	202.2	200.9	201.7	206.7	5.7	
	Middle East	523.5	541.1	566.8	587.6	606.2	629.4	17.4	
	Austral-Asia	492.1	491.9	492.5	515.1	535.1	564.8	15.6	
	North America	863.9	885.0	887.8	935.2	968.9	960.1	26.5	
	Latin America	170.1	177.3	178.3	179.5	172.8	167.5	4.6	
	OPEC	611.3	648.3	656.0	682.7	704.7	733.6	20.3	
	OPEC-Gulf	460.9	482.5	498.0	520.0	540.6	563.4	15.6	
	OECD	1,187.1	1,218.7	1,216.3	1,251.7	1,298.9	1,307.7	36.1	
	EU-28	175.6 [1]	170.8 [1]	168.0	148.3	134.3	130.9	3.6	

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

Table A-19: Natural gas consumption 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mrd. m³]	Share [%] country	Share [%] cumulative
1	USA	778.6	21.6	21.6
2	Russia	437.9	12.1	33.7
3	China	204.0	5.7	39.3
4	Iran	200.8	5.6	44.9
5	Japan	111.2	3.1	48.0
6	Saudi Arabia	109.4	3.0	51.0
7	Germany	101.5	2.8	53.8
8	Canada	99.9	2.8	56.6
9	Mexico	89.5	2.5	59.1
10	United Kingdom	81.4	2.3	61.3
11	U. Arab Emirates	71.8	2.0	63.3
12	Italy	64.5	1.8	65.1
13	Uzbekistan	50.7	1.4	66.5
14	Thailand	50.7	1.4	67.9
15	India	50.1	1.4	69.3
16	Argentina	49.6	1.4	70.7
17	Egypt	48.3	1.3	72.0
18	Turkey	46.5	1.3	73.3
19	Korea, Rep.	45.0	1.2	74.6
20	Indonesia	43.2	1.2	75.8
	...			
	other countries [90]	875,4	24,2	100,0
	World	**3,609.9**	**100.0**	
	Europe	521.0	14.4	
	CIS	598.0	16.6	
	Africa	131.9	3.7	
	Middle East	511.5	14.2	
	Austral-Asia	717.6	19.9	
	North America	968.0	26.8	
	Latin America	161.9	4.5	
	OPEC	540.9	15.0	
	OPEC-Gulf	452.4	12.5	
	OECD	1,682.6	46.6	
	EU-28	462.9	12.8	

Table A-20: Natural gas export 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[bcm]	Share [%] country	Share [%] cumulative
1	Russia	208.6	19.2	19.2
2	Qatar	124.5	11.4	30.6
3	Norway	115.0	10.6	41.2
4	Canada	82.4	7.6	48.8
5	USA	66.1	6.1	54.9
6	Australia	56.8	5.2	60.1
7	Algeria	53.0	4.9	65.0
8	Netherlands	52.3	4.8	69.8
9	Turkmenistan	47.2	4.3	74.1
10	Malaysia	32.2	3.0	77.1
11	Indonesia	31.0	2.9	79.9
12	Nigeria	23.2	2.1	82.1
13	Germany	19.3	1.8	83.8
14	Bolivia	16.1	1.5	85.3
15	Trinidad and Tobago	14.3	1.3	86.6
16	Kazakhstan	13.7	1.3	87.9
17	Myanmar	13.5	1.2	89.1
18	Uzbekistan	13.0	1.2	90.3
19	United Kingdom	10.6	1.0	91.3
20	Oman	10.3	0.9	92.2
	...			
	other countries [35]	84.4	7.8	100.0
	World	**1,087.6**	**100.0**	
	Europe	221.5	20.4	
	CIS	291.4	26.8	
	Africa	91.0	8.4	
	Middle East	152.4	14.0	
	Austral-Asia	144.9	13.3	
	North America	148.6	13.7	
	Latin America	37.8	3.5	
	OPEC	222.7	20.5	
	OPEC-Gulf	140.5	12.9	
	OECD	426.9	39.2	
	EU-28	105.8	9.7	

Table A-21: Natural gas import 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[bcm]	Share [%] country	Share [%] cumulative
1	Germany	112.0	10.3	10.3
2	Japan	108.5	10.0	20.3
3	USA	85.1	7.8	28.1
4	China	72.4	6.7	34.8
5	Italy	65.1	6.0	40.8
6	United Kingdom	48.5	4.5	45.2
7	France	46.4	4.3	49.5
8	Turkey	46.3	4.3	53.8
9	Korea, Rep.	44.2	4.1	57.9
10	Mexico	43.1	4.0	61.8
11	Netherlands	39.3	3.6	65.4
12	Spain	32.4	3.0	68.4
13	Belgium	25.0	2.3	70.7
14	India	22.5	2.1	72.8
15	Russia	21.7	2.0	74.8
16	Canada	21.0	1.9	76.7
17	U. Arab Emirates	18.4	1.7	78.4
18	Taiwan	17.9	1.7	80.1
19	Belarus	16.6	1.5	81.6
20	Poland	14.7	1.4	83.0
	...			
	other countries [58]	185.0	17.0	100.0
	World	**1,086.2**	**100.0**	
	Europe	487.1	44.8	
	CIS	63.8	5.9	
	Africa	15.8	1.5	
	Middle East	34.5	3.2	
	Austral-Asia	303.4	27.9	
	North America	149.2	13.7	
	Latin America	32.3	3.0	
	OPEC	30.0	2.8	
	OPEC-Gulf	29.6	2.7	
	OECD	791.0	72.8	
	EU-28	435.6	40.1	

Table A-22: Hard coal 2016 [Mt]

	Country / Region	Production	Reserves	Resources	Total Resources
EUROPE	Belgium	–	–	4,100	4,100
	Bulgaria	–	192	3,920	4,112
	Czech Republic	6.1	1,099	15,410	16,509
	France	–	–	160	160
	Germany	4.1	8	82,963	82,971
	Hungary	–	276	5,075	5,351
	Ireland	–	14	26	40
	Italy	0.1	10	600	610
	Montenegro	–	142	195	337
	Netherlands	–	497	2,750	3,247
	Norway	0.8	1	90	91
	Poland	70.6	19,808	160,946	180,754
	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	1.8	868	3,363	4,231
	Sweden	–	1	4	5
	Turkey	1.3	378	803	1,181
	United Kingdom	4.2	70	186,700	186,770
CIS	Armenia	–	163	154	317
	Georgia	0.4	201	700	901
	Kazakhstan	92.6	25,605	123,090	148,695
	Kyrgyzstan	0.2	971	27,528	28,499
	Russia	312.0	69,634	2,658,281	2,727,915
	Tajikistan	1.3	375	3,700	4,075
	Turkmenistan	–	–	800	800
	Ukraine	40.9	32,039	49,006	81,045
	Uzbekistan	–	1,375	9,477	10,852
AFRICA	Algeria	–	59	164	223
	Botswana	1.9	40	21,200	21,240
	Congo, DR	–	88	900	988
	Egypt	0.7	16	166	182
	Madagascar	–	–	150	150
	Malawi	0.1	2	800	802
	Morocco	–	14	82	96
	Mozambique	6.8	1,792	21,844	23,636
	Namibia	–	–	350	350
	Niger	0.2	–	90	90
	Nigeria	1.0	287	1,857	2,144
	South Africa	254.0	9,893	203,667	213,560
	Swaziland	0.1	144	4,500	4,644
	Tanzania	0.3	269	1,141	1,410
	Uganda	–	–	800	800
	Zambia	–	45	900	945
	Zimbabwe	2.7	502	25,000	25,502
ME	Iran	1.5	1,203	40,000	41,203

continuation of table A-22
[Mt]

	Country / Region	Production	Reserves	Resources	Total Resources
AUSTRAL-ASIA	Afghanistan	1.7	66	n. s.	66
	Australia	443.9	68,310	1,542,829	1,611,139
	Bangladesh	1.0	293	2,967	3,260
	Bhutan	0.1	n. s.	n. s.	n. s.
	China	3,102.5	128,112	5,331,336	5,459,448
	India	662.6	92,786	171,091	263,877
	Indonesia	396.2	15,068	93,358	108,426
	Japan	–	340	13,543	13,883
	Korea, DPR	34.0	600	10,000	10,600
	Korea, Rep.	1.7	326	1,360	1,686
	Laos	0.1	4	58	62
	Malaysia	1.3	141	1,068	1,209
	Mongolia	28.1	1,170	39,854	41,024
	Myanmar	0.5	3	248	252
	Nepal	< 0.05	1	7	8
	New Caledonia	–	2	n. s.	2
	New Zealand	2.7	825	2,350	3,175
	Pakistan	2.8	207	5,789	5,996
	Philippines	12.1	215	1,074	1,289
	Taiwan	–	1	101	102
	Viet Nam	38.5	3,116	3,519	6,635
NORTH-AMERICA	Canada	52.0	4,346	183,260	187,606
	Greenland	–	183	200	383
	Mexico	11.6	1,160	3,000	4,160
	USA	594.4	220,800	6,458,296	6,679,096
LATIN AMERICA	Argentina	0.1	500	300	800
	Bolivia	–	1	n. s.	1
	Brazil	3.5	1,547	4,665	6,212
	Chile	2.5	1,181	4,135	5,316
	Colombia	90.5	4,881	9,928	14,809
	Costa Rica	–	–	17	17
	Peru	0.3	102	1,465	1,567
	Venezuela	0.3	731	5,981	6,712
	World	**6,290.7**	**715,569**	**17,708,199**	**18,423,768**
COUNTRY GROUPS	Europe	89.0	23,837	470,051	493,888
	CIS	447.4	130,362	2,872,737	3,003,098
	Africa	267.7	13,150	283,611	296,761
	Middle East	1.5	1,203	40,000	41,203
	Austral–Asia	4,729.9	311,587	7,220,553	7,532,139
	North America	658.0	226,489	6,644,756	6,871,245
	Latin America	97.2	8,943	26,491	35,434
	Antarctica [1]	–	–	150,000	150,000
ECONOMIC COUNTRY GRP.	OPEC	2.8	2,279	48,002	50,281
	OPEC–Gulf	1.5	1,203	40,000	41,203
	OECD	1,197.7	320,561	8,672,021	8,992,582
	EU–28	86.8	22,914	468,510	491,424

[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 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	USA	6,458,296	36.5	36.5
2	China	5,331,336	30.1	66.6
3	Russia [1]	2,658,281	15.0	81.6
4	Australia	1,542,829	8.7	90.3
5	South Africa	203,667	1.2	91.5
6	United Kingdom	186,700	1.1	92.5
7	Canada	183,260	1.0	93.5
8	India	171,091	1.0	94.5
9	Poland	160,946	0.9	95.4
10	Kazakhstan	123,090	0.7	96.1
11	Indonesia	93,358	0.5	96.6
12	Germany	82,963	0.5	97.1
13	Ukraine [1]	49,006	0.3	97.4
14	Iran	40,000	0.2	97.6
15	Mongolia [1]	39,854	0.2	97.8
16	Kyrgyzstan	27,528	0.2	98.0
17	Zimbabwe	25,000	0.1	98.1
18	Mozambique	21,844	0.1	98.3
19	Botswana	21,200	0.1	98.4
20	Czech Republic [1]	15,410	0.1	98.5
	...			
	other countries [57]	272,540	1.5	100.0
	World	**17,708,199**	**100.0**	
	Europe	470,051	2.7	
	CIS	2,872,737	16.2	
	Africa	283,611	1.6	
	Middle East	40,000	0.2	
	Austral-Asia	7,220,553	40.8	
	North America	6,644,756	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	8,672,021	49.0	
	EU-28	468,510	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 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	USA	220,800	30.9	30.9
2	China	128,112	17.9	48.8
3	India	92,786	13.0	61.7
4	Russia[1]	69,634	9.7	71.5
5	Australia	68,310	9.5	81.0
6	Ukraine[1]	32,039	4.5	85.5
7	Kazakhstan	25,605	3.6	89.1
8	Poland	19,808	2.8	91.8
9	Indonesia	15,068	2.1	93.9
10	South Africa	9,893	1.4	95.3
11	Colombia	4,881	0.7	96.0
12	Canada	4,346	0.6	96.6
13	Viet Nam	3,116	0.4	97.0
14	Mozambique	1,792	0.3	97.3
15	Brazil	1,547	0.2	97.5
16	Uzbekistan	1,375	0.2	97.7
17	Iran	1,203	0.2	97.9
18	Chile	1,181	0.2	98.0
19	Mongolia[1]	1,170	0.2	98.2
20	Mexico	1,160	0.2	98.4
	...			
61	Germany[2]	8	< 0.05	100.0
	...			
	other countries [50]	11,736	1.6	100.0
	World	**715,569**	**100.0**	
	Europe	23,837	3.3	
	CIS	130,362	18.2	
	Africa	13,150	1.8	
	Middle East	1,203	0.2	
	Austral-Asia	311,587	43.5	
	North America	226,489	31.7	
	Latin America	8,943	1.2	
	OPEC	2,279	0.3	
	OPEC-Gulf	1,203	0.2	
	OECD	320,561	44.8	
	EU-28	22,914	3.2	

[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 2011–2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country/Region	2011	2012	2013	2014 [Mt]	2015	2016	Share [%] country	Share [%] cumulative
1	China	3,471.9	3,532.6	3,601.5	3,495.2	3,423.2	3,102.5	49.3	49.3
2	India	539.9	556.4	565.8	609.2	639.2	662.6	10.5	59.9
3	USA	920.4	850.5	823.4	835.1	748.8	594.4	9.4	69.3
4	Australia	352.0	381.0	411.3	441.5	441.1	443.9	7.1	76.4
5	Indonesia	364.5	406.3	430.0	410.8	401.6	396.2	6.3	82.7
6	Russia	258.5	276.1	279.0	287.0	300.1	312.0	5.0	87.6
7	South Africa	252.8	258.6	256.3	260.5	252.1	254.0	4.0	91.7
8	Kazakhstan	108.1	112.8	112.9	107.7	101.0	92.6	1.5	93.1
9	Colombia	85.8	89.0	85.5	88.6	85.5	90.5	1.4	94.6
10	Poland	76.4	79.8	77.1	73.3	72.7	70.6	1.1	95.7
11	Canada	57.4	57.0	59.9	60.5	51.2	52.0	0.8	96.5
12	Ukraine [1]	81.7	85.6	83.4	65.0	39.7	40.9	0.6	97.2
13	Viet Nam	46.6	42.1	41.0	41.1	41.7	38.5	0.6	97.8
14	Korea, DPR [2]	31.5	32.2	31.6	34.0	34.0	34.0	0.5	98.3
15	Mongolia [1]	26.1	23.6	27.0	18.1	18.2	28.1	0.4	98.8
16	Philippines	7.6	8.2	7.2	8.4	8.2	12.1	0.2	99.0
17	Mexico	21.0	16.3	15.7	15.9	15.7	11.6	0.2	99.1
18	Mozambique	0.6	5.0	5.9	6.3	6.6	6.8	0.1	99.2
19	Czech Republic [1]	11.0	10.8	8.6	8.3	7.6	6.1	0.1	99.3
20	United Kingdom	18.6	17.0	12.8	11.6	8.6	4.2	0.1	99.4
21	Germany	13.0	11.6	8.3	8.3	6.6	4.1	0.1	99.5
	...								
	other countries [32]	38.3	36.7	39.7	46.9	39.6	33.1	0.5	100.0
	World	**6,783.5**	**6,889.1**	**6,983.8**	**6,933.4**	**6,743.1**	**6,290.7**	**100.0**	
	Europe	132.5	131.7	117.6	109.5	101.4	89.0	1.4	
	CIS	449.0	475.5	476.6	461.3	443.0	447.4	7.1	
	Africa	257.6	267.6	268.2	276.7	267.1	267.7	4.3	
	Middle East	0.9	0.8	0.9	1.4	1.5	1.5	0.0	
	Austral-Asia	4,855.9	4,998.2	5,130.9	5,073.6	5,020.1	4,729.9	75.2	
	North America	998.7	923.8	899.0	911.5	815.7	658.0	10.5	
	Latin America	88.9	91.3	90.5	99.4	94.4	97.2	1.5	
	OPEC	3.6	2.7	3.3	3.8	2.4	2.8	0.0	
	OPEC-Gulf	0.9	0.8	0.9	1.4	1.5	1.5	0.0	
	OECD	1,488.5	1,441.8	1,435.3	1,473.1	1,366.0	1,197.7	19.0	
	EU-28	128.2 [3]	128.0 [3]	113.6	105.9	98.7	86.8	1.4	

[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 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%]	
			country	cumulative
1	China	3,349.4	53.4	53.4
2	India	852.9	13.6	67.0
3	USA	548.7	8.7	75.7
4	Japan	189.7	3.0	78.7
5	South Africa	178.5	2.8	81.6
6	Russia [1]	168.7	2.7	84.3
7	Korea, Rep.	136.2	2.2	86.5
8	Poland	69.7	1.1	87.6
9	Kazakhstan	69.0	1.1	88.7
10	Taiwan	65.6	1.0	89.7
11	Germany	56.9	0.9	90.6
12	Ukraine [1]	56.0	0.9	91.5
13	Australia	51.8	0.8	92.3
14	Viet Nam	50.9	0.8	93.1
15	Turkey	37.5	0.6	93.7
16	Indonesia	30.5	0.5	94.2
17	Malaysia	29.9	0.5	94.7
18	Canada	28.1	0.4	95.2
19	Brazil	23.0	0.4	95.5
20	Thailand	21.8	0.3	95.9
	...			
	other countries [81]	259.5	4.1	100.0
	World	**6,274.2**	**100.0**	
	Europe	279.8	4.5	
	CIS	297.1	4.7	
	Africa	195.6	3.1	
	Middle East	14.9	0.2	
	Austral-Asia	4,845.8	77.2	
	North America	596.6	9.5	
	Latin America	44.2	0.7	
	OPEC	4.9	0.1	
	OPEC-Gulf	3.8	0.1	
	OECD	1,275.4	20.3	
	EU-28	239.3	3.8	

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

Table A-27: Hard coal export 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	Australia	392.1	30.3	30.3
2	Indonesia	369.6	28.6	58.9
3	Russia	165.0	12.8	71.7
4	Colombia	91.5	7.1	78.7
5	South Africa	76.5	5.9	84.7
6	USA	54.7	4.2	88.9
7	Canada	30.2	2.3	91.2
8	Mongolia	25.8	2.0	93.2
9	Kazakhstan	23.6	1.8	95.0
10	Korea, DPR	22.5	1.7	96.8
11	Poland	9.2	0.7	97.5
12	China	8.7	0.7	98.2
13	Philippines	7.6	0.6	98.8
14	Mozambique	5.5	0.4	99.2
15	Czech Republic	3.4	0.3	99.4
16	Viet Nam	1.3	0.1	99.5
17	New Zealand	1.2	0.1	99.6
18	Norway	0.9	0.1	99.7
19	Chile	0.9	0.1	99.8
20	India	0.7	0.1	99.8
	...			
25	Germany	0.3	< 0.05	100.0
	...			
	other countries [4]	2.0	0.2	100.0
	World	**1,293.1**	**100.0**	
	Europe	14.7	1.1	
	CIS	189.2	14.6	
	Africa	82.0	6.3	
	Austral-Asia	829.5	64.1	
	North America	84.9	6.6	
	Latin America	92.9	7.2	
	OPEC	0.5	0.0	
	OECD	493.8	38.2	
	EU-28	13.8	1.1	

Table A-28: Hard coal import 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	China	255.6	20.0	20.0
2	India	191.0	14.9	34.9
3	Japan	189.7	14.8	49.8
4	Korea, Rep.	134.5	10.5	60.3
5	Taiwan	65.6	5.1	65.5
6	Germany	53.1	4.2	69.6
7	Turkey	36.2	2.8	72.4
8	Malaysia	28.5	2.2	74.7
9	Russia	21.7	1.7	76.4
10	Thailand	21.7	1.7	78.1
11	Philippines	20.0	1.6	79.7
12	Brazil	19.5	1.5	81.2
13	Italy	17.0	1.3	82.5
14	Ukraine	15.6	1.2	83.7
15	Netherlands	14.9	1.2	84.9
16	Spain	14.7	1.2	86.0
17	Viet Nam	13.6	1.1	87.1
18	Chile	11.9	0.9	88.0
19	France	11.8	0.9	89.0
20	Hong Kong	11.2	0.9	89.8
	...			
	other countries [65]	129.8	10.2	100.0
	World	**1,277.8**	**100.0**	
	Europe	203.3	15.9	
	CIS	38.9	3.0	
	Africa	9.9	0.8	
	Middle East	13.7	1.1	
	Austral-Asia	949.6	74.3	
	North America	23.5	1.8	
	Latin America	38.7	3.0	
	OPEC	2.4	0.2	
	OPEC-Gulf	2.3	0.2	
	OECD	569.4	44.6	
	EU-28	164.0	12.8	

Table A-29: Lignite 2016 [Mt]

	Country / Region	Production	Reserves	Resources	Total Resources
EUROPE	Albania	–	522	205	727
	Austria	–	–	333	333
	Bosnia & Herzegovina	7.3	2,264	3,010	5,274
	Bulgaria	31.2	2,174	2,400	4,574
	Croatia	–	n. s.	300	300
	Czech Republic	38.6	2,541	7,136	9,677
	France	–	n. s.	114	114
	Germany	171.5	36,100	36,500	72,600
	Greece	32.3	2,876	3,554	6,430
	Hungary	9.2	2,633	2,704	5,337
	Italy	–	7	22	29
	Kosovo	8.8	1,564	9,262	10,826
	Macedonia	5.1	332	300	632
	Montenegro	1.4	n. s.	n. s.	n. s.
	Poland	60.2	6,003	222,393	228,396
	Portugal	–	33	33	66
	Romania	23.0	280	9,640	9,920
	Serbia	38.0	7,112	13,074	20,186
	Slovakia	1.9	135	938	1,073
	Slovenia	3.3	315	341	656
	Spain	–	319	n. s.	319
	Turkey	56.9	10,975	3,405	14,381
	United Kingdom	–	–	1,000	1,000
CIS	Belarus	–	–	1,500	1,500
	Kazakhstan	5.3	n. s.	n. s.	n. s.
	Kyrgyzstan	2.3	n. s.	n. s.	n. s.
	Russia	73.7	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	3.5	n. s.	n. s.	n. s.
AFRICA	Central African Rep.	–	3	n. s.	3
	Madagascar	–	–	37	37
	Mali	–	–	3	3
	Morocco	–	–	40	40
	Niger	–	6	n. s.	6
	Nigeria	–	57	320	377
	Sierra Leone	–	–	2	2
	Australia	59.7	76,508	403,382	479,890
	Bangladesh	–	–	3	3
	China	140.0	7,801	324,654	332,455
	India	45.3	4,942	38,157	43,099

continuation of table A-29
[Mt]

	Country / Region	Production	Reserves	Resources	Total Resources
AUSTRAL-ASIA	Indonesia	60.0	7,530	34,705	42,235
	Japan	–	10	1,026	1,036
	Korea, DPR	7.0	n. s.	n. s.	n. s.
	Laos	< 0.05	499	22	521
	Malaysia	–	39	412	451
	Mongolia	7.0	1,350	119,426	120,776
	Myanmar	< 0.05	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	17.0	1,063	826	1,889
	Viet Nam	–	244	199,876	200,120
NORTH AMERICA	Canada	9.0	2,236	118,270	120,506
	Mexico	–	51	n. s.	51
	USA	66.2	30,116	1,367,962	1,398,078
LATIN AMERICA	Argentina	–	–	7,300	7,300
	Brazil	3.5	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	**990.2**	**316,534**	**4,423,861**	**4,740,395**
COUNTRY GROUPS	Europe	488.8	76,186	316,663	392,848
	CIS	85.1	93,065	1,295,775	1,388,840
	Africa	–	66	402	468
	Middle East	–	–	–	–
	Austral-Asia	337.6	109,741	1,304,673	1,414,414
	North America	75.2	32,403	1,486,232	1,518,635
	Latin America	3.5	5,073	20,118	25,191
ECONOMIC COUNTRY GRP.	OPEC	–	81	320	401
	OECD	509.2	177,609	2,173,719	2,351,328
	EU-28	371.4	53,416	287,407	340,824

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

Table A-30: Lignite resources 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	USA	1,367,962	30.9	30.9
2	Russia [1]	1,288,894	29.1	60.1
3	Australia	403,382	9.1	69.2
4	China	324,654	7.3	76.5
5	Poland	222,393	5.0	81.5
6	Viet Nam	199,876	4.5	86.1
7	Pakistan	176,739	4.0	90.1
8	Mongolia [1]	119,426	2.7	92.8
9	Canada	118,270	2.7	95.4
10	India	38,157	0.9	96.3
11	Germany	36,500	0.8	97.1
12	Indonesia	34,705	0.8	97.9
13	Serbia	13,074	0.3	98.2
14	Brazil	12,587	0.3	98.5
15	Romania	9,640	0.2	98.7
16	Kosovo	9,262	0.2	98.9
17	Argentina	7,300	0.2	99.1
18	Czech Republic [1]	7,136	0.2	99.2
19	Ukraine	5,381	0.1	99.4
20	New Zealand	4,600	0.1	99.5
	...			
	other countries [32]	23,924	0.5	100.0
	World	**4,423,861**	**100.0**	
	Europe	316,663	7.2	
	CIS	1,295,775	29.3	
	Africa	402	0.0	
	Austral-Asia	1,304,673	29.5	
	North America	1,486,232	33.6	
	Latin America	20,118	0.5	
	OPEC	320	0.0	
	OECD	2,173,719	49.1	
	EU-28	287,407	6.5	

[1] Lignite resources contains subbituminous coal

Table A-31: Lignite reserves 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[Mt]	Share [%] country	Share [%] cumulative
1	Russia [1]	90,730	28.7	28.7
2	Australia	76,508	24.2	52.8
3	Germany	36,100	11.4	64.2
4	USA	30,116	9.5	73.8
5	Turkey	10,975	3.5	77.2
6	China	7,801	2.5	79.7
7	Indonesia	7,530	2.4	82.1
8	Serbia	7,112	2.2	84.3
9	New Zealand	6,750	2.1	86.4
10	Poland	6,003	1.9	88.3
11	Brazil	5,049	1.6	89.9
12	India	4,942	1.6	91.5
13	Greece	2,876	0.9	92.4
14	Pakistan	2,857	0.9	93.3
15	Hungary	2,633	0.8	94.1
16	Czech Republic [1]	2,541	0.8	94.9
17	Ukraine [1]	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	**316,534**	**100.0**	
	Europe	76,186	24.1	
	CIS	93,065	29.4	
	Africa	66	0.0	
	Austral-Asia	109,741	34.7	
	North America	32,403	10.2	
	Latin America	5,073	1.6	
	OPEC	81	0.0	
	OECD	177,609	56.1	
	EU-28	53,416	16.9	

[1] Lignite reserves contains subbituminous coal

Table A-32: Lignite production 2011–2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2011	2012	2013	2014 [Mt]	2015	2016	Share [%] country	cumulative
1	Germany	176.5	185.4	183.0	178.2	178.1	171.5	17.3	17.3
2	China	136.3	145.0	147.0	145.0	140.0	140.0	14.1	31.5
3	Russia [1]	77.6	77.9	73.0	70.0	73.2	73.7	7.4	38.9
4	USA	73.6	71.6	70.1	72.1	64.9	66.2	6.7	45.6
5	Poland	62.8	64.3	65.8	63.9	63.1	60.2	6.1	51.7
6	Indonesia [1]	51.3	60.0	65.0	60.0	60.0	60.0	6.1	57.7
7	Australia	66.7	69.1	59.9	58.0	61.0	59.7	6.0	63.8
8	Turkey	72.5	68.1	57.5	62.6	56.1	56.9	5.7	69.5
9	India	42.3	46.5	44.3	48.3	43.8	45.3	4.6	74.1
10	Czech Republic [1]	46.8	43.7	40.6	38.3	38.3	38.6	3.9	78.0
11	Serbia [1]	40.6	38.0	40.1	29.7	37.7	38.0	3.8	81.8
12	Greece	58.4	62.4	54.0	50.4	45.6	32.3	3.3	85.1
13	Bulgaria [2]	34.5	31.0	26.5	31.3	35.9	31.2	3.2	88.2
14	Romania [1]	32.9	34.1	24.7	23.6	25.5	23.0	2.3	90.6
15	Thailand	21.3	18.1	18.1	18.0	15.2	17.0	1.7	92.3
16	Hungary [1]	9.5	9.3	9.6	9.6	9.3	9.2	0.9	93.2
17	Canada	9.7	9.5	9.0	8.5	8.4	9.0	0.9	94.1
18	Kosovo	8.2	8.0	8.2	7.2	8.2	8.8	0.9	95.0
19	Bosnia & Herzegovina [1]	7.1	7.0	6.2	6.2	6.0	7.3	0.7	95.7
20	Mongolia [1]	6.9	5.9	6.3	6.3	5.8	7.0	0.7	96.4
	Korea, DPR [3]	7.6	7.0	7.0	7.0	7.0	7.0	0.7	97.1
	...								
	other countries [14]	38.0	37.5	37.4	31.1	28.8	28.2	2.9	100.0
	World	**1,081.5**	**1,099.4**	**1,053.3**	**1,025.2**	**1,011.8**	**990.2**	**100.0**	
	Europe	566.7	566.9	530.7	514.3	516.5	488.8	49.4	
	CIS	90.8	90.6	84.9	82.6	84.2	85.1	8.6	
	Africa	0,0	0,0	0,0	0,0	0,0	n. s.	0,0	
	Austral-Asia	334.6	353.6	349.5	344.1	334.2	337.6	34.1	
	North America	83.3	81.1	79.0	80.6	73.4	75.2	7.6	
	Latin America	6.0	7.1	9.1	3.6 [4]	3.6 [4]	3.5 [4]	0.4	
	OECD	584.4	590.8	556.3	547.3	530.2	509.2	51.4	
	EU-28	428.4 [5]	436.8 [5]	410.3	400.5	400.7	371.4	37.5	

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

n. s. not specified

Table A-33: Lignite consumption 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country/Region	[Mt]	Share [%] country	Share [%] cumulative
1	Germany	168.2	17.0	17.0
2	China	140.0	14.2	31.2
3	Russia [1]	73.7	7.5	38.7
4	USA	66.2	6.7	45.4
5	Poland	60.2	6.1	51.5
6	Indonesia [1]	60.0	6.1	57.6
7	Australia	59.7	6.1	63.7
8	Turkey	56.9	5.8	69.4
9	India	45.3	4.6	74.0
10	Czech Republic [1]	38.6	3.9	77.9
11	Serbia [1]	38.0	3.8	81.8
12	Greece	32.3	3.3	85.0
13	Bulgaria [1]	31.2	3.2	88.2
14	Romania [1]	23.0	2.3	90.5
15	Thailand	16.9	1.7	92.2
16	Hungary [1]	9.2	0.9	93.2
17	Canada	9.0	0.9	94.1
18	Kosovo	8.8	0.9	95.0
19	Bosnia & Herzegovina [1]	7.3	0.7	95.7
20	Mongolia [1]	7.0	0.7	96.4
	Korea, DPR	7.0	0.7	97.1
	...			
	other countries [14]	28.2	2.9	100.0
	World	**986.8**	**100.0**	
	Europe	485.4	49.2	
	CIS	85.1	8.6	
	Africa	0,0	0,0	
	Austral-Asia	337.6	34.2	
	North America	75.2	7.6	
	Latin America	3.5	0.4	
	OECD	505.9	51.3	
	EU-28	368.0	37.3	

[1] Lignite consumption contains subbituminous coal

Table A-34: Uranium 2016 [kt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
EUROPE	Bulgaria	–	–	–	25	25	25
	Czech Republic	0.1	112	–	342	454	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	0.1	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	24.6	294	229	1,248	1,771	1,477
	Russia	3.0	165	27	794	986	822
	Ukraine	1.0	22	42	321	385	363
	Uzbekistan	2.4	55	37	118	210	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	3.7	128	–	520	648	520
	Niger	3.5	143	18	459	620	476
	Somalia	–	–	–	8	8	8
	South Africa	0.5	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	–	< 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	6.3	206	–	1,781	1,986	1,781
	China	1.6	42	95	185	322	280
	India	0.4	12	–	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	14.0	511	240	1,314	2,065	1,554
	Greenland	–	–	–	278	278	278
	Mexico	n. s.	< 0.5	1	5	7	6
	USA	1.1	376	17	121	514	138
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	**62.4**	**2,636**	**1,224**	**11,576**	**15,436**	**12,800**
COUNTRY GROUPS	Europe	0.2	457	26	560	1,043	586
	CIS	31.0	536	336	2,481	3,352	2,817
	Africa	7.6	487	224	2,127	2,838	2,351
	Middle East	–	< 0.5	–	114	114	114
	Austral-Asia	8.4	262	205	3,780	4,247	3,985
	North America	15.2	887	259	1,717	2,863	1,976
	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	21.7	1,531	285	4,031	5,847	4,316
	EU-28	0.2	457	20	560	1,037	579

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

Table A-35: Uranium resources 2016 (> 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	15.4	15.4
Mongolia	–	33	33	21	1,390	1,444	12.5	27.9
Canada	246	217	464	150	700	1,314	11.3	39.2
Kazakhstan	134	578	712	236	300	1,248	10.8	50.0
South Africa	92	190	281	159	411	851	7.4	57.3
Russia	247	421	668	126	n. s.	794	6.9	64.2
Namibia	298	165	463	57	n. s.	520	4.5	68.7
Niger	298	95	394	14	51	459	4.0	72.7
Brazil	–	121	121	300	n. s.	421	3.6	76.3
Czech Republic	51	68	119	223	–	342	3.0	79.2
Ukraine	97	81	179	23	120	321	2.8	82.0
Greenland	103	125	228	n. s.	50	278	2.4	84.4
India	121	18	139	106	n. s.	245	2.1	86.5
Colombia	–	n. s.	–	11	217	228	2.0	88.5
China	33	144	178	4	4	185	1.6	90.1
USA	121	n. s.	121	–	–	121	1.0	91.1
Uzbekistan	18	76	93	25	–	118	1.0	92.2
Jordan	–	48	48	–	50	98	0.8	93.0
Viet Nam	1	3	4	81	n. s.	85	0.7	93.7
Argentina	3	11	14	14	56	85	0.7	94.5
Botswana	14	60	74	n. s.	n. s.	74	0.6	95.1
Peru	–	19	19	20	20	59	0.5	95.6
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	97.9
Mauritania	1	23	24	–	–	24	0.2	98.1
...								
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	**3,174**	**3,290**	**6,465**	**1,704**	**3,408**	**11,576**	**100.0**	
Europe	90	173	263	284	13	560	4.8	
CIS	496	1,157	1,652	409	420	2,481	21.4	
Africa	797	583	1,380	259	487	2,127	18.4	
Middle East	1	50	52	12	50	114	1.0	
Austral-Asia	1,316	831	2,147	239	1,394	3,780	32.7	
North America	470	344	814	153	750	1,717	14.8	
Latin America	4	152	156	347	293	797	6.9	
OPEC	26	4	29	12	–	42	0.4	
OPEC-Gulf	1	3	4	12	–	16	0.1	
OECD	1,715	1,145	2,860	411	760	4,031	34.8	
EU-28	90	173	263	284	13	560	4.8	

n. s. not specified
– no resources

Table A-36: Uranium reserves 2016 (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	Canada	240	19.6	19.6
2	Kazakhstan	229	18.7	38.4
3	South Africa	168	13.7	52.1
4	Brazil	156	12.7	64.8
5	Mongolia	108	8.8	73.7
6	China	95	7.8	81.4
7	Ukraine	42	3.4	84.9
8	Tanzania	38	3.1	88.0
9	Uzbekistan	37	3.0	91.0
10	Russia	27	2.2	93.2
11	Niger	18	1.4	94.7
12	USA	17	1.4	96.1
13	Peru	14	1.1	97.2
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	**1,224**	**100.0**	
	Europe	26	2.1	
	CIS	336	27.4	
	Africa	224	18.3	
	Austral-Asia	205	16.7	
	North America	259	21.1	
	Latin America	175	14.3	
	OECD	285	23.3	
	EU-28	20	1.6	

Table A-37: Uranium resources 2016 (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	32.8	32.8
2	Canada	374.2	10.8	43.6
3	Kazakhstan	275.8	8.0	51.6
4	South Africa	237.6	6.9	58.5
5	Niger	235.3	6.8	65.3
6	Russia	228.4	6.6	71.9
7	Namibia	189.6	5.5	77.4
8	Brazil	155.9	4.5	81.9
9	China	128.3	3.7	85.6
10	Mongolia	108.1	3.1	88.7
11	Ukraine	82.9	2.4	91.1
12	USA	62.9	1.8	92.9
13	Uzbekistan	54.6	1.6	94.5
14	Tanzania	40.4	1.2	95.7
15	Central African Rep.	32.0	0.9	96.6
16	Peru	14.0	0.4	97.0
17	Botswana	13.7	0.4	97.4
18	Zambia	9.9	0.3	97.7
19	Slovakia	8.8	0.3	98.0
20	Argentina	8.6	0.2	98.2
	...			
	other countries [16]	62.3	1.8	100.0
	World	**3,458.5**	**100.0**	
	Europe	37.8	1.1	
	CIS	641.7	18.6	
	Africa	776.9	22.5	
	Middle East	1.2	0.0	
	Austral-Asia	1,383.5	40.0	
	North America	438.9	12.7	
	Latin America	178.5	5.2	
	OPEC	6.0	0.2	
	OPEC-Gulf	1.2	0.0	
	OECD	1,615.4	46.7	
	EU-28	31.7	0.9	

Table A-38: Natural uranium production 2011–2016
The most important countries and distribution by regions and economic country groupings

Rank	Country / Region	2011	2012	2013	2014 [kt]	2015	2016	Share [%] country	Share [%] cumulative
1	Kazakhstan	19.5	21.3	22.6	23.1	23.8	24.6	39.4	39.4
2	Canada	9.1	9.0	9.3	9.1	13.3	14.0	22.5	61.9
3	Australia	6.0	7.0	6.4	5.0	5.7	6.3	10.1	72.0
4	Namibia	3.3	4.5	4.3	3.3	3.0	3.7	5.9	77.8
5	Niger	4.4	4.7	4.5	4.1	4.1	3.5	5.6	83.4
6	Russia	3.0	2.9	3.1	3.0	3.1	3.0	4.8	88.2
7	Uzbekistan	3.0	2.4	2.4	2.4	2.4	2.4	3.9	92.1
8	China	1.5	1.5	1.5	1.5	1.6	1.6	2.6	94.7
9	USA	1.5	1.6	1.8	1.9	1.3	1.1	1.8	96.5
10	Ukraine	0.9	1.0	1.1	0.9	1.2	1.0	1.6	98.1
11	South Africa	0.6	0.5	0.5	0.6	0.4	0.5	0.8	98.9
12	India	0.4	0.4	0.4	0.4	0.4	0.4	0.6	99.5
13	Czech Republic	0.2	0.2	0.2	0.2	0.2	0.1	0.2	99.7
14	Romania	0.1	0.1	0.1	0.1	0.1	0.1	0.1	99.8
15	Pakistan	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.1	99.9
	Germany [1]	0.1	0.1	< 0.05	< 0.05	0.0	< 0.05	0.1	99.9
17	Brazil	0.3	0.2	0.2	0.2	< 0.05	< 0.05	0.1	100.0
18	Malawi	0.8	1.1	1.1	0.4	< 0.05	< 0.05	< 0.05	100.0
	World	**54.6**	**58.4**	**59.6**	**56.2**	**60.5**	**62.4**	**100.0**	
	Europe	0.4	0.4	0.3	0.3	0.2	0.2	0.4	
	CIS	26.3	27.5	29.2	29.4	30.4	31.0	49.6	
	Africa	9.0	10.7	10.5	8.3	7.5	7.6	12.2	
	Austral-Asia	7.9	8.9	8.2	6.9	7.7	8.4	13.4	
	North America	10.7	10.6	11.2	11.1	14.6	15.2	24.3	
	Latin America	0.3	0.2	0.2	0.2	0.0	0.0	0.1	
	OECD	17.0	17.9	17.8	16.3	20.4	21.7	34.7	
	EU-28	0.4 [2]	0.4 [2]	0.3	0.3	0.2	0.2	0.4	

[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 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	[kt]	Share [%] country	Share [%] cumulative
1	USA	18.16	28.6	28.6
2	France	9.21	14.5	43.2
3	Russia	6.26	9.9	53.1
4	China	5.34	8.4	61.5
5	Korea, Rep.	5.01	7.9	69.4
6	Ukraine	2.25	3.6	72.9
7	United Kingdom	1.73	2.7	75.7
8	Germany	1.69	2.7	78.3
9	Canada	1.63	2.6	80.9
10	Sweden	1.47	2.3	83.2
11	Spain	1.27	2.0	85.2
12	Finland	1.13	1.8	87.0
13	Belgium	1.02	1.6	88.6
14	India	1.00	1.6	90.2
15	Slovakia	0.92	1.4	91.6
16	Taiwan	0.78	1.2	92.9
17	Japan	0.68	1.1	93.9
18	Czech Republic	0.57	0.9	94.8
19	Switzerland	0.52	0.8	95.6
20	Hungary	0.36	0.6	96.2
	...			
	other countries [11]	2.41	3.8	100.0
	World	**63.40**	**100.0**	
	Europe	20.62	32.5	
	CIS	8.60	13.6	
	Africa	0.30	0.5	
	Middle East	0.18	0.3	
	Austral-Asia	13.08	20.6	
	North America	20.07	31.7	
	Latin America	0.54	0.9	
	OPEC	0.18	0.3	
	OPEC-Gulf	0.18	0.3	
	OECD	45.88	72.4	
	EU-28	20.10	31.7	

Table A-40: Geothermal energy 2016[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}]
Albania	–	–	16	30
Austria	1	2	77	298
Belgium	–	–	7	18
Bosnia & Herzegovina	–	–	23	83
Bulgaria	–	–	106	399
Croatia	–	–	68	131
Czech Republic	–	–	7	25
Denmark	–	–	48	–
France	17	100	493	1,306
Germany	38	174	391	1,304
Greece	–	–	83	245
Hungary	–	–	753	1,874
Iceland	665	5,200	2,131	7,676
Italy	916	5,900	1,371	2,916
Lithuania	–	–	14	34
Macedonia	–	–	45	123
Netherlands	–	–	115	667
Poland	–	–	105	354
Portugal	29	200	20	108
Romania	< 0.5	< 0.5	176	362
Serbia	–	–	111	488
Slovakia	–	–	148	–
Slovenia	–	–	66	137
Sweden	–	–	33	140
Switzerland	–	–	40	250
Turkey	775	6,000	2,844	12,278
United Kingdom	–	–	3	17
Europe	2,441	17,577	9,292	31,262
EU-28	1,001	6,377	4,082	10,335

[1] Reliable actual data for countries outside of Europe covering the year 2015 is not available as of yet
Data based on
EGEC, GeotIS (for Germany), IRENA Renewable Statistics 2017

– no data available

Table A-41: Geothermal – electricity installed power 2011–2016

Rank	Country / Region	2011	2012	2013	2014 [MW_e]	2015	2016	Share [%] country	Share [%] cumulative
1	USA	3,389	3,442	3,525	3,450	3,567	3,596	26.7	26.7
2	Philippines	1,848	1,904	1,917	1,870	1,930	1,929	14.3	41.1
3	Indonesia	1,341	1,333	1,401	1,340	1,404	1,590	11.8	52.9
4	New Zealand	843	895	971	1,005	973	971	7.2	60.1
5	Italy	876	876	916	916	915	916	6.8	66.9
6	Mexico	1,017	1,017	834	1,017	1,069	907	6.7	73.7
7	Turkey	242	167	368	397	624	775	5.8	79.5
8	Kenya	249	249	590	594	607	676	5.0	84.5
9	Iceland	660	664	665	665	661	665	4.9	89.4
10	Japan	537	537	539	519	540	544	4.0	93.5
11	Costa Rica	207	207	208	207	218	208	1.5	95.0
12	El Salvador	204	204	204	204	204	204	1.5	96.5
13	Nicaragua	150	150	160	159	155	160	1.2	97.7
14	Russia	82	82	82	82	97	82	0.6	98.3
15	Papua New Guinea	56	56	56	50	56	56	0.4	98.8
16	Guatemala	48	48	48	52	49	48	0.4	99.1
17	Germany	29	24	27	27	31	38	0.3	99.4
18	Portugal	23	29	29	29	23	29	0.2	99.6
19	China	27	27	27	27	27	27	0.2	99.8
20	France	17	17	17	16	18	17	0.1	99.9
	...								
	other countries [2]	49	11	10	10	10	9	0.1	100.0
	World	**11,893**	**11,938**	**12,594**	**12,636**	**13,178**	**13,447**	**100.0**	
	Europe	1,848	1,850	1,850	2,133	2,273	2,440	18.1	
	CIS	82	82	82	82	97	82	0.6	
	Africa	220	200	200	601	614	683	5.1	
	Austral-Asia	4,720	4,800	4,800	4,812	4,930	5,119	38.1	
	North America	4,920	5,100	5,100	5,089	4,636	4,503	33.5	
	Latin America	639	609	620	622	626	620	4.6	
	OECD	7,635	7,670	7,894	8,043	8,423	8,460	62.9	
	EU-28	946 [2]	946 [2]	991	989	988	1,000	7.4	

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

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

Table A-42: Geothermal energy resources 2016

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 2016 [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	349.2	263.1	86.1
2	USA	143.0	59.2	83.8
3	Brazil	105.9	86.9	19.0
4	Canada	97.0	87.8	9.2
5	India	45.6	29.1	16.5
6	Germany	42.6	4.8	37.9
7	Russia	42.4	42.2	0.2
8	Japan	36.9	18.1	18.8
9	Norway	33.0	32.4	0.5
10	Italy	24.3	9.3	15.0
11	Spain	23.6	8.1	15.5
12	France	21.6	13.5	8.2
13	Turkey	20.4	15.2	5.2
14	Sweden	20.2	14.1	6.1
15	United Kingdom	18.7	1.2	17.5
16	Venezuela	13.9	13.9	< 0.05
17	Viet Nam	13.8	13.7	0.1
18	Austria	11.4	9.0	2.4
19	Colombia	11.1	10.6	0.5
20	Mexico	10.9	6.8	4.1
	...			
	other countries [48]	244.3	171.2	73.1
	World	**1,329.9**	**910.3**	**419.6**
	Europe	271.8	130.9	140.8
	CIS	56.9	56.2	0.7
	Africa	30.8	25.8	5.0
	Middle East	5.5	4.7	0.7
	Austral-Asia	512.6	368.1	144.5
	North America	250.9	153.9	97.1
	Latin America	184.2	156.0	28.2
	OPEC	20.7	20.3	0.4
	OPEC-Gulf	3.1	2.9	0.2
	OECD	586.9	316.8	270.1
	EU-28	214.3	78.7	135.6

Table A-44: Renewable energy – installed electrical capacity 2016
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country/Region	[MW]	Share [%]	
			country	cumulative
1	China	545,916	27.2	27.2
2	USA	214,766	10.7	37.9
3	Brazil	122,951	6.1	44.0
4	Germany	104,704	5.2	49.2
5	Canada	97,517	4.9	54.1
6	India	90,748	4.5	58.6
7	Japan	71,809	3.6	62.2
8	Russia	51,350	2.6	64.7
9	Italy	51,070	2.5	67.3
10	Spain	47,954	2.4	69.7
11	France	44,666	2.2	71.9
12	Turkey	34,467	1.7	73.6
13	United Kingdom	33,516	1.7	75.3
14	Norway	32,744	1.6	76.9
15	Sweden	27,877	1.4	78.3
16	Austria	18,516	0.9	79.2
17	Mexico	18,301	0.9	80.1
18	Viet Nam	17,973	0.9	81.0
19	Australia	17,669	0.9	81.9
20	Switzerland	15,196	0.8	82.7
	...			
	other countries [191]	347,910	17.3	100.0
	World	**2,007,619**	**100.0**	
	Europe	513,229	25.6	
	CIS	76,363	3.8	
	Africa	37,905	1.9	
	Middle East	16,494	0.8	
	Austral-Asia	826,529	41.2	
	North America	330,583	16.5	
	Latin America	206,095	10.3	
	OPEC	36,823	1.8	
	OPEC-Gulf	13,189	0.7	
	OECD	932,751	46.5	
	EU-28	420,445	20.9	

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Bundesamt für Strahlenschutz – BfS

Bundesamt für Wirtschaft und Ausfuhrkontrolle – BAFA

Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit – BMUB

Bundesministerium für Wirtschaft und Energie – BMWi

Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung – BMZ

Bundesverband Geothermie – GtV

Bureau of Energy, Ministry of Economic Affairs (Taiwan)

Bureau of Resources and Energy Economics – BREE (Australia)

Canadian Association of Petroleum Producers – CAPP (Canada)

CARBUNION (Spain)

China Coal Information Institute

Coal India Limited – CIL

Comité Professionnel Du Pétrole – CPDP (France)

CORES (Spain)

Customs Statistics of Foreign Trade (Russian Federdation)

Department of Business Enterprise & Regulatory Reform – BERR (United Kingdom)

Department of Energy – DOE (Philippinen)

Department of Energy (South Africa)

Department of Natural Resources and Mines (Australia)

Department of Industry, Innovation and Science (Australia)

Department of Resources, Energy and Tourism (Australia)

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

Deutsches Pelletinstitut – DEPI

Digest of UK Energy Statistics – DUKES

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

DTEK Annual reports (Ukraine)
Energy Fact Book (Australia)
Energy Resources Conservation Board – ERCB (Canada)
Environmental Protection Agency – EPA
Euratom Supply Agency, European Commission – ESA
European Biomass Association – AEBIOM
European Geothermal Congress – EGC
European Geothermal Energy Council – EGEC (Belgium)
Extractive Industries Transparency Initiative – EITI
Gazprom (Russian Federation)
Geological Survey of Czech Republic – ČGS
Geological Survey of India – GSI
Geological Survey of Namibia
Geoscience Australia
Geothermal Energy Association – GEA (USA)
Geothermisches Informationssystem für Deutschland – GeotIS
Gesamtverband Steinkohle e.V. – GVSt
Global Methan Initiative – GMI (USA)
Government of Australia, Australian Energy Ressource Assessment
Grubengas Deutschland e. V. – IVG
Handbook of Energy & Economics Statistics (Indonesia)
IHS McCloskey Coal Report
INA-Industrija nafte, d.d. (INA, d.d.) (Croatia)
Instituto Colombiano de Geología y Minería – INGEOMINAS
Interfax Russia & CIS
Intergovernmental Panel on Climate Change – IPCC
International Atomic Energy Agency – IAEA
International Energy Agency – IEA (France)
International Geothermal Association – IGA
International Journal of Geothermal Research and its Applications – Geothermics
International Renewable Energy Agency – IRENA
Korea Energy Economics Institute – KEEI
Kosmos Energy (Mauretania)
Landesamt für Bergbau, Energie und Geologie – LBEG
Mineral Resources and Petroleum Authority of Mongolia – MRPAM
Mineralölwirtschaftsverband e.V. (MWV)

Ministerie van Economische Zaken (Netherlands)

Ministerio de Energia y Minas (Guatemala)

Ministerio de Energia y Minas (Peru)

Ministério de Minas e Energia (Brazil)

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

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

Ministry of Coal (India)

Ministry of Ecology, Sustainable Development and Energy (France)

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

Ministry of Economic Development (New Zealand)

Ministry of Energy of the Russian Federation (Russian Federation)

Ministry of Energy and Coal Mining (Ukraine)

Ministry of Energy and Energy and Energy Industries Trinidad & Tobago

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

Ministry of Energy and Mining (Algeria)

Ministry of Energy and Natural Resources (Turkey)

Ministry of Energy Myanmar

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

Ministry of Energy (Islamische Republik Iran)

Ministry of Energy (United Arab Emirates)

Minister of Energy and Mineral Resources of Kazakhstan – MEMP PK

Ministry of Land and Resources (MLR) (China)

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

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

Ministry of Mines and Energy – MME (Brazil)

Ministry of Petroleum and Natural Gas (India)

Ministry of Science, Energy & Technology (Jameika)

Ministry of Statistics and Programme Implementation – MOSPI (India)

Nacionalni naftni komitet Srbije (Serbia)

NAFTA (Slovakia)

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

National Coal Mining Engineering Technology Research Institute (China)

National Energy Board (Canada)

National Oil & Gas Authority – NOGA (Bahrain)

Natural Gas Europe – NGE

Natural Gas World (Namibia)

National Rating Agency (Russian Federation)

Norsk Petroleum (Norway)

Norwegian Petroleum Directorate – NPD

Nuclear Energy Agency – NEA

Oberbergamt des Saarlandes

Oil and Gas Authority (United Kingdom)

Oil & Gas Journal

Organization for Economic, Co-operation and Development – OECD

Organization of the Petroleum Exporting Countries – OPEC

Oxford Institute for Energy Studies (United Kingdom)

Petrobangla (Bangladesh)

Petróleos Mexicanos – PEMEX (Mexico)

Petroleum Association of Japan (Japan)

Petróleos de Venezuela S. A – PDVSA (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)

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)

TÜRKİYE KÖMÜR İŞLETMELERİ KURUMU – TKI

Türkiye Taşkömürleri Kurumu – TTK (Turkey Coal Company)

Unidad de Planeación Minero Energética –UPME (Columbia)

U.S. Energy Information Administration – EIA

U.S. Geological Survey – USGS

Verein der Kohlenimporteure e.V. – VDKi

Wirtschaftskammer Österreich – WKO (Austria)

Wismut GmbH

World Coal Association

World Energy Council – WEC

World Geothermal Congress – WGC

World Nuclear Association – WNA

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
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 m³ natural gas, Super-Giant: > 680 million t oil or > 850 billion m³ natural gas, Mega-Giant: > 6,800 million t oil or > 8,500 billion m³ natural gas
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 Nm^3 natural gas, 1 m^3 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

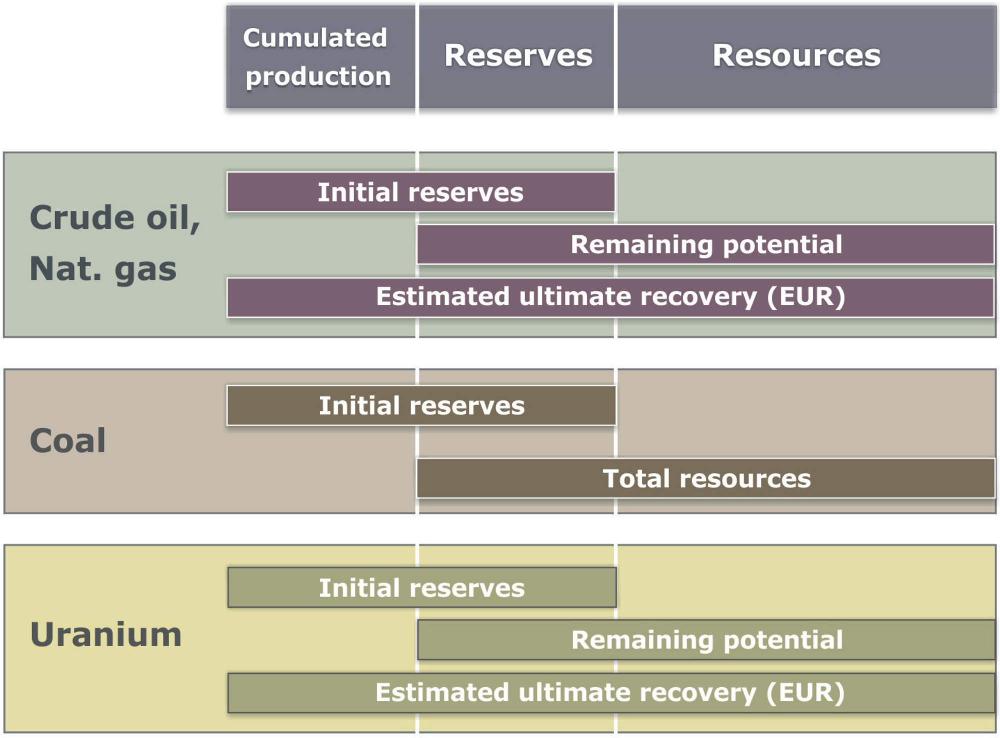
NCG	Non-condensable gases
NEA	Nuclear Energy Agency; part of OECD, headquarters in Paris
NGB	North German Basin
NGL	Natural gas liquids
NGPL	Natural gas plant liquids: constituents of produced natural gas which are liquefied separately in the processing plant, (→ Condensate)
OECD	Organisation for Economic 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
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
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.

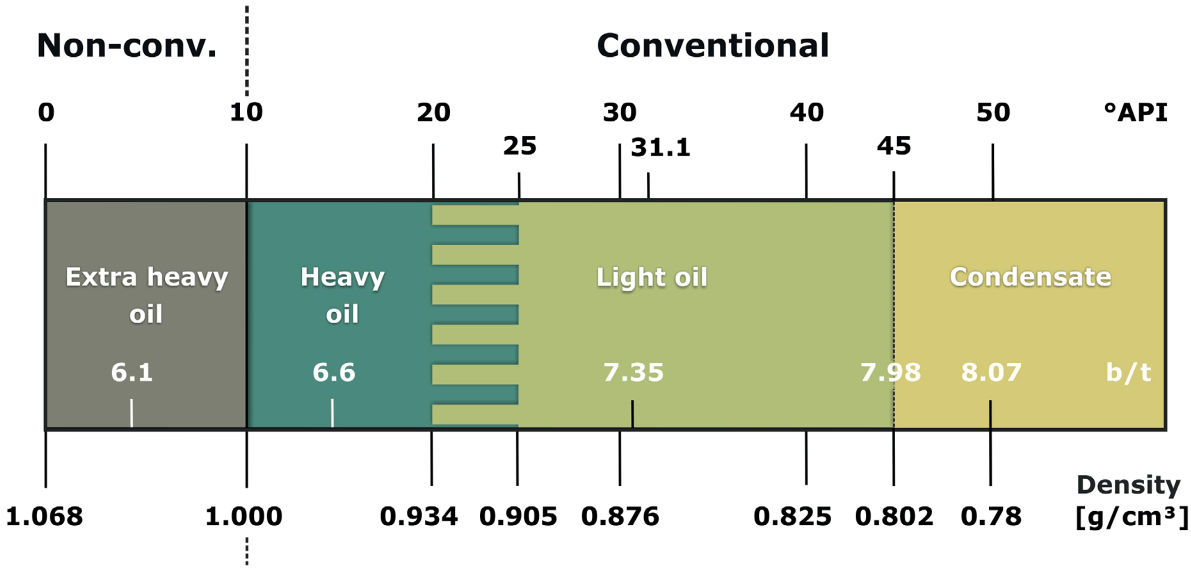
URG	Upper Rhine Graben
USAID	United States Agency for International Development
USD	US-Dollar; currency of the United States of America
USGS	United States Geological Survey
VDKi	Verein der Kohlenimporteure e.V. (Coal Importer Association); headquarters in Berlin
WEC	World Energy Council, headquarters 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

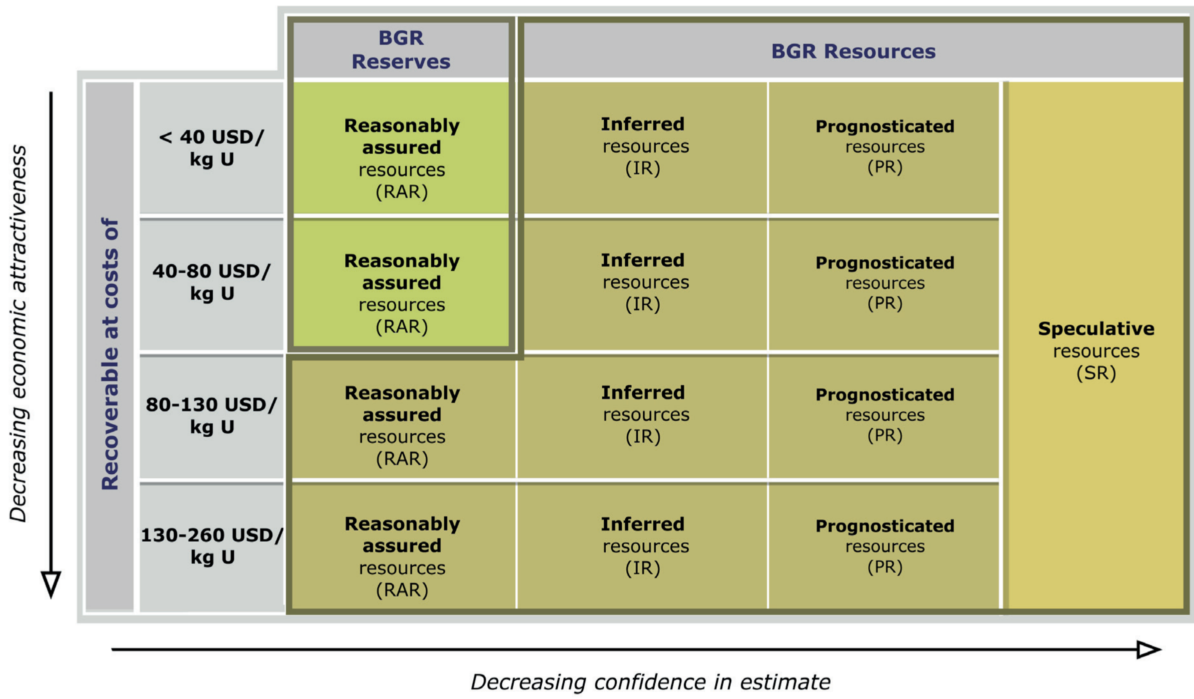


Uranium reserves classification according to cost categories

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

Europe

Albania, Andorra, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, 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

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: 2016

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, Czech Republic, 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; 168 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, Czech Republic, 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, San Marino, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, South Africa, South Sudan, 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, Czech Republic, 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; 13 countries)

Algeria, Angola, Ecuador, 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 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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