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Reserves, Resources and Availability of Energy Resources

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Editor:	Federal Institute for Geosciences and Natural Resources (BGR), Department B1.3, Geology of energy resources, polar geology Stilleweg 2 30655 Hannover, Germany E-Mail: energierohstoffe@bgr.de
Authors:	Harald Andruleit (Koordination), Hans Georg Babies, Stephanie Fleig, Stefan Ladage, Jürgen Meßner, Martin Pein, Dorothee Rebscher, Michael Schauer, Sandro Schmidt, Gabriela von Goerne
Contributions by:	Andreas Bahr, Uwe Benitz, Jennifer Bremer
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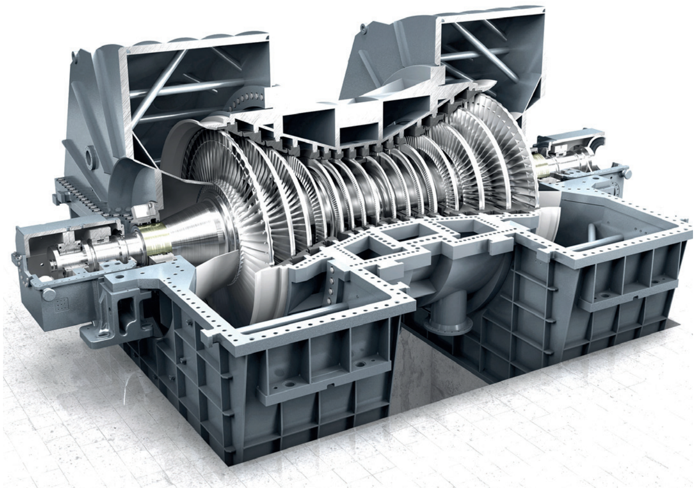
The Federal Institute for Geoscience and Natural Resources (BGR) is a technical
and scientific agency of the Federal Ministry for Economic Affairs and Energy (BMWi).

FOREWORD

The internationally binding Paris Climate Treaty came into force in November 2016, and will have significant consequences for global energy production. With its ongoing energy transition „Energiewende“, Germany started the conversion of its domestic energy supplies several years ago. The energy transition is vital if the objectives formulated in the Paris treaty are to be achieved. This implies both expanding the use of renewable energies to become a key energy resource, as well as implementing additional accompanying measures.

The conversion of energy systems, as well as the search for material substitutes for fossil energy resources, is a complex and lengthy process. Developing storage systems, boosting energy efficiency, and adapting power grids, are just a few of the measures required to solve the challenges ahead. At a global scale, this means that the energy mix will only change very gradually and significant shifts in the proportions of different types of energy resources are going to take decades rather than years. Experience gained in Germany – for example with the conversion of the energy infrastructure – also underlines the long periods of time involved in the transformation process, even in the favourable light of the social consensus which has already been reached on the issue of the future orientation of the country‘s energy policy. The dependency on fossil fuels built up over many decades is too entrenched to be resolved within only a few years.



The reliable and economical provision of primary energy builds the foundation for our prosperity, and is essential for the development of functioning economies. The global population will continue to grow in the coming decades, and therefore increase the demand for primary energy when compared to today. In the light of these challenges, supplying the world with energy will also continue to involve the provision of fossil fuels. This is why fossil energy resources will still be indispensable in global energy production in the foreseeable future – even if the proportions decline and greater efficiencies are achieved – to enable the expansion of renewable energy, and to implement the change in the energy mix without causing any disruptions.

The Energy Study 2016 provides facts and figures on the availability and development of all energy resources, i.e. crude oil, natural gas, coal, uranium and renewable energy, including deep geothermal energy. The „Energy resources in focus“ section looks in more detail at the following topics: „The crude oil and natural gas potential of countries around the Horn of Africa“, „Shale oil and shale gas in Germany – resources and environmental aspects“, and „Underground energy storages for the energy transition“.

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1 SUMMARY

Introduction – Just like in Germany, energy consumption around the world is primarily covered by fossil fuels. Despite high energy efficiency gains, the increase in the number of people living on the planet, and the rise in overall living standards, will lead to a long-term rise in the demand for energy. The dependency on energy supplies from fossil energy resources will therefore continue into the foreseeable future. Growing international competition for energy resources is therefore expected. Despite the high growth rates achieved by renewable energies in Germany, the decline in domestic production and the withdrawal from nuclear power generation means that there will be no foreseeable decline in the country‘s high level of dependency on imported fossil energy resources. Crude oil, natural gas, coal and lignite still make the largest contribution to covering German primary energy consumption, amounting to around 80 %.

Methodology – The contents of the latest Energy Study issued by the Federal Institute for Geosciences and Natural Resources (BGR) contains statements and analyses 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 fossil energy resources, and a detailed look is also taken at topical and socially-relevant energy issues. The study serves as a consultation document on the natural resources situation for the Federal Ministry for Economic Affairs and Energy (BMWi), German industry, and the general public. The datasets and evaluations are based on continuous evaluations of information in technical journals, scientific publications, reports issued by the industry, specialist organisations and political bodies, internet sources and the results of our own surveys. If not explicitly mentioned otherwise, all of the data presented here comes from BGR‘s energy resources database.

Results – According to the information currently available, there are still comprehensive amounts of fossil fuels available. A global comparison of the so far produced energy resources and the presently existing reserves and resources reveals that major unexhausted energy potential still exists in all regions around the world (Fig.1). Whilst the potential appears almost untouched in Austral-Asia, CIS and North America, even in Europe only a small proportion has been extracted to date. This wealth in resources is primarily attributable to the large deposits of coal to be found on all continents, and 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.

The largest share of global non-renewable energy resources (552,523 Exajoules/EJ) 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 particular energy resource. The energy content of all reserves rose slightly last year to 38,443 EJ (plus 1.3 %) because of new and higher evaluations, in particular with respect to lignite. However, the changes in resources, as well as reserves, were minor overall. With respect to the energy content, coal is the dominant energy resource both in terms of resources and reserves. Crude oil, however, continues to dominate consumption and production and even increased its shares slightly 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 in 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 a 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.

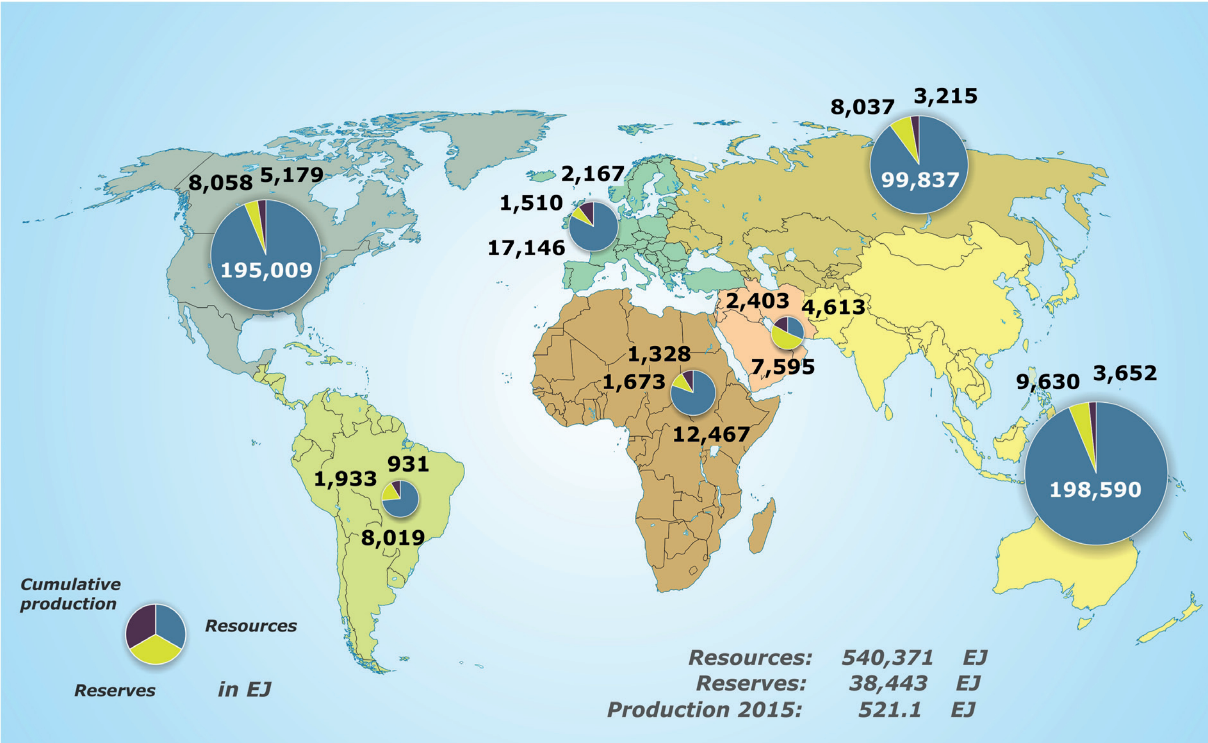

Figure 1: Total potential of fossil energy resources including uranium in 2015: regional distribution excluding coal resources in the Antarctic, and excluding resources of oil shale, aquifer gas, natural gas from gas hydrates, and thorium, because these cannot be classified regionally (estimated accumulative production of coal since 1950).

Energy resources in focus:

In the light of the current discoveries of natural gas and crude oil in Eastern Africa, the question arises of whether there is also **hydrocarbon potential in the region around the Horn of Africa** and if so, how much can be expected. The evaluation of 45 sedimentary basins in the countries of Ethiopia, Djibouti, Eritrea, Somalia and Kenya reveals a potential totalling 687 million t of crude oil, and almost 800 bcm of natural gas resources. However, given the ongoing conflicts in the region, it is not possible to foresee when these resources will be explored or possibly developed.

BGR investigated the resource potential of shale gas and shale oil in Germany, and published the study **“Schieferöl und Schiefergas in Deutschland – Ressourcen und Umweltaspekte”** at the beginning of 2016. According to this study, shale gas has a significant resource potential of around 800 billion m³, whilst shale oil has a relatively low resource potential of around 50 million t. For large areas in Germany, felt earthquakes induced by fracking have a low likelihood. Moreover, potential contamination pathways in connection with hydraulic stimulations in the deep underground are even considered to be unlikely in the long term. From a geo-scientific point of view, fracking technology can generally be employed in a controlled and safe manner.

Energy storage for the energy transition – The ground beneath our feet provides two different options for the storage of large volumes of energy in the form of man-made salt caverns and natural pore storages. Both of these types of energy storage could play a key role in the energy transition, because they provide a means of storing energy in the short term as well as the long term. Important areas of application are opened up by the storage of the energy resources compressed air and hydrogen. The energy storage potential for cavern storages in north German salt structures is around 4.5 TWh for compressed air and around 1,614 TWh for hydrogen.

Key findings on crude oil, natural gas, coal, nuclear fuels, deep geothermal energy, and renewable energy:

Crude oil

- **Crude oil is the most important energy resource in the world, and will continue to be so in the foreseeable future.** The share of crude oil in primary energy consumption increased to 35 % during the reporting period.

- **In terms of the geology of natural resources, a moderate rise in the supplies of crude oil can be maintained in the next few years.** During the reporting period, production as well as resources, rose slightly, whilst reserves declined to a minor extent.

- **The development of crude oil prices in the short term is unpredictable.** The decline in the price of crude oil continued in 2015 because of the continuing oversupply. However, price rises are still expected in the future.

- **Conventional crude oil production is crucially important for the global supply of liquid hydrocarbons.** Conventional crude oil reserves account for around 80 % of the total reserves, and the share of total production is around 90 %.

- **Crude oil is the only energy resource where growing demand in the coming decades can probably no longer be covered.** There is already a risk of supply shortages developing in the medium term due to the continuing low amount of investment made by the oil and gas industry as a consequence of the decline in the price of crude oil, because the declining production from currently producing fields may no longer be adequately compensated for.

- **The supplies of crude oil to Germany are currently comprehensively diversified with 39 supplying countries.** The most important supplying country continues to be the Russian Federation, followed by Norway and the United Kingdom. These three countries alone cover more than 60 % of German imports.

Natural gas

- **From a geological point of view, supplying the world with natural gas will still be possible for decades.** 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 less than 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 2015.** The gas transported by pipeline increased further here than the trade in LNG, even though the latter achieved its greatest trading volumes to date.

- **The first LNG export terminal on the continental United States was commissioned at the beginning of 2016.** In addition to South America and Asia, Europe (Portugal) was also supplied with liquefied natural gas from shale gas production in April 2016.

- **The closer integration of the various natural gas markets driven by the generous supplies of LNG contributed to the increased convergence of global prices.** Increasing volumes of LNG will be available in the market in coming years, and this will generally lead to more competition and improve the supply situation.

- **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.

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 55 % 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 against the background of the expected rise in global primary energy consumption.** However, global coal production and consumption are currently declining because of a decrease in demand in the last two years.

- **The current price increases on the global market for hard coal indicate an end to the many years of oversupply – at least in the short term.** The decline in global coal production of around 3 % in 2015, and a probable further reduction of 7 % in 2016, are leading to the present shortages and the associated rise in prices.

- **The development in global, and therefore also European coal prices, is primarily determined by the current situation in Asia.** Driven by the shortage in the Asian (Chinese) market, coal prices rose again for the first time after 5 years in late summer 2016.

- **Germany increased its imports of hard coal again in 2015 to today‘s level of around 55.5 Mt.** Together with coke and briquettes, Germany currently imports 89 % of its demand for coal and 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 accidents in Fukushima, continued for the fourth year in a row.

- **Further increase in global uranium production.** Production was expanded in Kazakhstan and Canada in particular. With a share of almost 40 %, Kazakhstan continues to be the most important uranium producer in the world. The Cigar Lake Mine in Canada, became the second largest production site in the world in 2015 in only the first year of its commercial operations.

- **There continues to be a growing interest in the use of nuclear fuels for the generation of energy world-wide.** 65 nuclear reactors were under construction in 15 countries at the end of 2015. 24 of these are 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.** The global reserves are extremely extensive, and currently total 1.3 Mt reserves (cost category < 80 USD/kg U) and 13.7 Mt uranium resources.

- **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 it is from a geopolitical point of view.** This technology is innovative, boasts low emissions, and is capable of generating base load power. In addition, deep geothermal energy has a relatively small surface footprint.

- **The global geothermal energy potential is very large although it has only been exploited to a very minor extent so far.** Up to a depth of 3 km, the potential is estimated to a total of 42 million EJ.

- **With the exception of geothermally favourable regions, the practical implementation and profitability of geothermal projects is currently still considered to be challenging.** This is mainly due to long periods of project planning and high exploration risks.

- **Globally, the use of geothermal energy shows an extremely diverse picture.** Favourable conditions are given in countries with high enthalpy resources. Geothermal energy could become particularly important for developing countries such as those in East Africa, where it can help to provide electricity and heat in regions with poor infrastructures.

- **The importance of geothermal energy remains low in Germany.** The contribution of deep geothermal energy to power production reached 0.03 % in 2015, whilst the share of geothermally generated heat was 0.09 %. In the last five years, the installed capacity and the amount of electricity generated has increased by a factor of almost five and totalled almost 32 MW_e and 151 GW_{th}, respectively. Geothermal energy is subsidised in Germany by the Renewable Energies Sources Act (EEG).

Renewable energy

- **Renewable energy is of great significance in terms of global energy supplies.** Around 14 % of global primary energy consumption in 2015 was covered by renewable energy, and particularly by „classic“ regenerative energy resources such as solid biomass and hydropower. The proportion of „modern“ energy resources such as wind power and photovoltaics, is still relatively low despite rapid global expansion.

- **The contribution to the global installed power generation capacity is considerable.** Power generation capacities installed world-wide for renewable energy total 1,985 GW. This corresponds to around 30 % of the estimated global power generation capacity. China is the market leader, and in terms of photovoltaics, with a total installed capacity of 43 GW, has ousted Germany from its previous number one position in terms of installed power generation capacity (39 GW).

- **The interest in the use of renewable energy is growing around the world.** Around 173 countries have currently formulated specific targets for further expansion. Around 77 % of the global expansion of installed power generation capacities in 2015 was accounted for by the installation of renewable energy.

- **The proportion of renewable energy in the German power mix in 2015 reached a new record of 30.1 %.** The main share of this is accounted for by wind power, biomass and photovoltaics.

2 ENERGY SITUATION IN GERMANY

2.1 Energy supplies and primary energy consumption

As a highly-developed industrial nation, Germany is one of the largest energy consumers in the world. Germany is currently expanding the generation capacities for primary energy from renewable sources as part of the implementation of its energy transition, and to comply with the obligations inherent in the Paris Climate Treaty signed in 2015. However, around 80 % of its primary energy consumption still has to be provided by fossil fuels. Germany has to import the majority of the energy resources it requires. Of the total value of imported natural resources (mineral and energy resources) imported in 2015 and totalling € 106.8 billion, the largest share with over 60 % was accounted for by the energy resources crude oil, natural gas and hard coal (Fig. 2). Whilst the absolute amounts of imported energy resources have risen clearly (plus 6.9 %), the import costs have declined. This is due in particular to the significant drop in crude oil prices. The relative shares in the value of the energy resources were 50.1 % for crude oil, 42.5 % for natural gas, 6.5 % for hard coal, and 1.0 % for nuclear fuels. In total, 246 million t of energy resources were imported with a value of € 65.7 billion (BGR 2016a). The most significant importing countries for fossil fuels to Germany were the Russian Federation, Norway and the Netherlands.

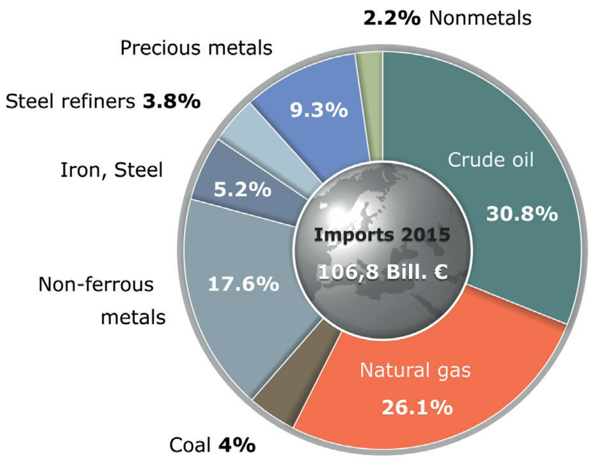

Figure 2: Proportions and value of German natural resource imports in 2015.

Only around 2 % of crude oil production, and almost 10 % of natural gas production, are still derived from domestic production (Fig. 3). The decline in production is primarily attributable to the increasing depletion of fields, and the lack of new discoveries. The production of domestic hard coal will also completely disappear in 2018, the year of the planned withdrawal from subsidised hard coal mining. In 2015, domestic hard coal production accounted for 11 % of consumption. The foreseeable continuing considerable demand for hard coal will then have to be completely covered by imports. Of all of the energy resources, lignite is the only non-renewable energy resource which is available in Germany in large economically extractable amounts. Germany supplies all its own needs here, and is the world‘s largest producer and consumer.

Primary energy consumption (PEC) in Germany 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.

Compared to the previous year, PEC in Germany rose slightly by 1.1 % to reach 13,306 PJ in 2015, and therefore the same level reached in the 1970s. The strongest influence on the rise in energy consumption was the colder weather compared to 2014, and the associated rise in demand for

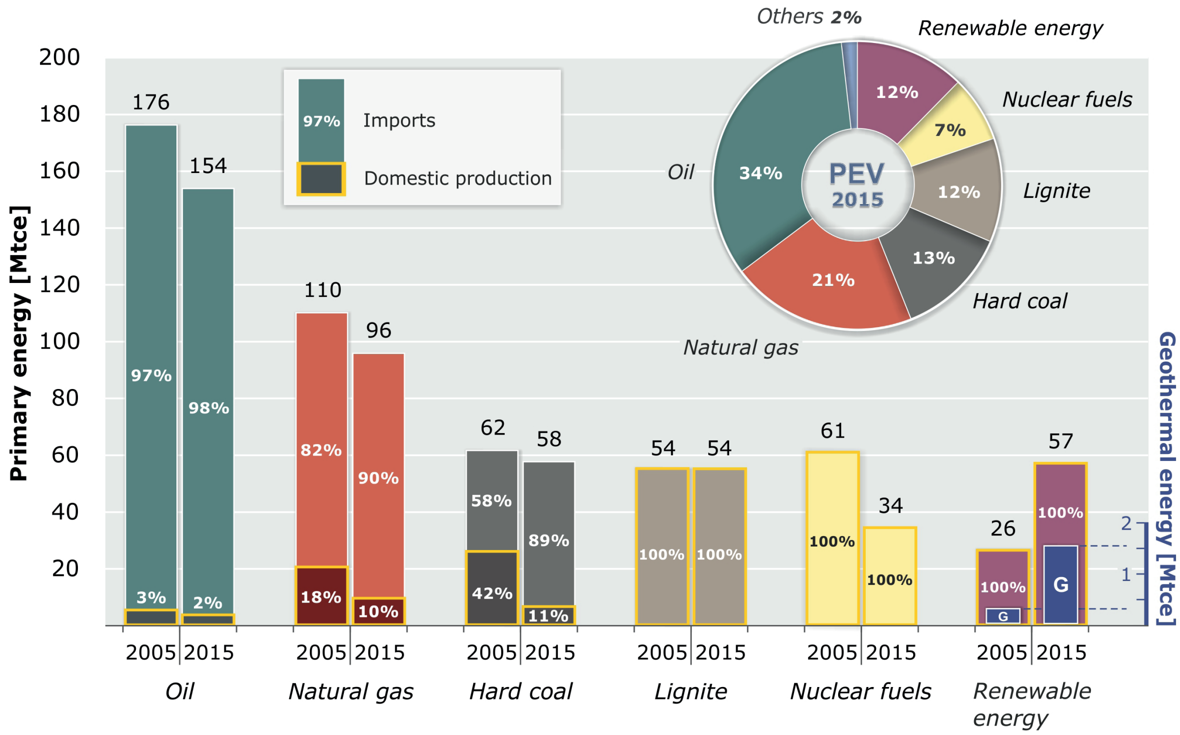

Figure 3: Germany's import dependency and domestic supply levels for specific primary energy resources in 2005 and 2015 (sources: AGEB 2016, LBEG 2016, BMU 2013).

heating. According to AGEB (2016), the growth in consumption associated with the positive rise in economic activity (plus 1.7 %) as well as the growth in the number of inhabitants (plus 1 million people) was balanced out by increases in energy efficiency. When adjusted for the weather, energy consumption last year would have been down around 0.4 % (AGEB 2016).

With the exception of renewable energy and natural gas, there was a decline in the consumption of all of the other energy resources. Because of the decline in nuclear power generation, the use of nuclear power sank by the largest amount, namely 5.5 %. Hard coal consumption dropped in 2015 by only 0.7 %, following a significant decrease the previous year. The same also applies to lignite whose use declined 0.3 % in 2015 compared to the previous year. Mineral oil consumption as well in 2015 remained almost constant after the decline in the previous year, and despite the different trends for the most important petroleum products (AGEB 2016). At 33.9 %, it still continued to account for the largest proportion of PEC. This was followed by natural gas whose consumption in 2015 increased by 5 %, largely in line with the temperatures, to rise to more than 21 %, whilst coal accounted for 12.7 %, and was closely followed by renewable energy in fourth position with 12.5 %. Lignite accounted for an 11.8 % share of primary energy consumption, whilst nuclear power accounted for 7.5 % of total primary energy consumption. Renewable energy increased its contribution in 2015 by around 10 % overall to almost 1,670 PJ. Whilst the use of biomass rose by around 3 %, hydropower (excluding pumped hydro storages) stayed close to the previous year's level. The biggest increase by far was accounted by wind power (onshore and offshore), with a rise of 53 % compared to the previous year. The rise of only 6 % for solar power (photovoltaic and solar thermal energy) was smaller than in the previous years. There was a decline in biofuels of around 6 % (AGEB 2016).

In a 10-year comparison, the share of renewables has increased considerably whilst all fossil fuels, and nuclear power in particular, now account for smaller proportions of German PEC. Energy consumption has stagnated since the beginning of the 1990s despite the growth in the economy. The increasing decoupling of economic growth from energy consumption is largely attributable to technological advancement in the energy industry, more frugal and more rational energy use, and changes in economic structures. Fluctuations in energy consumption in previous years were primarily attributable to the influence of weather conditions. In absolute terms, the proportion of fossil fuels in the German primary energy consumption mix declined from their maximum at the end of the 1970s right through to the 2000s, and have stuck at a relatively high level ever since. Given the decline in production from domestic conventional crude oil and natural gas fields, and the imminent end of subsidised hard coal mining, there is a continuing decline in the level of self-sufficiency. Against this background, there is currently no foreseeable reduction in Germany‘s high dependency on imported fossil fuels.

2.2 Energy resources and energy in detail

Crude oil

The total assured and probable crude oil reserves compared to the previous year has grown by 2.9 million t (plus 9.2 %), and totalled 33.9 million t at the end of 2015. The growth in reserves is attributable to the re-evaluation of producing oil fields as well as the commissioning of new segments of fields. German crude oil reserves are primarily located in the North German Basin, where Schleswig-Holstein (45.7 %) and Lower Saxony (24.6 %) account for more than 70 % of German reserves. No new fields were discovered (LBEG 2016).

2.41 million t crude oil (including condensate) were produced in 2015. Production therefore remained very close to the previous year‘s level (minus 0.1 %). Oil production in the largest German oil field at Mittelplate/Dieksand also remained relatively stable at 1.32 million t (minus 1.4 %) and continued to account for more than half of total German production. Production in the following oil fields was as follows: Römerberg (Rhineland-Palatinate) 0.178 million t (plus 6.1 %); Rühle 0.170 million t (minus 5.5 %); Emlichheim 0.161 million t (minus 3.1 %) (both in Lower Saxony), (LBEG 2016). Overall, 1,033 production wells were in operation with an average daily production per well of around 6.4 t crude oil.

Enhanced oil recovery methods (EOR) to increase the recovery rates in oil fields were implemented in the Rühle, Georgsdorf and Emlichheim fields, and involved steam and hot/warm water flooding. A water flooding project under test conditions is currently under way in the Bockstedt field, and involves adding a biologically degradable biopolymer derived from a fungus. EOR measures in total accounted for 11.7 % of total pure oil production.

The condensate produced during natural gas production accounted for a 0.6 % share of total German crude oil production, and amounted to 14,030 t. More than 15 % of German condensate production is from the A6/B4 gas field in the German North Sea. Crude oil was produced from 50 fields, the same number as in the previous year (LBEG 2016).

The decline in the price of crude oil since the end of 2014 had a considerable impact on the amount of exploration and development activity in the oil and gas sector. The drilling of wells, measured in the total number of drilled metres, declined by a third year-on-year to almost 32,000 m – the lowest level since 2003. Geophysical activities such as the shooting of 2-D and 3-D seismic surveys, as well as gravimetric surveys to explore underground rock formations, also declined significantly in 2015 (LBEG 2016). The German oil and gas industry had a total workforce of 9,804 in 2015, 240 down on the previous year (BVEG 2016).

Crude oil production royalties paid by the oil production companies to the relevant German states also declined considerably because of the fall in the price of crude oil. In 2015, the federal states received production royalties from crude oil production totalling € 79.9 million, down on € 147.8 million and € 189.3 million in 2014 and 2013 respectively (BVEG 2016). The size of the royalties primarily depends on the market value of the crude oil and the amount of crude oil produced.

The most important oil production companies and their production levels in 2015 in Germany according to consortium shares were as follows (BVEG 2016):

- Wintershall Holding AG 928,898 t
- DEA Deutsche Erdöl AG 684,003 t
- GDF Suez E&P Deutschland GmbH 394,938 t
- BEB Erdgas und Erdöl GmbH & Co. KG 237,355 t

The amount of crude oil imported by Germany rose by around 2.1 % in 2015 to approximately 91.3 million t. The share of the crude oil in primary energy consumption was 33.9 %, and therefore the same level as the previous year. The main supply regions were the CIS (48 %), Europe (26 %), and Africa (almost 19 %) (Fig. 4). The four most important supplying countries were the Russian Federation (32.6 million t, plus 8.5 %), Norway (12.5 million t, minus 18 %), United Kingdom (9.9 million t, plus 2.3 %), and Nigeria (6.7 million t, minus 6 %). Significant increases in the amount of imported oil were reported for Azerbaijan (plus 28.7 %), Egypt (plus 94.6 %), and Iraq (plus 160 %). There was a decline in imports of crude oil from Libya as well as Saudi Arabia (BAFA 2016a). Table 10 (in the Appendix) provides a list of all crude oil supplying countries in 2015).

Before the ongoing unrest, Libya was one of Germany‘s most important sources of crude oil. The imports of crude oil from Libya declined from levels of around 8.6 million t in 2012, to only around 2.9 million t in 2015 (BAFA 2016a). Oil production and therefore oil exports are currently only possible in a restricted way. The German company Wintershall Holding AG, one of the largest producers of crude oil in Libya, has largely shut down its onshore production operations, and significantly curtailed its exploration and production activities (Wintershall Holding AG 2016).

Exports of crude oil from Germany into neighbouring countries rose considerably in 2015 from 30,131 t to 333,292 t. The trade in petroleum products is also mainly transacted with EU countries. Exports of petroleum products here rose by around 5 % to 22.3 million t (2014: 21.2 million t), whilst imports rose slightly to 37.4 million t (2014: 37 million t) (BAFA 2016a).

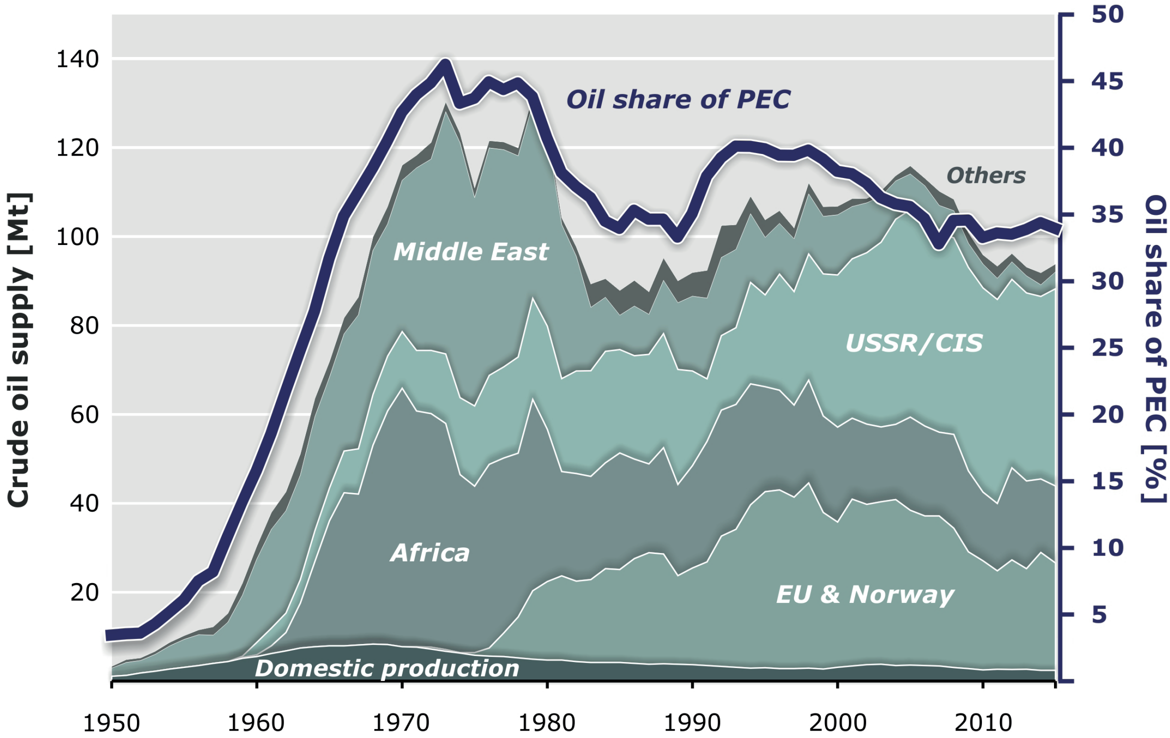

Figure 4: Germany's crude oil supplies from 1950–2015.

German companies produced almost 7 million t of crude oil outside of the country, which corresponds to a slight rise of 3.2 % compared to the previous year (6.7 million t). Bayerngas, E.ON, RWE-DEA, VNG and Wintershall were able to significantly boost their production in part. Because of the unrest in Libya, Suncor suffered a significant decline in production levels.

The most important German crude oil producing companies and their foreign production in 2015 according to consortium shares (BVeG 2016, BGR-research):

- Wintershall AG 4.5 million t
- DEA Deutsche Erdöl AG 1.4 million t
- E.ON Exploration & Production 1.6 million t
- Bayerngas Norge AS 0.7 million t
- VNG-Verbundnetz Gas AG 0.2 million t
- Suncor Energy Germany GmbH 0.1 million t

Natural gas

The total proven and probable natural gas reserves in Germany as at 31.12.2015 were 74.4 billion m³ (V_n) raw gas (minus 16 %) and 67.6 billion m³ (V_n) pure gas (minus 18.2 %). There was therefore another strong decline in reserves. In addition, a comparison of the current reserves with the production-adjusted reserves from the previous year reveals that the raw gas reserves had to be revised downwards by 4.8 billion m³ (V_n), and the pure gas reserves by 6.6 billion m³ (V_n) after a re-evaluation of the fields. Moreover, the absence of any significant new discoveries in recent years means that the produced volumes of natural gas cannot be replaced by additions to the reserves.

During the 2015 reporting year, natural gas production in Germany declined further by 0.7 and 0.6 billion m³ (V_n) to 9.3 billion m³ (V_n) raw gas and 8.5 billion m³ (V_n) pure gas, respectively. This corresponds to a decline of 7.3 % in raw gas and 6.9 % in pure gas compared to the previous year's figures. The declining production figures are primarily attributable to natural shrinkage in production associated with the increasing depletion of the fields in the two most important production areas, Weser-Ems and Elbe-Weser, in other words, in the areas with the north German Zechstein/Bunter Sandstone/Carboniferous and Rotliegend reservoirs (LBEG 2016).

Natural gas definitions in Germany

The figures for the 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 upper calorific value of H_u = 9.7692 kWh/m³ (V_n), which is also known as the "Groningen calorific value" by the gas production industry. It is a fundamental parameter in the gas industry (LBEG 2016).

The total German natural gas production of 9.3 billion m³ (V_n) only includes around 65 million m³ (V_n) of oil-associated gas which is primarily produced in Lower Saxony (59 %) and Schleswig-Holstein (28 %). During the reporting year, a total of 476 production wells were operating in 77 gas fields. Over 90 % of the fields were located in Lower Saxony.

Based on their consortium shares, five companies accounted for more than 98 % of domestic pure gas production in 2015 (WEG 2016). These are as follows:

▪ BEB Erdgas und Erdöl GmbH & co. KG	3.510 billion m³
▪ Mobil Erdgas-Erdöl GmbH	2.052 billion m³
▪ DEA Deutsche Erdoel AG	1.550 billion m³
▪ GDF Suez E&P Deutschland GmbH	0.659 billion m³
▪ Wintershall Holding AG	0.562 billion m³
Total	8.333 billion m³

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 0.63 million t 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 Lower Saxony. Natural gas production in 2003 was still at around 22 billion m³ but has continuously declined since 2004, and was well below half 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 trillion m³, and lie at a depth of 1,000 to 5,000 m (BGR 2016b). In addition, coal seams are estimated to have a potential of 0.45 trillion m³ of natural gas resources (BGR 2015).

Developing shale gas deposits and coal seam gas requires the use of hydraulic stimulation („fracking“). This technology is the subject of controversial public discussions because of worries about potential environmental consequences. 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 given 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 1.8 % compared to 2014, and totalled around 24.8 billion m³ in the reporting year. The highest levels of production by far in 2015 (accounting for around 66 %) 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 also one of the largest natural gas producers in the Netherlands. E.ON AG was the second largest German overseas natural gas producer in 2015, and was able to boost its production slightly compared to 2014. The lion‘s share of E.ON‘s production (accounting for around 5.9 billion m³) is from its participation in one of the largest natural gas fields in the world, Yushno Russkoje, in the Russian Federation. E.ON also produced 1.95 billion m³ of natural gas in the North Sea (E.ON 2016).

Natural gas consumption in Germany increased year-on-year in 2015. The growth in the use of natural gas for heating compared to 2014 was primarily attributable to the lower temperatures in 2015 during the heating period. There was a slight decline in the use of natural gas in power and heat plants operated by general utilities (AGEB 2016).

With respect to the natural gas volume, consumption rose compared to the previous year to a calculated amount of 96.4 billion m³ (Tab. 11 in the Appendix). The share of natural gas in primary energy consumption (PEC) rose year-on-year from 20.4 % to 21.1 % (Fig. 5). Natural gas is the second most important energy resource in Germany behind petroleum (AGEB 2016). 9.7 % of the volume of natural gas consumed in Germany came from domestic gas production. The calculated volume of the total amount of natural gas turned over from domestic production and imports was 124.9 billion m³. Around 31.2 billion m³ of this was re-exported, and around 2.8 billion m³ was extracted from German natural gas storages.

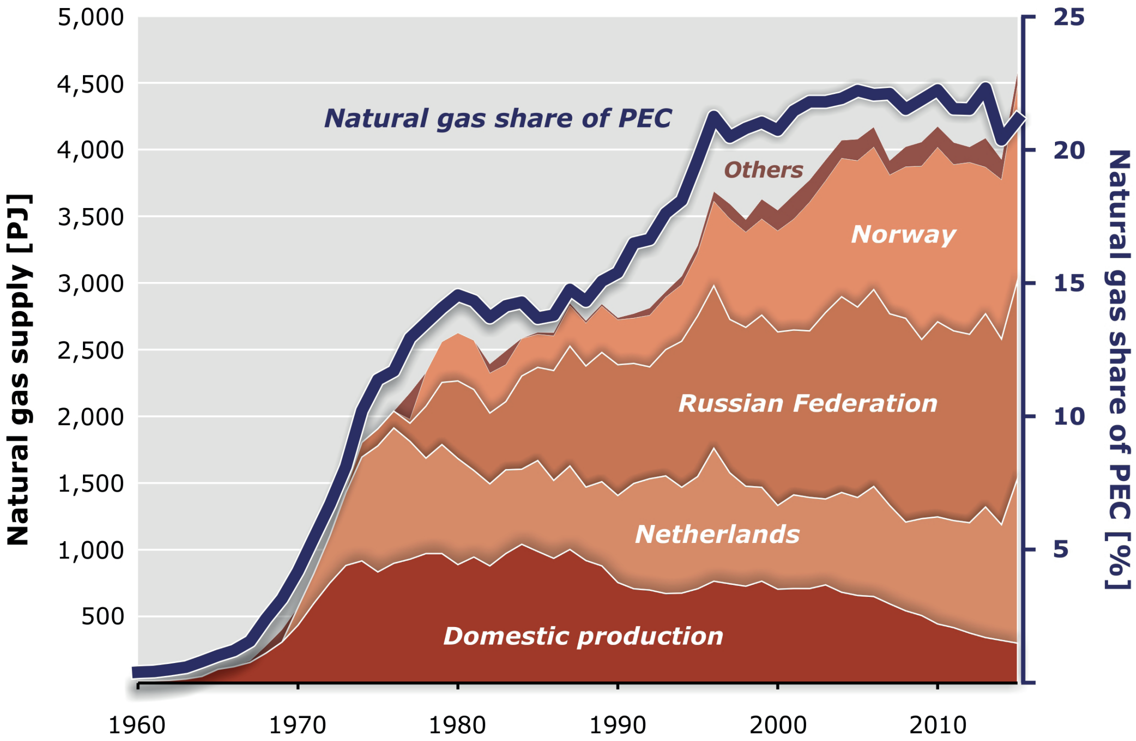

Figure 5: Natural gas supplies in Germany from 1960–2015.

Imports of natural gas in the reporting period from January to December 2015 totalled 4,284,853 TJ, and therefore 18.9 % more than the associated volume during the reference period from January to December 2014 (3,604,567 TJ). According to preliminary calculations by the Federal Office for Economic Affairs and Export Controls (BAFA), the amount of natural gas imported into Germany in December 2015 was 397,552 TJ, and therefore 6.9 % up on the corresponding volume in the same month of the previous year (371,898 TJ).

The three most important supplying countries this year were again the Russian Federation (1,484,664 TJ), Norway (1,459,548 TJ) and the Netherlands with 1,235,875 TJ (Fig. 5). With respect to the energy content, the latter exported more than 40 % more natural gas to Germany in 2015 than in the previous year (BAFA 2016b). This primarily involves high calorific natural gas previously imported into the Netherlands. Together, these three countries accounted for around 98 % of total German natural gas imports. The remainder comes from Danish and British production areas. The Russian Federation accounted for almost 35 % of natural gas imports to Germany in 2015, followed by Norway, accounting for 34 %, and the Netherlands accounting for almost 29 %. The value of the natural gas imported from Russian, Dutch, Norwegian, Danish and British production areas during the reporting period from January to December 2015 was € 24.1 billion, compared to € 23.6 billion in the same period of the previous year (BAFA 2016b).

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. 6). The figures in 2015 were 6.2 Mt saleable output (4 % compared to 1956). Domestic hard coal has been replaced in previous decades by crude oil, natural gas, uranium and in particular by imported coal (Fig. 7). Germany's total coal resources (total reserves and resources) is around 83 Gt, of which around 12 Mt are still exploitable to the end of 2018.

Two mines in the Ruhr coalfield accounted for 73.7 % (4.6 Mt saleable output) of German hard coal production in 2015. German hard coal was produced from one mine in the Ibbenbüren coalfield accounting for 26.3 % (1.6 Mt saleable output). Hard coal production in the Saar coalfield ended at the end of June 2012. The shift output across the country in 2015 declined slightly year-on-year by 3.2 % to 7,251 kg saleable output. The total sales of German hard coal declined significantly by 18.5 % in the reporting period – as a consequence of the decline in production. It dropped by 1.5 Mt to 6.6 Mt (GVST 2016, SDK 2016).

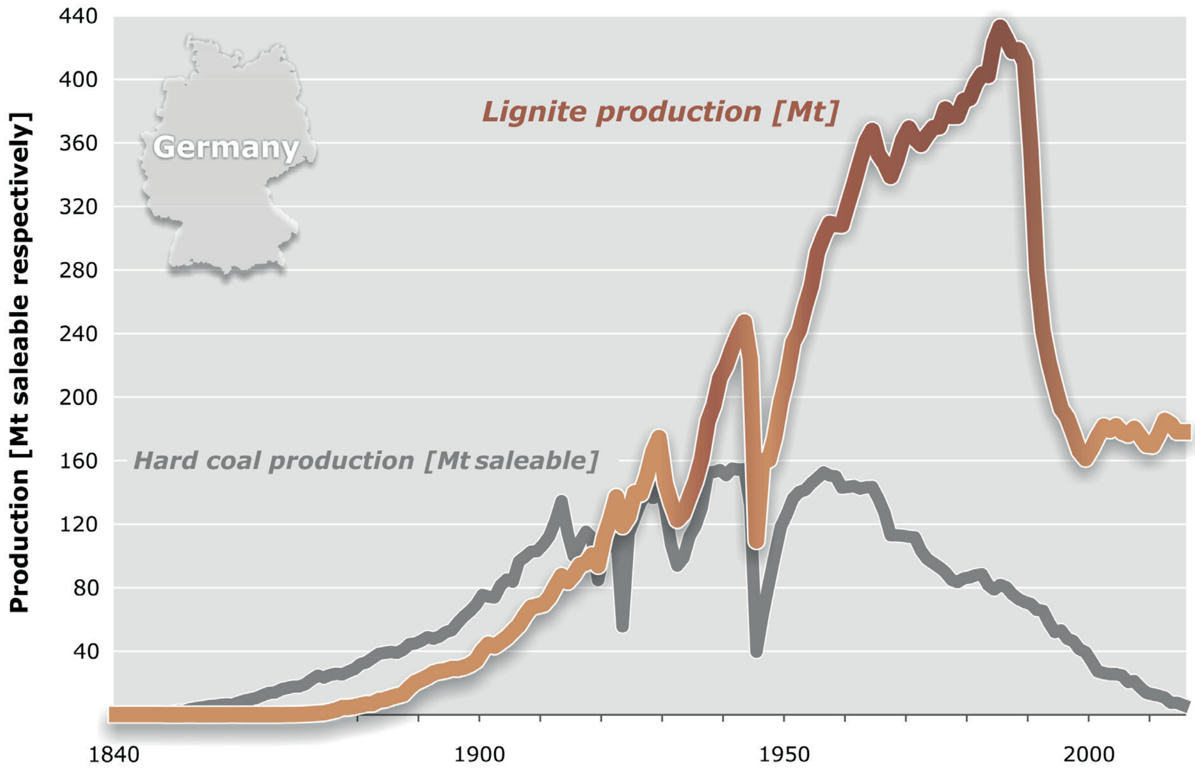

Figure 6: German coal production from 1840 to 2015 (according to SDK 2016).

Hard coal mining in Germany has not been internationally competitive for many years because of the unfavourable geological conditions in particular. It will therefore also probably not be possible to mine hard coal in Germany in future at world market prices. According to the estimates of the Association of Coal Importers (Verein der Kohlenimporteure e.V. –VDKI), average German production costs in 2015 were 180 €/tce. The annual average price for imported steam coal, however, was 67.90 €/tce (VDKI 2016a). Domestic hard coal mining is therefore 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 € 1,503.4 million in public subsidies in the 2015 reporting year (BMWi 2016a).

In February 2007, the German government, the state of North Rhine-Westphalia and the Saarland, reached an agreement to end the subsidised production of hard coal in Germany in a socially acceptable way by the end of 2018. One of the provisions of this agreement was that it should be reviewed by the German parliament in 2012. Recourse to this amendment clause was waived as a result of changes to the 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 2016a). The workforce in the German hard coalfields has declined continuously since 1958. The number of employees in 2015 decreased by a further 19.2 % compared to 2014 and now totals 9,640 (at the end of 2015; SDK 2016).

Compared to 2014, the consumption of hard coal in Germany was slightly lower during the reporting year according to preliminary estimates. It reduced by 0.7 % to around 57.7 Mtce. This reduced the proportion of hard coal in primary energy consumption from 12.9 % the previous year to 12.7 % this year. Only around 11 % of German hard coal consumption was covered by domestic production in 2015 (AGEB 2016).

Imports of hard coal and hard coal products rose by 2.3 % compared to 2014 to a level of 57.5 Mt. Most of this hard coal came from the Russian Federation, the USA, Colombia, Australia, Poland and South Africa. With around 16.7 Mt (29.1 %), the Russian Federation was again the biggest supplier in 2015, followed by the USA (19 %) and Colombia (17.3 %). Imports from Poland – the last major coal exporting country in the European Union (EU-28) – declined slightly to around 4.1 Mt. Of this, around 1 Mt was accounted for by coke (VDKI 2016b). The share of imports in total hard coal turnover in Germany rose compared to the previous year to around 89 %. Import dependency on hard coal will increase further with the planned German mine closures in the next few years. After the closure of the Auguste Victoria mine at the end of 2015, the closure is also planned of the Ibbenbüren mine and the Prosper-Haniel mine at the end of 2018 (RAG Stiftung 2015, van de Loo & Sitte 2016).

The prices (here: cross-border prices) for imported steam coal dropped from around 72 €/tce at the beginning of 2015 to around 60 €/tce at the end of the year. The annual average price was 67.90 €/tce (minus 7 % compared to 2014). The same also applied to coking coal and coke. The annual average price for coking coal declined by around 4 % from the previous year‘s level of 104.67 €/t to around 100.52 €/t. The price of coke declined by around 3 % compared to the previous year, and the annual average price was 187.04 €/t (BAFA 2016c, VDKI 2016a, b).

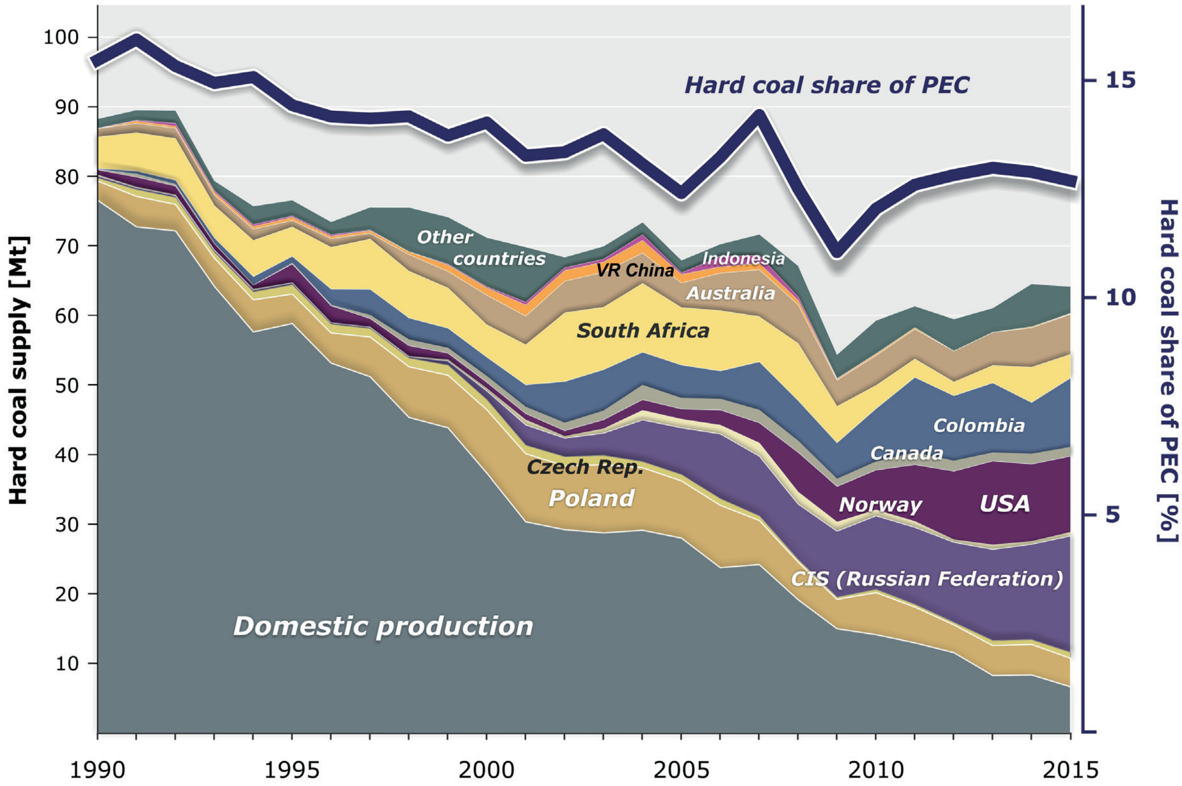

Figure 7: Germany's coal supplies from 1990 to 2015 (AGEB 2016, IEA 2016a, SDK 2016, VDKI 2016a).

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 power 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 5 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.

Lignite is mined in Germany in four fields. The German total in 2015 was 178.1 Mt which was around 0.1 % down compared to the previous year (Fig. 6). In the Rhenish lignite field, RWE Power AG operates three opencast mines at Garzweiler, Hambach and Inden, which had a total production in 2015 of 95.2 Mt. The Garzweiler and Hambach opencast mines supply lignite by rail to the Frimmersdorf, Goldenberg, Neurath and Niederaußen power plants. The Weisweiler power plant is supplied by the Inden opencast mine. Production in the Lausitz lignite field, totalling 62.5 Mt during the reporting year, came from the five opencast mines in Jänschwalde, Cottbus-Nord (production shut down on 23.12.2015), Welzow-Süd, Nochten and Reichwalde. The mines are operated by

Vattenfall Europe Mining AG. Lignite is almost completely sold to the modernised and/or new power plants operated by Vattenfall Europe Generation AG & Co. KG (formerly Vereinigte Energiewerke – VEAG). The main power plants supplied here are Jänschwalde, Boxberg and Schwarze Pumpe. In early 2016, Vattenfall announced the sale of its opencast mines and power plants to the Czech energy company Energetický a Průmyslový Holding (EPH), and its finance partner PPF Investments. The change in ownership structure took place on 30 September following consent from the EU competition authorities. An announcement was made at the beginning of October 2016 that the opencast mines and the lignite power plants will be operated in future under new names: Lausitz Energie Bergbau AG and Lausitz Energie Kraftwerke AG respectively. Both companies share the same brand name LEAG (2016). The production of 18.9 Mt from the central German lignite field in 2015 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. After a landslip led to the temporary closure of the Amsdorf opencast mine on 6 January 2014, lignite production did not begin again until 1 April 2015. In the Helmstedt lignite field, the Schöningen opencast mine supplied around 1.5 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 2013 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 and 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. Stand-by operations mean that the power plant is no longer used in the market but that start-up is only permitted on the request of the transmission grid operator responsible for maintaining the system stability of the transmission/power grids (HSR 2016b).

Lignite sales during the reporting year matched the previous year‘s level of 167.6 Mt. Its share of primary energy consumption declined slightly compared to the previous year to 11.8 % (53.5 Mtce).

Whilst the sale of lignite briquettes declined year-on-year by 2.4 % to 1.6 Mt, the sale of lignite dust, a processing product, rose slightly by 0.4 % to 4.8 Mt.

A workforce of 15,428 (minus 3.2 % compared to the previous year) was active country-wide in lignite mining (AGEB 2016, SDK 2016).

The external trade balance with lignite and lignite products was positive in 2015, albeit at a relatively low level. Total imports declined to 61,000 t. There was also a decline in exports (briquettes, coke, dust and lignite) of around 12.3 % to 2.36 Mt. The main customers are countries in the EU-28 (SDK 2016).

Nuclear power

The key factor in the energy transition is the withdrawal from nuclear power production. With the 13th amendment to the Atomic Energy Act adopted on 6 August 2011, the German government sealed the end of the use of nuclear power for commercial power generation. The act stipulates that the last nuclear power plant in Germany will be switched off in 2022 at the latest. The withdrawal takes place in phases with specific shut-down dates. The shut-down on 27 June 2015 of the Grafenrheinfeld nuclear power plant (gross capacity 1,345 MW_e) marked the next step in the withdrawal from nuclear power. The eight nuclear power plant still active are to be switched off at the end of a specific year (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 slightly to 1,001 PJ (2014: 1,060 PJ), corresponding to 34.2 Mtce. This share of primary energy consumption was therefore 7.5 % (2014: 8.1 %). As in the previous year, with its share of 14.1 % of public power supplies, nuclear power was only in position four behind renewable energy (30.1 %), lignite (23.8 %), and coal (18.1 %).

All the nuclear power plants in Germany generated 651.8 TWh, and therefore around 3.8 % more power than in the previous year (2014: 627.8 TWh). The share of nuclear power in gross power generation decreased again by around 5.5 % to 91.8 TWh, compared to 97.1 TWh in 2014. The net power generation was 86.8 TWh (2014: 91.8 TWh). Before the decommissioning of eight nuclear power plants in 2011, there were 17 nuclear power plants installed in Germany with a gross capacity of 21,517 MW_e. Only eight nuclear power plants were still connected to the grid from the middle of 2015 to the end of the year, and with a capacity of 11,357 MW_e (gross). The temporal load availabilities and the generating load availabilities were 91.76 % (2014: 90.56 %), and 91.17 % (2014: 89.11 %) respectively.

The demand for natural uranium in nuclear fuel was 2,000 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, 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 (2014: 33 t; 2015: < 0.05 t).

The decommissioning and remediation of former production sites and facilities operated by SDAG WISMUT entered the 25th year of clean-up operations in 2015.

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 85 % (€ 6 billion) had already been spent by the end of 2015. 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 million m^3 of contaminated water was treated in 2015, and discharged into the nearest river.

The approval procedures for the conversion work required to adapt the current water treatment facilities to the future conditions will be carried out in 2016. A new water treatment works is currently being planned for Wismut GmbH's Crossen site. This step is necessary to satisfy the changes in quality specifications regarding the water treatment, as well as the forecast reduction in water volumes. The new plant will be designed to operate as automatically as possible. The main focus of the work at the Ronneburg site is the modernisation and expansion of the system for containing the increasing volumes of flooding water in Gessental, with the aim of avoiding any uncontrolled leakage at the surface. Also at the Ronneburg site, work on the intermediate and final sealing and covering of the former industrial settling tank facility in Culmitzsch was continued, as well as establishing the connection to the nearest discharge point into the river system.

Deep geothermal energy

The six geothermal electric power plants connected to the grid in Germany generated a total of around 150 GWh/a power in 2015 (GEOTIS 2016, Agemar et al. 2014). As of yet, no new geothermal plant was added. The doubling of electricity production compared to the previous year (80 GWh/a) is primarily attributed to a strong increase in production in four of the five electric power plants built between 2012 and 2014. Taking a period of ten years into account, i.e. from 2005 to the end of 2015, a significant increase in the amount of geothermally generated electricity occurs since 2012 (Fig. 8). The installed capacity substantially stepped up in the past ten years from 0.2 MW_e to 32 MW_e. During the same period, the heat generation changed from 100 MW_{th} (2005) to around 340 MW_{th} (2015), an increase almost by a factor of four. Heat use doubled from around 520 GWh/a to approximately 1,100 GWh/a (GeotIS 2016), see Fig. 8. The generated heat was used at almost 200 locations spread over Germany. However, direct geothermal energy primarily used in the southern half of Germany, in areas, where also the electric power generating geothermal plants are located (Fig. 9).

Geothermal electric power production in Germany is largely restricted to the Upper Rhine Graben and the South German Molasse Basin, as well as the North German Basin (Fig. 9).

Deep geothermal energy uses earth's geothermal heat in depths below 400 metres. In addition to using this energy directly as heat, electrical power can be generated where a high temperature in the subsurface is available. One distinguishes between two different geological reservoir types: rock layers with high permeability and porosity, where the generated energy originates from the formation fluid and tight rock, where the thermal energy stored in the rock itself is used. The first case is classified as hydrothermal energy. In the second reservoir type, which is defined as petrothermal energy, be water has to be injected as a medium for heat transport. Thermal energy is ubiquitous in the subsurface: The theoretical hydrothermal potential is estimated at 1,574 EJ (BMU 2007). Compare this with the primary energy consumption in Germany of 13.2 EJ in 2015 (BMWi 2016b).

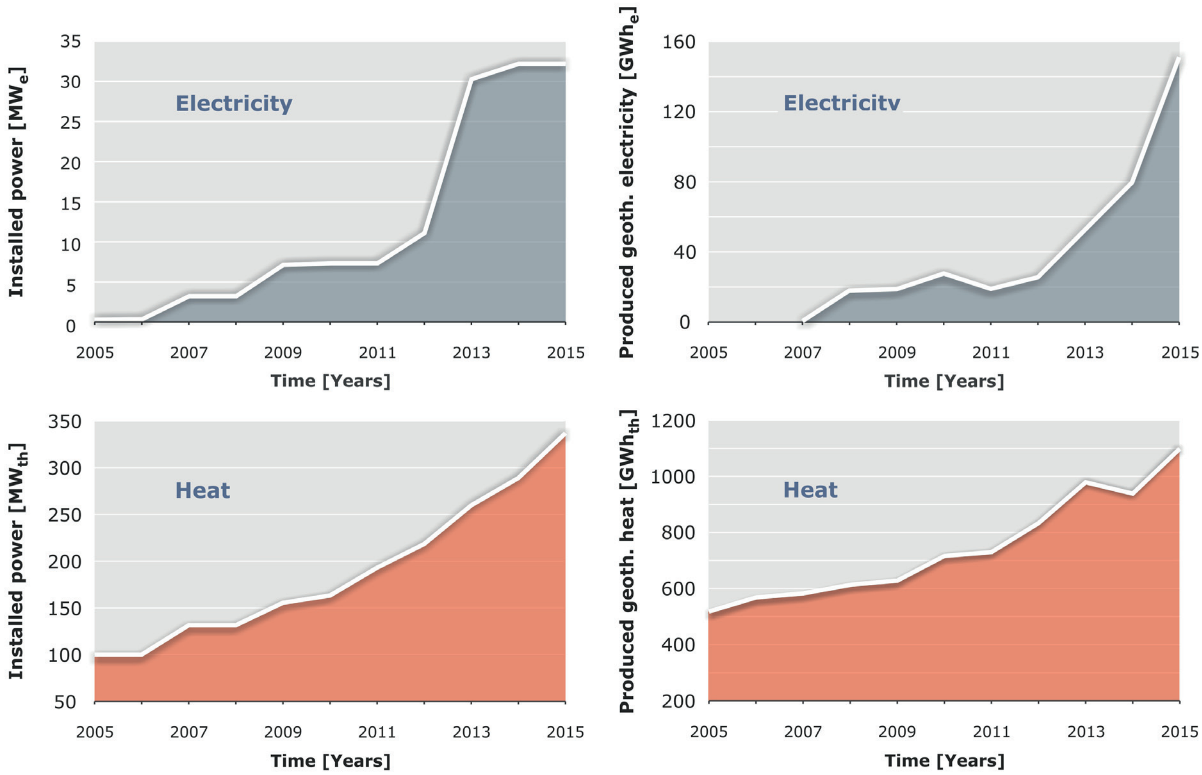

Figure 8: Development in the installed capacity for electrical power and direct use, as well as the amount of energy generated by deep geothermal energy in Germany from 2005 to 2015. (Data source: GeotIS 2016, Agemar et al. 2014).

Geothermal electric power production in Germany is largely restricted to the Upper Rhine Graben and the South German Molasse Basin, as well as the North German Basin (Fig. 9). In the latter, production is almost exclusively concentrated on geothermal heat despite having the largest theoretical potential in comparison with the two other basins. Heat generation in 2015 was close to 1,020 EJ (BMU 2007). The inhomogeneous use in Germany is also due to the given temperature distribution in the subsurface. There are regions with above average temperature gradients in parts of the Upper Rhine Graben and the Molasse Basin, as well as in some areas within the North German Basin (orange to dark red colours in Figure 9).

Geothermal utilisation depends on other parameters besides the temperature distribution: these include in particular the mineralisation of hot water, the permeability of rocks, as well as thermal water flow rates. The yield of an aquifer mainly depends on the presence of open fractures, an example being the Upper Rhine Graben, which is a geotectonic graben system with large-scale faulting and associated favourable porosity with effective permeability (PK Tiefe Geothermie 2007, GRS 2014). Here, geothermal electric power as well as heat is generated. The southernmost of the three main geothermally exploited regions in Germany, has the lowest theoretical potential when compared to the other two sedimentary basins (Fig. 9). However, the South German Molasse Basin scores due to its higher flow rates of the highly permeable Malm carbonate (Upper Jurassic). These carbonates therefore form the most important geothermal exploitation formation in Germany. Another notable feature is that, unlike the other regions, this area still contains fresh water even at great depths (deeper than 1,000 m) (GRS 2014), see Tab. 1. These low mineralised waters are less problematic with respect to precipitation and corrosion, and therefore are more beneficial for commercial operations (Seibt & Thorwart 2011).

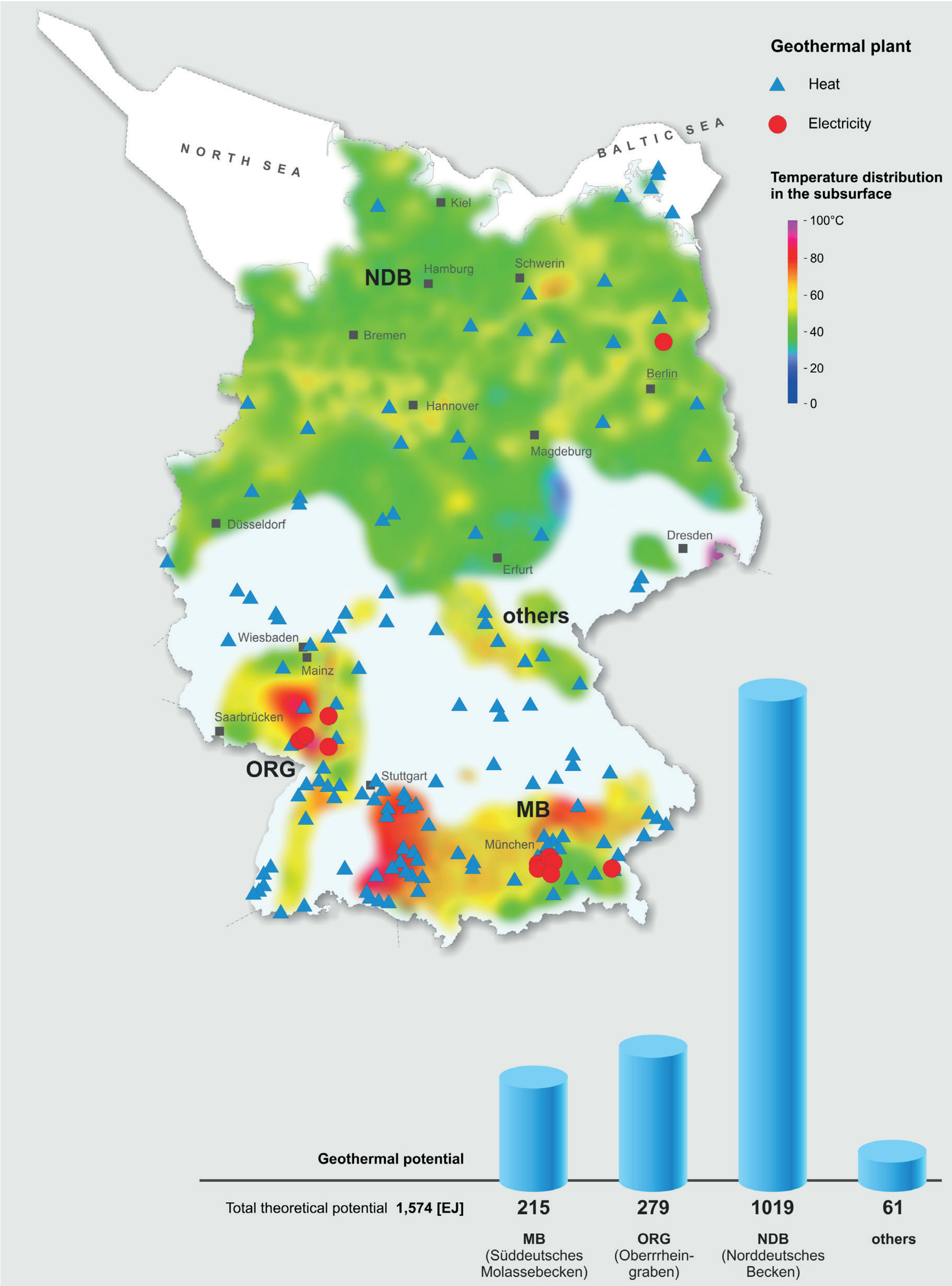

Figure 9: Temperature distribution at 1,000 m depth in the large onshore sedimentary basins in Germany, i.e. North German Basin (NGB), Upper Rhine Graben (URG), and South German Molasse Bain (MB). This figure also shows the electric power producting sites (12 locations with a total of 32 MW_e, 150 GWh/a) and the locations, where heat is exploited (196 locations with a total of 330 MW_{th}, 1,100 GWh/a). The total theoretical potential amounts to 1,574 EJ, see blue columns (rounded production data (GeotIS 2016), potential data (BMU 2007)).

The Alpine Foothills is currently Germany‘s most important region for geothermal energy. Almost two thirds of all of the deep geothermal energy plants operated in the country are located in the South German Molasse Basin. The installed capacity here totals to approximately 260 MW_{th} and almost 27 MW_e (GeotIS 2016). Half of the planned 30 geothermal projects for the generation of electricity in Germany are also located in Bavaria (GTV 2016). Moreover, the city of Munich set itself the ambitious target of being the first major German city to produce all of its district heating from renewable energy by 2040. This is primarily to be achieved by expanding the deep geothermal energy output (SWM 2016). Hot water reserves with temperatures of 125 °C and high flow rates of 140 l/s are located deep beneath Munich at a depth of 3,350 m (Tab. 1, Unterhaching).

Table 1: Typical examples of geothermal plants in the three sedimentary basins: North German Basin (NGB), Upper Rhine Graben (URG), and South German Molasse Basin (MB), as well as their characteristic features. The temperature in the productive horizon is rounded to 5 °C (unless otherwise stated, data from GeotIS 2016)

Type locality	Basin	Installed capacity	Temperature at production depth	Production	Minerali-sation	Data Mineralisation of thermal water
Neustadt-Glewe	NGB	4.0 MW_{th}	100 °C at 2,450 m	35 l/s	approx. 220 g/l	Schröder & Hesshaus 2009
Insheim	URG	4.3 MW_e	165 °C at 3,600 m	80 l/s	approx. 107 g/l	unec 2016
Unterhaching	MB	3.4 MW_e 38 MW_{th}	125 °C at 3,350 m	140 l/s	0,9 g/l	Birner 2013

Although the production of deep geothermal energy in Germany increased the overall significance still remains small. In 2015, its share of electric power generation totalled 0.03 %, whilst its share of heat generation reached only 0.09 % (BMWi 2016b). This low proportion is mainly due to economic reasons. Besides others, Janczik & Kaltschmitt (2016) list as the main reasons long project planning periods and high exploration risks. Adequate values for production rates and temperatures at the productive depth are the dominate capacity and economic efficiency of a geothermal power plant are. With respect to the utilisation of heat, further expansion is often hindered by a lack of consumers (primarily during summer months) and the absence of district heating. Bavaria has therefore established a funding programme to intensify the expansion of thermal networks for deep geothermal energy applications. The Kreditanstalt für Wiederaufbau (KfW) provides subsidy programmes throughout Germany for measures exploiting geothermal energy for the generation of heat (KfW 2016). Without any significant expansion, geothermal energy will continue to play only a minor role in the future for German energy supplies.

Geothermal potentials are quantified according to various definitions. Common categories are theoretical, technical, economically sustainable, and economically developable potentials (e.g. Rybach 2015). At the 25th meeting of the UNECE Committee on Sustainable Energy on 30 September 2016, the the specifications and applications of the definitions for the reserves and resources of fossil energy resources and mineral resources (UN 2010) were extended to include geothermal resources (UNECE 2016). In this study, the category „theoretical potential“ corresponds to the definition by BMU (2007), comparable to that of Falcone et al. (2013). No use is made of „technical potential“ (roughly equivalent to the term „reserves“, see comment below):

*„The **theoretical potential** describes the total existing geothermal heat resources that could theoretically be used within a region.“*

*„The t**echnical potential**“ describes the share of the theoretical potential, which could be exploited by using today‘s standard engineering practises. This takes into consideration infrastructural and environmental restrictions, as well as statutory provisions.“*

***Comment:** At the present time, BGR does not consider it prudent to use the term „technical potential“ in accordance with the aforementioned definition, asthe technology for the exploitation of deep geothermal energy, and petrothermal energy in particular, has not yet been adequately developed.*

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. The German government has the aim of generating 40 to 45 % of the electricity used in Germany from renewable energy by 2025. The target for 2035 is 55 to 60 %, and rises further to 80 % by 2050 (Fig. 10).

The installation of renewable energy is primarily focused on the power sector to date. Solar and wind power are the most important renewables in Germany for power generation. Biomass, hydroelectric power and geothermal energy also make a contribution to covering energy consumption. The proportion of renewable energy in gross power consumption rose from 6 % in 2000 to 30.1 % in 2015.

In 2015, the proportion of renewable energy in German gross power consumption increased primarily because of the continued strong expansion of wind power (addition of 6 GW in 2015), as well as favourable wind conditions (strong wind year). During the three winter months of January, November and December, 10 billion kWh was generated by wind power alone (AGEB 2016). The total power generation from wind power was 88 billion kWh. 79.3 billion kWh of this was generated by onshore wind power plants representing an increase of 23.4 billion kWh compared to the previous year. This is an increase of almost 42 %. The offshore plants generated 8.7 billion kWh which is 7.3 billion kWh more than in 2014 (AGEB 2016). Germany has a total installed wind power capacity of 45,000 MW (onshore and offshore).

Solar energy (photovoltaics) is the second most important renewable energy resource for power generation in Germany. Its contribution to the German power mix was 38.4 billion kWh, corresponding to around 5.9 %. This is an increase of 2.4 billion kWh compared to the previous year.

Around 1.4 GW new installed photovoltaic capacity was added in 2015, although this represents another slight decline in the rate of growth: 3.3 GW were added in 2012, but only 1.9 GW last year. One of the reasons for this is probably the decrease in the reimbursement rates for solar power in accordance with the EEG. Investment in photovoltaic plants in 2015 declined by around 36 % year-on-year (BMWi 2016b). The total installed photovoltaic capacity in Germany is currently around 40,000 MW.

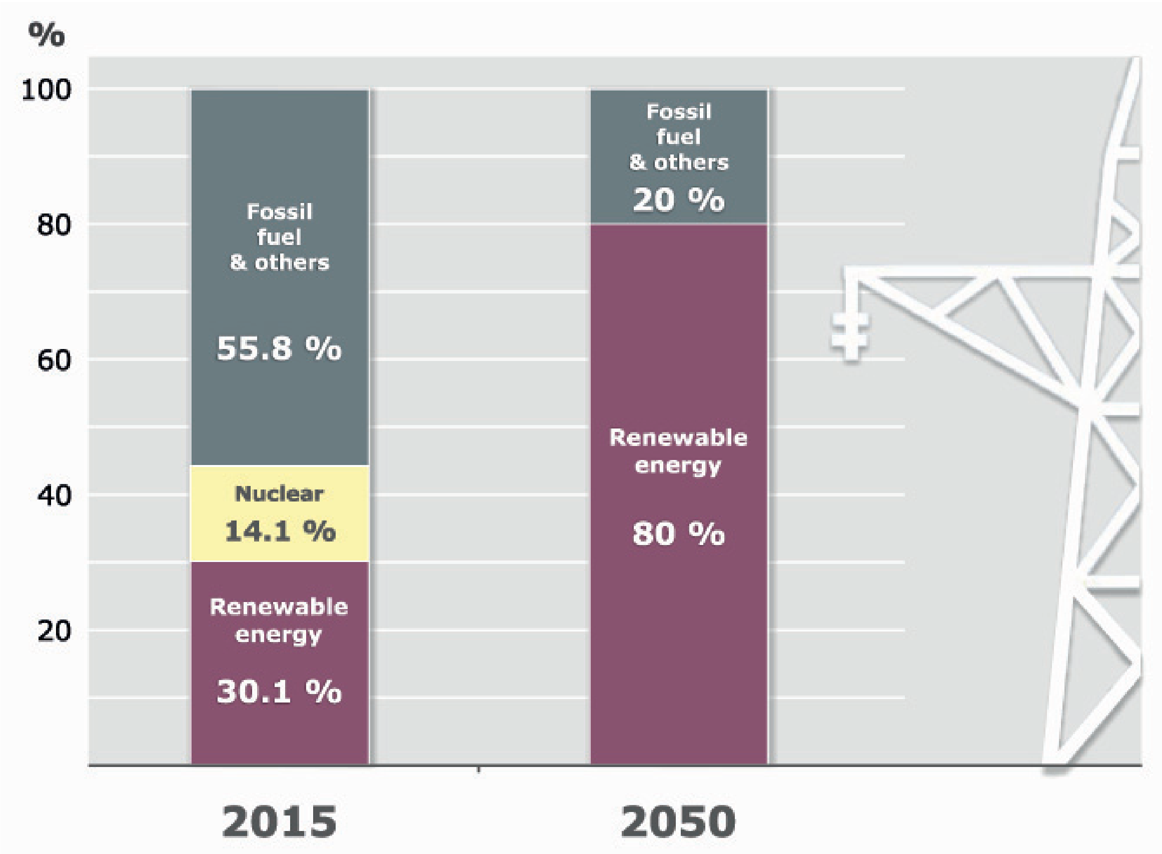

Figure 10: Share of gross power generation of specific energy resources (modified after BMWi).

Renewable energy can be used in very diverse ways, ranging from power generation, to heat and cold utilisation, as well as fuels for the mobility and freight sectors. The proportion of renewable energy in overall heat consumption in 2015 grew to 13.2 %. This is attributable in 2015 in particular to the rise in wood consumption in private households as a response to the weather conditions, and the increasing expansion of solar thermal energy, heat pumps and wood pellet heating systems (BMWi 2016b). In the transport sector, biofuels, such as bioethanol, biodiesel and biogas, accounted for around 5.3 % of total fuel consumption in Germany (BMWi 2016b).

With respect to the proportion of renewable energy in primary energy consumption (PEC), and according to application sectors, power generation was dominant with a share of 56 %, followed by heat 36 %, and the transport sector with around 8 % (AGEB 2016). The dominant energy form amongst the renewables with a share of almost 57 % is biomass, followed by wind power (19 %), solar power (10 %), waste (8 %), hydroelectric power (4 %), and geothermal energy (3 %).

3 ENERGY RESOURCES WORLD-WIDE

The reliable and uninterrupted provision of energy is an essential prerequisite for the proper functioning of modern societies today. Global demand for energy has therefore also been rising with hardly any break for decades (Fig. 11). And a growing global population combined with rising general living standards can also lead to a long-term rise in energy demand. Despite continuing shifts in the global energy mix, energy supplies today are still maintained by just a limited number of energy resources. Renewable energy has enjoyed high growth rates world-wide in its share of primary energy generation. Nevertheless, at a scale of decades, the global rise in energy demand will most likely continue to be primarily provided by non-renewable energy resources.

Following the global review of the reserves situation, a more detailed look is undertaken at individual fossil fuels and energies in terms of resources and potential, production, consumption and important developments. Deep geothermal energy is the only energy resource in the geological sphere, which is termed a renewable energy. This is due to the fact that changes in the geothermal energy available in the interior of of the earth during exploitation is negligible on human timescales. Therefore, geothermal energy will be covered in chapter of its own.

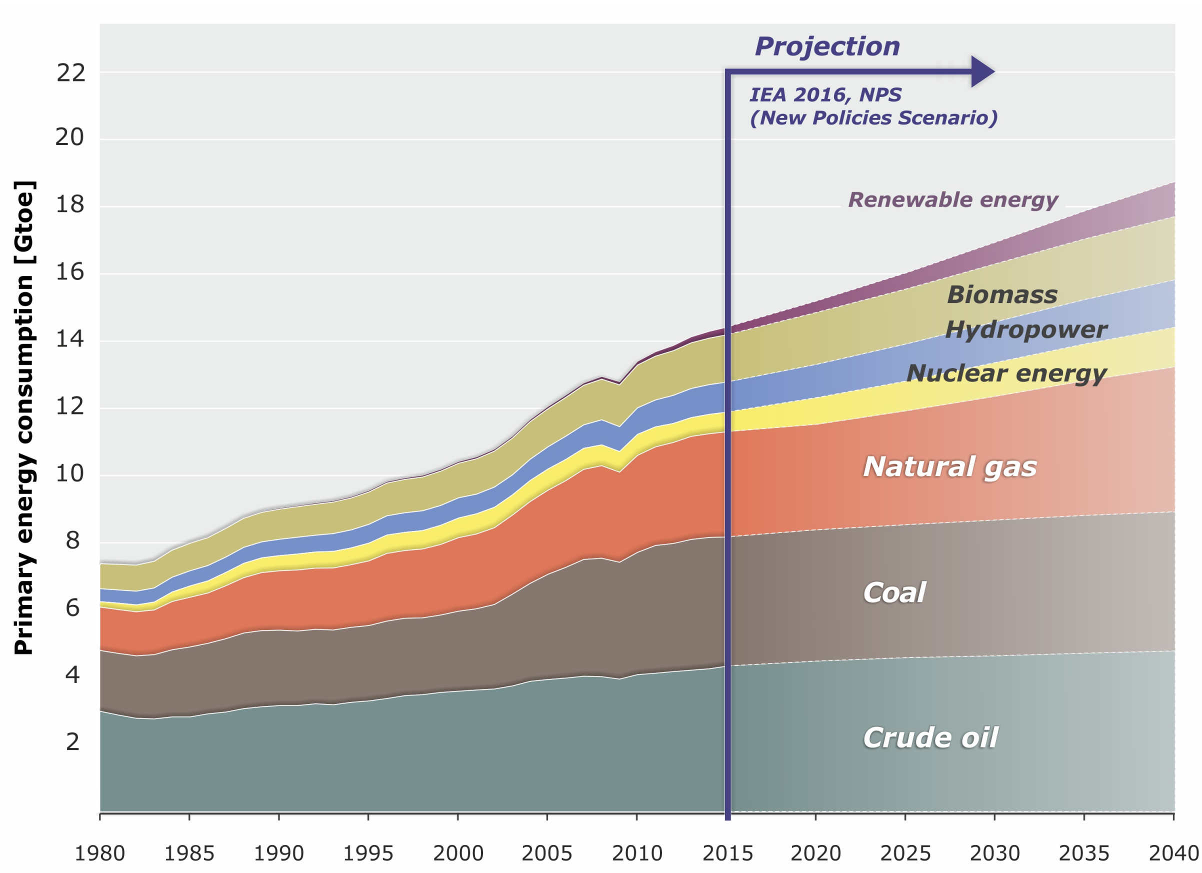

Figure 11: Development in global primary energy consumption per energy resource and a possible scenario for future developments (New Policies Scenario, IEA 2016b).

3.1 Global reserves situation

Table 2 shows all known global potential for fossil energy resources including nuclear fuels. Values are derived from the total of the country data as listed individually in Tables 13 to 49 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 gaps in the data, non-conventional potential is presented as far as possible. These include the resources and reserves of ultra-heavy oil, crude oil from tight rocks (tight oil) and bitumen (oil sand) 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 552,523 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, the resources only rose minimally by 0.1 % compared to the previous year (BGR 2015). There were slight increases in many resources of conventional crude oil (plus 2.6 %) (cf. Chap. 4.1 – The crude oil and natural gas potential of countries around the Horn of Africa), as well as non-conventional crude oil (oil sand plus 6.6 %, and shale oil plus 4.9 %), in the light of re-evaluations. When compared to all energy resources, coal continues to dominate (hard coal and lignite) with a share of 89 % (Fig. 12). Trailing well behind in second place are natural gas resources accounting for 5.9 %, which are dominated by the proportion of non-conventional deposits. The other energy resources, including crude oil (3.5 %), only play a subordinate role with respect to the energy content of their resources. Only very minor changes have taken place compared to the previous year.

The energy content of the reserves in 2015 totalled 38,443 EJ, and was therefore slightly up on the previous year‘s value (plus 1.3 %). The largest absolute changes occurred as a result of re-evaluations of Australian lignite reserves (plus 290 EJ or 8.9 %), as well as the Canadian oil sands (minus 161 EJ or 14.6 %). Other significant changes concerned coal bed methane reserves (plus 27.9 %), in the light of higher valuations in China and Australia, as well as shale gas reserves (plus 23.2 %) derived from updated data from the USA (now as at 2014). Higher uranium reserves (plus 9.2 %) are primarily attributable to successful exploration and the use of modern production technologies. Despite relatively low prices for energy resources in 2015, this had hardly any impact on reserves, in fact, they actually rose slightly in total.

In terms of energy content, coal with a share of reserves of 55.4 % continued to be the dominant energy resource. Crude oil (conventional and non-conventional) accounts for 23.5 % of total reserves, natural gas 19.4 %, and uranium 1.7 %. This means that the relative shares of all energy resources have only changed to a minor extent compared to the previous year. The volume of crude oil produced was completely compensated for by the transfer of resources to reserves. The relatively high proportion of crude oil in the reserves figure is an expression of the intense exploration and production activities for this energy resource invested over many decades.

In 2015, non-renewable energy resources were produced with an energy content of around 521 EJ. This is almost the same as last year‘s figure (2014: 522 EJ). In the production mix based on energy content, the shares of crude oil, natural gas and nuclear fuels rose as a result of larger production volumes, but also because of the decline in production of lignite and hard coal in particular (Fig. 12). Crude oil (34.9 %) continues to be the most important energy resource, ahead of hard coal (31.4 %), followed by natural gas (26.1 %), uranium (5.8 %) and lignite (1.9 %).

Table 2: Reserves and resources of non-renewable energy resources

Fuel	Unit	Reserves (cf. left column)	EJ	Resources (cf. left column)	EJ
Conventional crude oil	Gt	172	7,171	167	6,993
Conventional natural gas	Tcm	188	7,148	323	12,293
Conventional hydrocarbons [total]	Gtoe	342	14,319	461	19,285
Oil sand	Gt	23	944	67	2,785
Extra heavy oil	Gt	21	886	61	2,539
Shale oil	Gt	< 0.5	14	60	2,494
Oil shale	Gt	k. A.	k. A.	102	4,248
Non–conventional oil [total]	Gtoe	44	1,844	289	12,066
Shale gas	Tcm	6.2 [1]	234 [1]	215	8,162
Tight gas	Tcm	– [2]	– [2]	63	2,385
Coal-bed methane	Tcm	2.3	87	51	1,950
Aquifer gas	Tcm	–	–	24	912
Gas hydrates	Tcm	–	–	184	6,992
Non–conventional gas [total]	Tcm	8.4	321	537	20,402
Non–conventional hydrocarbons [total]	Gtoe	52	2,165	776	32,468
Hydrocarbons [total]	Gtoe	394	16,484	1,237	51,753
Hard coal	Gtce	605	17,737	14,969	438,705
Lignite	Gtce	121	3,560	1,775	52,019
Coal [total]	Gtce	727	21,297	16,744	490,723
Fossil fuels [total]	–	–	37,781	–	542,477
Uranium [3]	Mt	1.3 [5]	663 [5]	14 [6]	6,869 [6]
Thorium [4]	Mt	–	–	6.4	3,178
Nuclear fuels [total]	–	–	663	–	10,047
Non-renewable fuels [total]	–	–	38,443	–	552,523

— no reserves or resources

[1] partly status 2014

[2] included in conventional natural gas reserves

[3] 1 t U = 14,000 to 23,000 tce, lower value used or 1 t U = 0.5 x 10^{15} J

[4] 1 t Th assumed to have the same tce-value as for 1 t U

[5] RAR recoverable up to 80 USD / kg U

[6] Total from RAR exploitable from 80 to 260 USD / kg U and IR and undiscovered < 260 USD / kg U

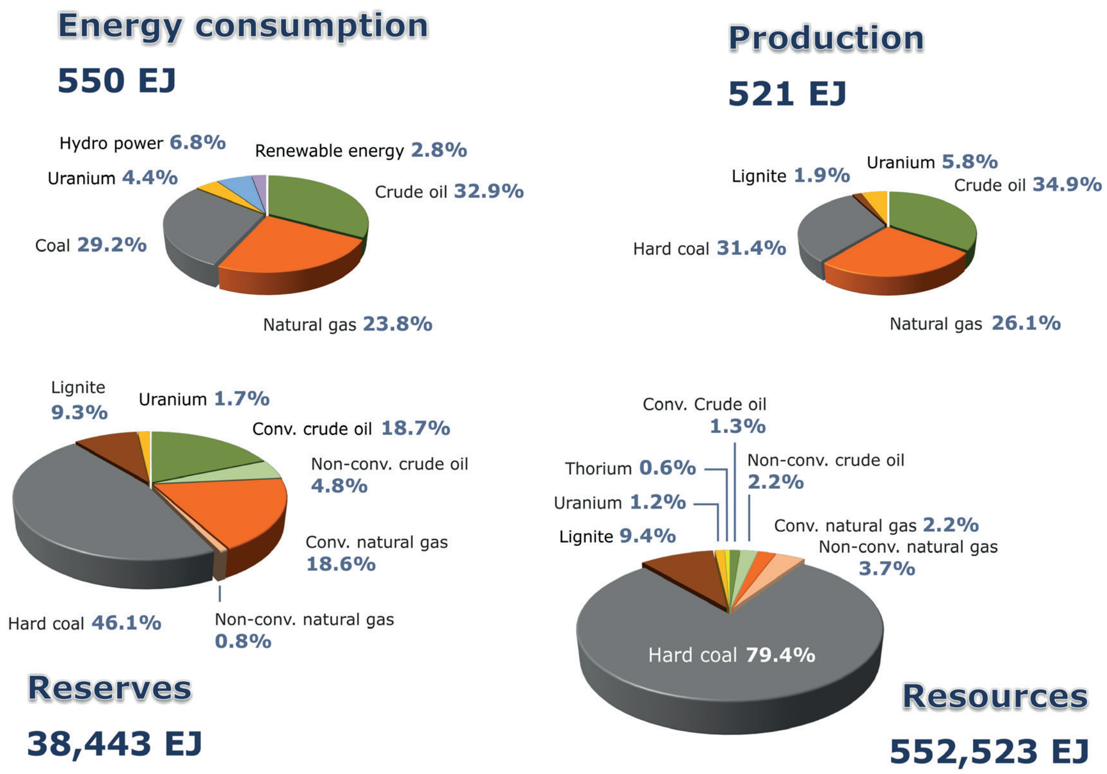

Figure 12: Global consumption shares of all energy resources (BP 2016), as well as the production, reserves and resources of non-renewable energy resources only, at the end of 2015.

Consumption during the reporting period rose by 10 EJ to 550 EJ (plus 1.9 %). The fossil fuels still dominate the composition of the global energy mix to a considerable extent, i.e. the amount of energy actually consumed. Renewable energy enjoyed high growth rates (excluding hydroelectric power), and increased its share of primary energy provision by 2.1 EJ to 15.3 EJ (plus 16 %). It now accounts for a share of 2.8 % of global energy production (BP 2016). Although unchanged in the previous year, hydroelectric power still has a significant share of around 6.8 %. Coal was the only energy resource whose consumption declined slightly (BP 2016).

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. The further growth in global energy demand will have to be covered by the rising production of fossil energy resources in the foreseeable future, in addition to the expansion of renewable energy. 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 rose to 35 %. Global production rose significantly by 2.5 % compared to the previous year, and totalled 4,346 million t (2014: 4,240 million t). This means that around 183 billion t crude oil have been produced since the beginning of industrial production, and that therefore more crude oil has been consumed than exists today in known conventional crude oil reserves. 71 % of the crude oil produced world-wide in the reporting year came from onshore fields (EIA 2016a).

Major changes occurred in terms of crude oil resources (conventional and non-conventional). The total crude oil resources increased by 3.2 % to 354.3 billion t. Thanks to an improvement in the database, the oil sand resources in China, the USA and the Russian Federation have risen. New resource estimates for conventional crude oil also became available for Ethiopia, Eritrea, Kenya and Somalia (Chap. 4.1).

The global crude oil reserves (conventional and non-conventional) declined by 1.5 % (minus 3.2 billion t) in 2015 to 215.7 billion t. Whilst conventional reserves rose slightly by 0.4 % to 171.5 billion t, non-conventional crude oil reserves dropped slightly because of a re-evaluation of the Canadian oil sand reserves, which therefore lowered the overall figure to 44.1 billion t. The largest share of total reserves is in the Middle East with around 110 billion t (51 %), followed by North America with 31.4 billion t (14.6 %), and Latin America with 30.7 billion t (14.2 %) (Fig.13). Europe‘s share of almost 2 billion t (1 %) of total reserves, is very small. Saudi Arabia, Canada, Iran and Iraq alone had over 60 % of total reserves, whilst the leading 20 countries account for over 95 %.

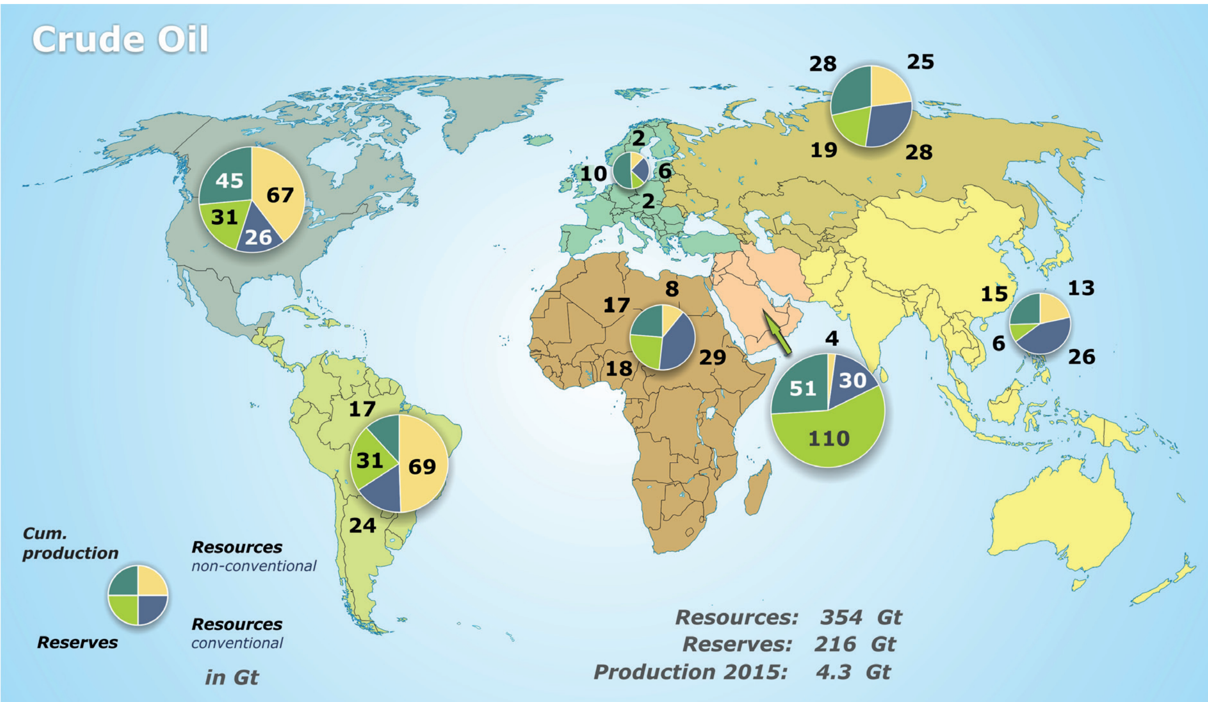

Figure 13: Total crude oil potential 2015 (excluding oil shale): regional distribution.

The three countries with the highest production were the USA, Saudi Arabia and the Russian Federation, all of which were able to boost their production further. The USA boosted its crude oil production again by a considerable amount (plus 9 %). This makes the USA the largest crude oil producer in the world – a position it last held in 1976. The rise in crude oil production is primarily attributable to a further rise in shale oil production (crude oil from tight rocks), which with annual growth rates in double figures since 2008, is basically responsible for the whole increase in US-American production. During the reporting year, the USA even broke its historic production record previously achieved in 1970. However, a significant decline in US-American crude oil production is expected in 2016 as already indicated at the end of 2015. Amongst the OPEC countries, Saudi Arabia (plus 7 %), Iraq (plus 23 %), Iran (plus 8 %), and Angola (plus 7 %), were among the countries to significantly boost their production. OPEC countries overall increased their production by 2.6 %. Thanks to the reduction in sanctions against Iran, the country again has stronger access to the international crude oil and financial markets since the beginning of 2016. Iran is currently involved in a huge effort to modernise its production facilities and refineries by importing technology and investing. Despite delays in the development of its deep water oil project, Brazil increased its oil production by 6 %. The United Kingdom was able to boost its oil production for the first time in 15 years (plus 15 %). This is attributable to a large amount of investment in the production technology of producing fields in the British North Sea in recent years. In Libya, a traditionally important source of oil supplies for Germany, in which German companies such as Wintershall own production permits, suffered another decline in production of 20 % to 20 million t, because of the civil war. This is the lowest crude oil production in the country since 1962.

The production of crude oil from non-conventional fields at an industrial scale has previously been limited to the USA (shale oil), Canada (oil sand, shale oil) and Venezuela (ultra-heavy oil). Other countries such as China (shale oil, oil sand), Argentina (shale oil), and the Republic of Congo (oil sand), are endeavouring to develop their non-conventional oil deposits. Although the production from non-conventional oil fields is increasing, this can have little impact on the status of conventional crude oil for securing supplies with liquid hydrocarbons, given that it currently accounts for around 86 % of total production (including NGLs). Conventional crude oil is so significant because it not only represents around 80 % of total global crude oil reserves, but because it is also technically easier to produce than non-conventional crude oil. Moreover, because conventional crude oil is usually of higher quality, it is also easier and cheaper to refine than non-conventional crude oil, which usually requires energy-intensive and resource-intensive technologies. Furthermore, conventional crude oil fields boast higher production rates, as well as larger energetic recovery factors than non-conventional reservoirs.

The global consumption of petroleum products in 2015 rose again overall year-on-year by 1.1 % to 4,352 million t (Fig. 14). Whilst consumption stagnated or declined marginally in Europe and North America, it dropped back considerably in the CIS by 13 %. In the major regions Middle East, Africa, and Austral-Asia, petroleum consumption rose significantly between 3 to 6 %. The OECD countries consumed around half of the petroleum, headed by the USA which accounted for almost 20 %. Three quarters of global petroleum was used in the 20 leading consuming countries. The two largest petroleum consuming countries are easily the USA (845 million t) and China (560 million t). These two countries alone consumed around one third of the global petroleum.

Petroleum consumption is very heterogeneously distributed. For instance, the states of Africa and the OECD countries have a similar number of inhabitants in total. However, petroleum consumption per person is around 10 times as high in the OECD countries (1.62 t petroleum per person per year in OECD countries).

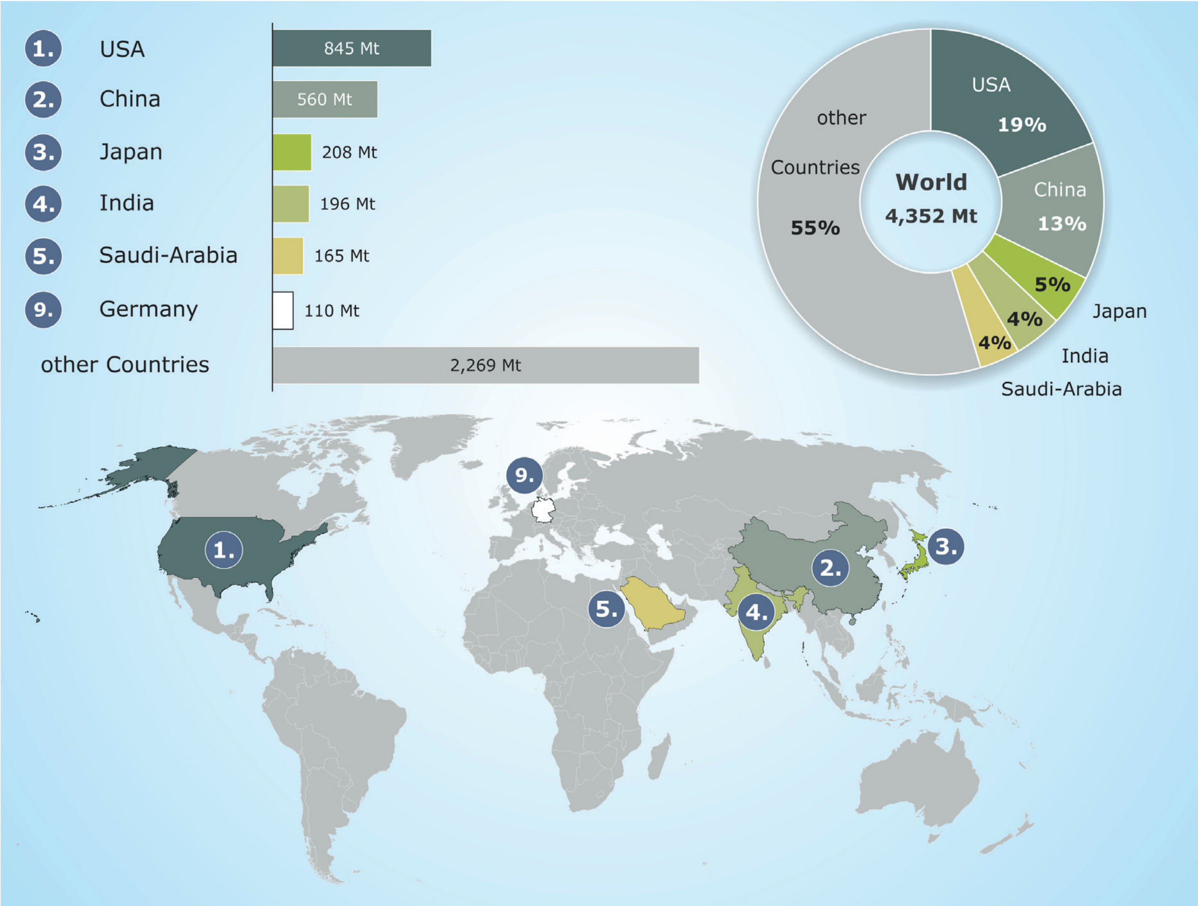

Figure 14: The world's biggest petroleum consumers 2015.

Of the crude oil produced in 2015, 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. Last year, around 2,106 million t of crude oil was exported world-wide, around 71 million t more than in 2014. Imports increased by around 96 million t (plus 4.6 %) to 2,205 million t. The regions with the strongest exports were the Middle East, the CIS countries and Africa. The three leading exporting countries, Saudi-Arabia, the Russian Federation and Canada, covered around one third of global crude oil exports. The highest growth in exports of the 20 leading crude oil exporting countries was reported by Brazil (plus 47 %), Iraq (plus 19 %), and the Russian Federation and Mexico (each plus 9 %). Global refinery capacities rose to around 4,831 million t.

The most important importing regions were Austral-Asia, Europe and North America. The largest crude oil importing country continued to be the USA with 368 million t. This was followed in second place by China whose imports increased by more than 8 % to 334 million t. Crude oil imports to Germany rose around 2.1 % to 91 million t.

There are various reference types of different quality for crude oil which are largely traded in a standard way on global markets, with the exception of minor surcharges or discounts. The annual average price of the European crude oil reference type „Brent“ declined very strongly year-on-year by 46.65 USD/bbl to 52.32 USD/bbl. This considerably intensified the slump in prices which began in the last quarter of 2014. Although the price appeared to stabilise in the first half of the year at slightly above 60 USD/bbl in June, it collapsed to the end of December to a minimum value of only 31.67 USD/bbl. The price for the US-American reference type „West Texas Intermediate“ (WTI), and the OPEC basket price (average price of selected OPEC crude oil types) experienced similar fluctuations in prices.

Tables 13 to 19 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).

Crude oil price and crude oil production – current developments and consequences

Prices for crude oil (e.g. WTI) have declined since the third quarter 2014 from over 100 USD/bbl to less than 40 USD/bbl at the end of 2015. This decline is correlated with a significant oversupply situation since the beginning of 2014 (Fig. 15). In general, long-term price rises and reductions can generally be correlated with a disparity between supply and demand (Fig. 15). The high price rises between 2006 and 2008, therefore reflect the excess demand during this time period. The current excess supply since the middle of 2014 is primarily attributable to the expansion of production in Iraq (plus 29 %), Brazil (plus 20 %), the USA (plus 17 %), Canada (plus 12 %), and Saudi-Arabia (plus 8 %).

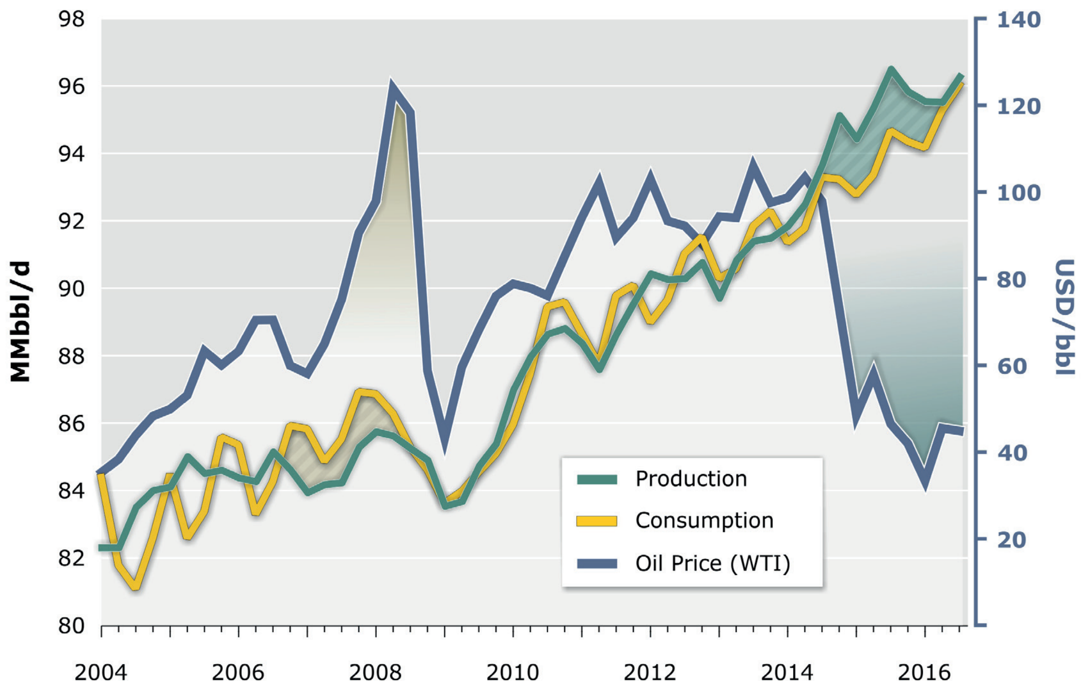

Figure 15: Quarterly development in crude oil production and consumption (EIA 2016b) and WTI price development 2004 to 2015.

The global storage capacities for crude oil and crude oil products (strategic reserves and industrial storages), held in caverns or surface tank farms, rose to record levels at the end of 2015. The OECD countries alone held 3 billion bbl of crude oil and crude oil products in storage at the end of 2015 (EIA 2016b). Assuming unchanged consumption, this corresponds to a static reserve of around 64 days. The size of the strategic reserves of crude oil and crude oil products in OECD countries is therefore above the long-term average of around 57 days. These amounts, however, appear relatively small in relation to the geological reserves and the continuing high consumption.

The USA has considerably boosted its crude oil production since 2008 by developing its shale oil deposits. This was achieved by using new production technologies such as hydraulic stimulation (fracking) and horizontal drilling. Whilst conventional crude oil production in the USA remained relatively constant in recent years, the proportion of shale oil has risen strongly and accounted for around half of total production in autumn 2016. Production in 2015 rose by another nine per cent compared to the previous year, but declined again at the end of the year (Fig. 16). The decline in crude oil prices is closely correlated with the number of crude oil wells drilled within a year, which also sank considerably, albeit with a time lag. Although delayed by continuous technological advances (e.g. multi-stage-fracking), the decline in drilling activity inevitably led to a drop in the amount of shale oil production beginning at the end of the reporting year. Given the continuing relatively low price, it is likely that shale oil production will continue to decline further, and all the more, the longer the phase of low crude oil prices continues.

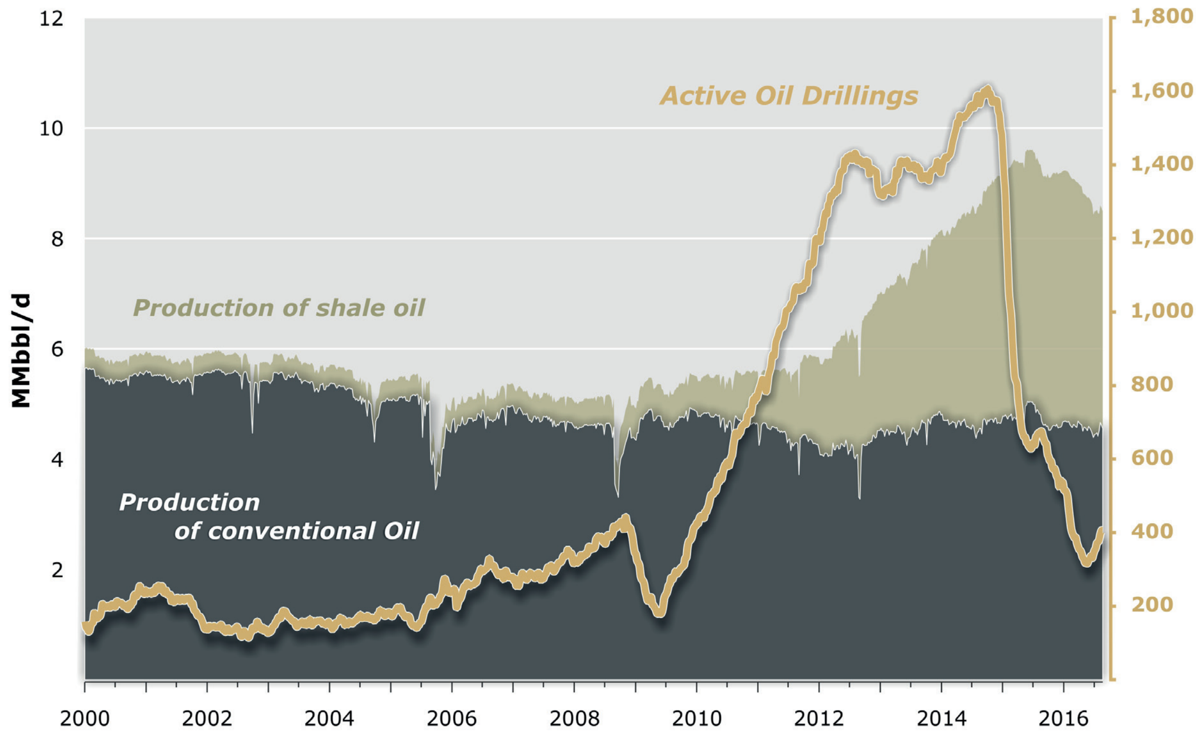

Figure 16: Compilation of US American crude oil production (EIA 2016c, 2016d) and crude oil drilling activity (Baker-Hughes 2016).

The decline in crude oil prices led to a previously unprecedented reduction in global investment in the upstream sector of almost 30 % alone from 2014 to 2015 (Barclays Research 2016). This could give rise to a major challenge in the medium to long term in supplying the world with liquid hydrocarbons because the decline in production in the major oil and condensate fields – which in some cases have been producing for decades, and which account for a large proportion of total production – will need to be replaced. The development of around 68 major oil and gas projects around the world with a total volume of 27 billion barrels crude oil equivalent, has been postponed or cancelled since the start of the decline in crude oil prices (Wood Mackenzie 2016). Independent of the further development in crude oil prices, this means that originally planned large volumes of production will now no longer either come on line or only after several years delay. It remains to be seen whether shale oil production – which can be ramped up relatively quickly – can compensate for the gap in production when crude oil prices start to rise again.

3.3 Natural gas

Natural gas remains the third most important energy resource in global primary energy consumption, behind crude oil and hard coal, with a slight increase to 23.8 % (BP 2016) compared to the previous year. After many years of low growth, global natural gas consumption rose by 2.3 % to again approach its historic 10-year growth average of 2.6 %. Whether this is an indication of a change in the trend, and heralding natural gas as a “bridging energy”, remains to be seen.

The largest natural gas resources by far (conventional and non-conventional) are in the Russian Federation, followed by China, the USA, Canada and Australia (Tab. 21). The most extensive conventional natural gas resources in the world are assumed to be in the Russian Federation, followed by the USA, China, Saudi-Arabia and Turkmenistan. In total, the natural gas resources in commercially used conventional and non-conventional accumulations are estimated at 652 trillion m³ (previous year 650 trillion m³) (Fig. 17).

With the inclusion of aquifer gas and natural gas from gas hydrates, global resources are assumed to be in the order of 860 trillion m³ (Tab. 2). Amongst those non-conventional natural gas deposits with established production techniques, shale gas resources dominate with around 215 trillion m³, followed by tight gas with 63 trillion m³ and coal bed methane (CBM) with 51 trillion m³ (Tab. 2). Hardly any country-based and reliable estimates of the resources of natural gas in tight sandstones and carbonates (tight gas) are currently available. Even though rough estimates of in place figures exist in some countries, it is difficult to quantify a recovery rate and therefore the amount that can be technically exploited. Moreover, one can generally assume that tight gas is present in most basins around the world with proven gas, particularly in Palaeozoic reservoirs. In this context, the global resources of 63 trillion m³ specified in the study must be seen as a considerable underestimation. In terms of the resources of aquifer gas and natural gas from gas hydrates, the data currently available primarily consists of global estimates and very few detailed regional studies. According to our current understanding, 24 trillion m³ natural gas are reported in aquifers and 184 trillion m³ natural gas in gas hydrates. It still remains to be seen whether and when this potential can be commercially utilised. Nevertheless, with respect to gas hydrates in particular, some countries with minor domestic resources of conventional energy resources, such as Japan, continue to pursue research projects with the aim of developing domestic gas hydrate deposits within their 200-mile-zones (exclusive economic zone) as potential sources of energy.

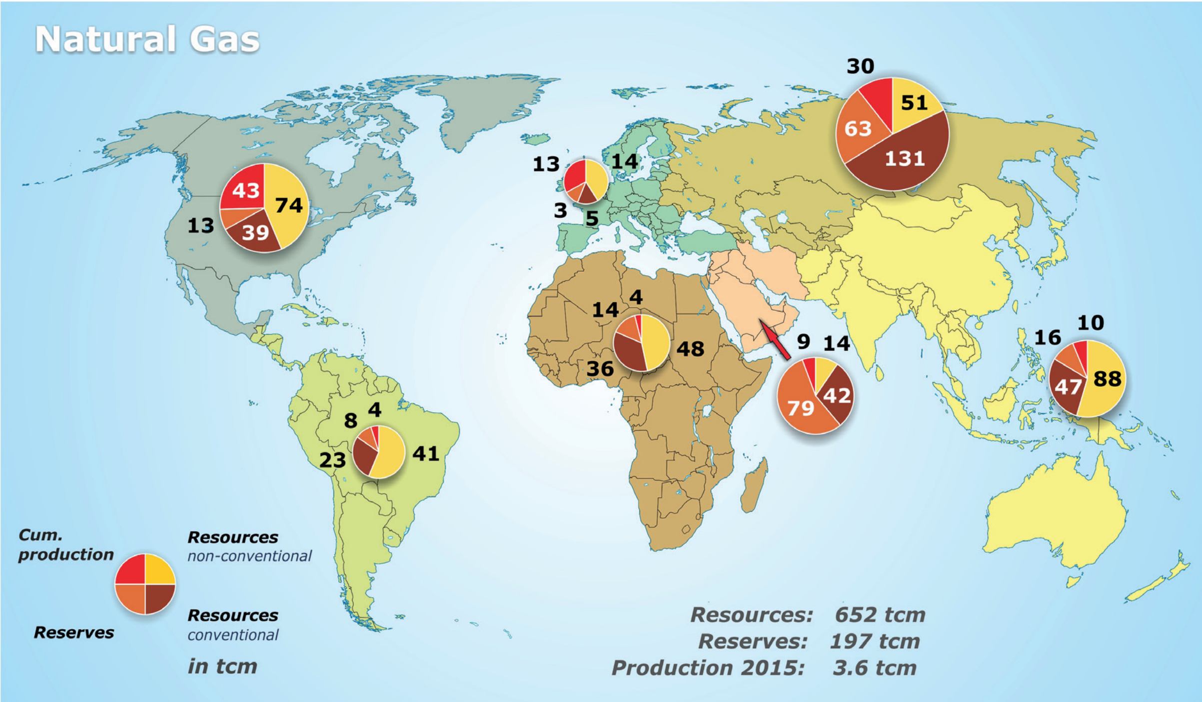

Figure 17: Total natural gas potential 2015 (excluding aquifer gas and gas hydrates): regional distribution.

Compared to the previous year, global natural gas reserves had declined more strongly by 0.7 %, and are estimated at 197 trillion m³ at the end of 2015 (Fig. 17). When the annual production in 2015 of 3,574 billion m³ is taken into consideration, this shows that almost two thirds of the production could be compensated for by additions to reserves. At a global scale, the proportion of non-conventional reserves is relatively low, and will probably remain so into the foreseeable future as well (Tab. 22). However, tight gas reserves are usually not reported separately, which means that precise reporting as part of the global study is not possible. Estimates in the USA assume that tight gas reserves account for more than around 20 % of the remaining reserves (IEA 2013). However, the USA is a special case because the initially subsidised tight gas has already been produced there for many decades. Significant shale gas reserves are also currently only reported in the USA: these were given as 5.7 trillion m³ at the end of 2014, and now account for a share of more than 50 % of the total reserves in the country. Over half of global natural gas reserves are in the Russian Federation, Iran and Qatar (Fig. 17). Around 80 % of global reserves are located in OPEC and CIS countries.

With 126 trillion m³, almost two thirds of global natural gas reserves are located onshore. The offshore proportion has grown for many years and now accounts for more than one third (71 trillion m³). Figure 18 provides an overview of the global distribution of reserves. Offshore reserves dominate onshore natural gas reserves in Europe, Austral-Asia and the Middle East. The Middle East also has the world‘s most extensive offshore reserves, of which the major share is found in the world‘s largest natural gas field, the South Pars/North Dome (Iran/Qatar) in the Persian Gulf. Most onshore reserves are located in the CIS, in particular in the Russian Federation (75 %).

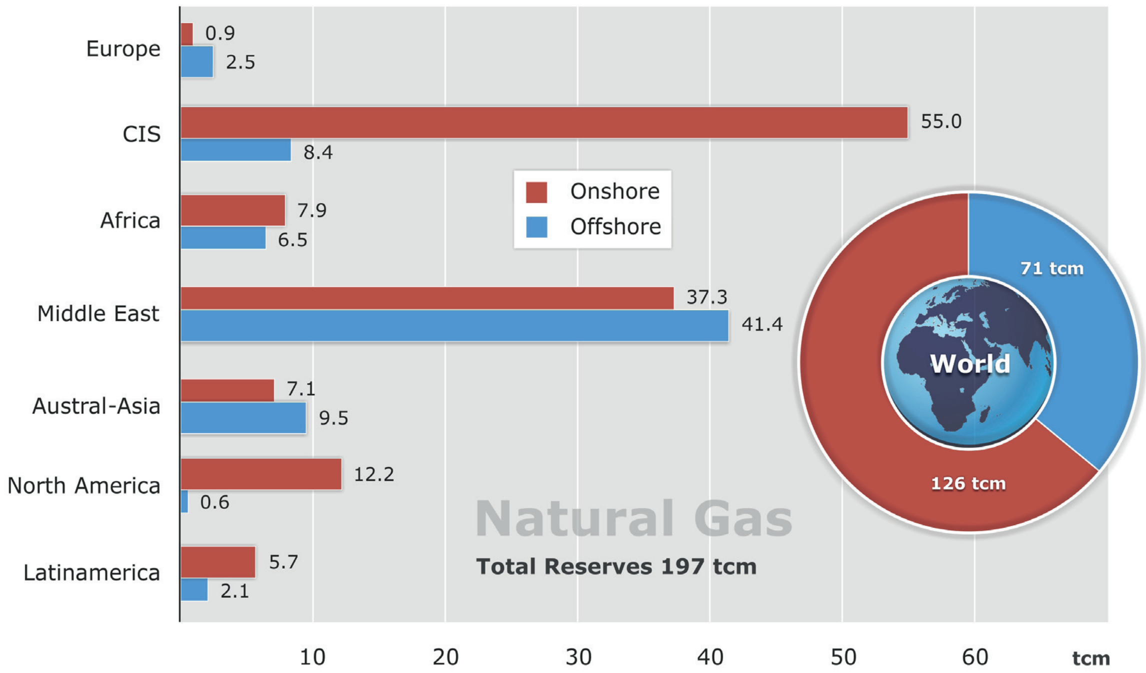

Figure 18: Global natural gas reserves subdivided into onshore and offshore.

The rise in the global natural gas production figures in 2015 to 3,574 billion m³ (plus 2.6 %) was primarily attributable to the increased consumption in Europe, Africa, the Middle East and North America. This was higher than last year's rise of around 1.8 %, and now again lies in the range of the long-term 10-year average of 2.5 %. In regional terms, the largest increase in production in percentage terms came from Austral-Asia (3.9 %), followed by North America (3.6 %), the Middle East (3.2 %), and the CIS with an increase of 3.1 %. In contrast, the European Union suffered another strong decline: production here sank by 9.4 %, primarily because of the further throttling of production from the enormous Groningen natural gas field in the Netherlands. This has been done in response to earthquakes which have developed as a consequence of the many decades of natural gas production.

The natural gas produced from the Groningen field is classified as L-gas (low calorific gas). Many other natural gas fields in the world produce H-gas (high calorific gas). These two types are formally differentiated by the Wobbe-Index which measures the calorific value as well as the density of the natural gas. L-gas has an index value of below 46.5 MJ/m³, whilst natural gas with a Wobbe-Index exceeding 46.5 MJ/m³ is classified as H-gas. In Germany, there are still two pipeline networks which are operated in parallel to carry L-gas and H-gas. However, the natural gas grid is to be successively converted to carry H-gas alone by 2030 (DIW 2015).

The USA continues to be the world's largest natural gas producer ahead of the Russian Federation and Iran (Tab. 23), and was theoretically capable of covering almost its total natural gas consumption from domestic production. The rise in the USA of 5.3 % was slightly lower than in the previous year, and is due to an increase in shale gas production. The latter accounts for almost half of natural gas production in the USA (EIA 2016e), followed by production from tight gas reservoirs with a share of around 18 % (EIA 2016f). During the reporting year, the only other countries apart from the USA with commercial shale gas production were Canada (42.4 billion m³), China (5.2 billion m³) and Argentina (0.7 billion m³) – albeit at much lower levels than the USA.

The first LNG export terminal in the continental USA was commissioned at the beginning of 2016 at Sabine Pass/Texas. In addition to South America and Asia, liquefied natural gas from shale gas production was also supplied to Europe (Portugal) in April 2016.

The highest volumetric growth in natural gas production was reported from the USA (39 billion m³), followed by the Russian Federation (25.9 billion m³), Australia (14.6 billion m³), Norway (12.5 billion m³), Iran and Qatar (each 11.3 billion m³), as well as Turkmenistan (10.9 billion m³). Production in the Netherlands, however, declined significantly again (minus 15.1 billion m³), whilst China was able to boost its natural gas production by 5.4 billion m³ or 4 % (Tab. 23). The strongest increase in percentage terms (26.4 %) was in Australia, primarily because of the significant rise in the production of coal bed methane. The beginning of 2016 also saw the first shipment of liquefied coal bed methane to Asia. With the progressive development of Galkynysh, the world‘s second largest natural gas field, Turkmenistan was again able to significantly boost its production (15.7 %).

The Russian Federation and the USA together produced 1.4 trillion m³ in 2015. This corresponds to around 40 % of global natural gas production (Fig. 19).

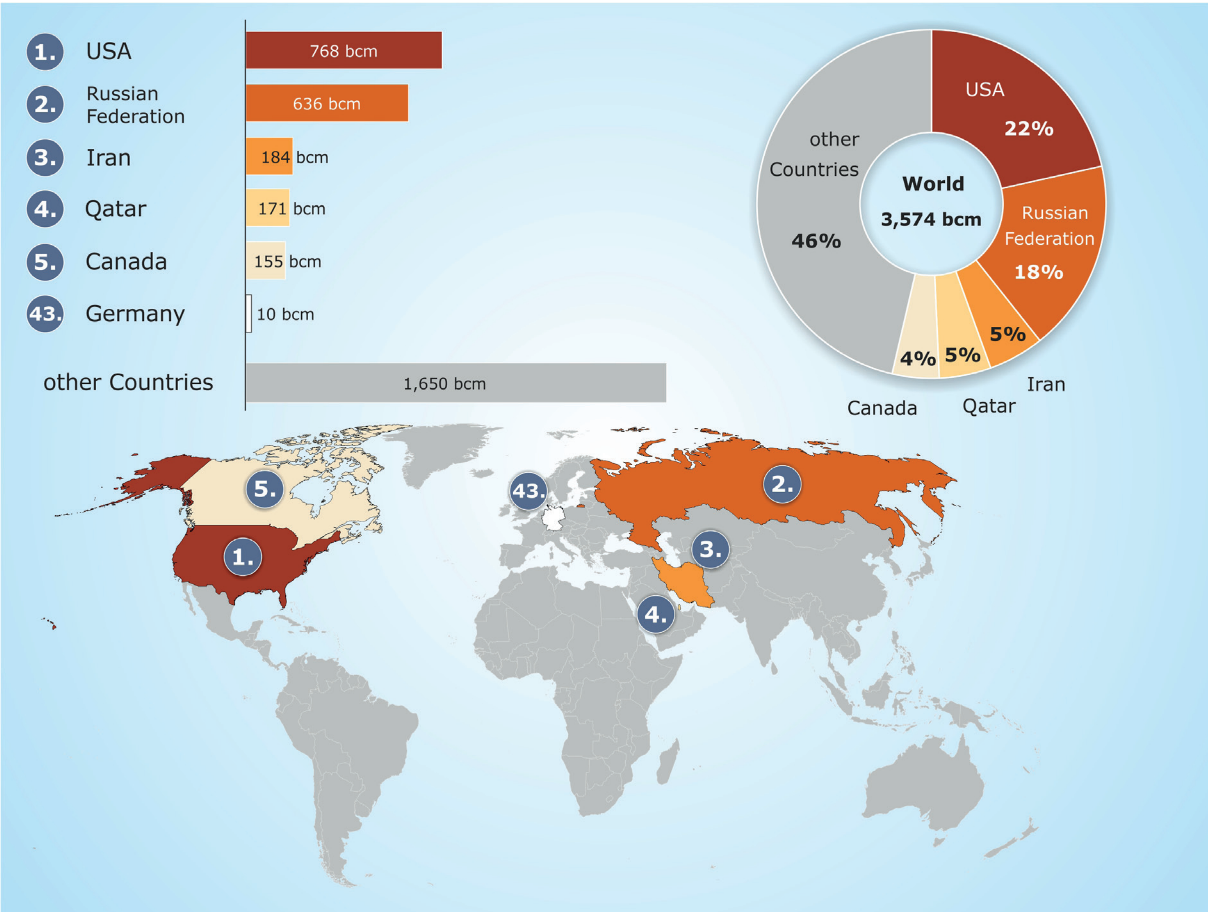

Figure 19: The biggest gas producing countries in 2015.

After years of minor growth, natural gas consumption in 2015 rose globally by almost 2.3 % (previous year 1.5 %) to 3,562 billion m³, and therefore approached the historic 10-year average of 2.6 %. With the exception of Latin America, consumption in all regions around the world rose to a lesser or greater extent. The largest natural gas consumers by far were the USA, followed by the Russian Federation, China, Iran and Japan (Tab. 24).

The USA and the Russian Federation alone account for almost 35 % of global demand. Compared with other regions, demand in the EU increased by the largest amount (plus 5.7 %), after declining by 10 % the previous year. In contrast, demand rose only slightly in Austral-Asia and the CIS. Although China's natural gas demand increased by 3.5 %, this was well below the long-term average growth rate.

In the reporting year, around 1,042 billion m³ natural gas (BP 2016) and thus 29.3 % of the natural gas produced world-wide, was traded across borders (excluding transit trade), of which 32.5 % (338 billion m³) in the form of liquefied natural gas (LNG). Trailing quite far behind Qatar, Australia was the second largest exporter of LNG, followed by Malaysia.

The global trade in natural gas overall has increased again compared to the previous year. Although the global trade in LNG increased less strongly than the trade in pipeline gas, it was still able to reach record levels. Japan continued to be the world's largest importer of liquefied natural gas, and is sourced from a large number of countries. Around two thirds was imported from Australia, Malaysia, Qatar and the Russian Federation. Although Germany was the largest importer of natural gas world-wide in 2015 with 115.5 billion m³, it exported around 27 % of this again. Germany is followed by Japan with 111.4 billion m³. Whilst Germany imports all of its natural gas via pipelines, Japan has to import all of its natural gas in liquefied form.

Although supra-regional natural gas markets exist around the world, the global trade in LNG is leading to increasing convergence. The closer connections between the various natural gas markets caused by the generous availability of LNG, has reduced the global variation in prices somewhat. Natural gas continued to be cheap in the USA in 2015 because of the large volumes available on the supply side. The average natural gas price (Henry Hub spot price) was 2.6 USD/million BTU in the USA (previous year: 4.35 USD/million BTU). Natural gas in Germany was two and a half times more expensive on average, whilst the prices for LNG imported to Japan were up to four times higher on average than the price in the USA. However, the prices in Asia have recently approached European levels because of the weaker demand and additional supplies in the region. As a consequence, Japanese import prices, which are primarily coupled to the price of crude oil, declined during the course of the year by 78 % (IGU 2016), and spot prices for LNG in East Asia were at 4.5 USD/million BTU at the beginning of 2016. Increasing volumes of LNG, in particular from the USA and Australia, will be available in the market in the years to come, and should help stimulate more competition, as well as ease the situation on the supply side.

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 here is basically in a relatively comfortable position, although geopolitical risks are still a key factor affecting natural gas supplies.

Tables 20 to 26 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 of the fossil fuels, coal is the energy resource with easily the largest global reserves and resources. With a share of 29.2 % of global PEC (hard coal 27.5 %, lignite 1.7 %), coal was the second most important energy resource in 2015 behind crude oil (after BP 2016). Coal accounted for a share of 39.3 % of global power generation in 2014, which is more than any other fuel (IEA 2016c).

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) only changed by a very minor amount compared to the previous year (minus 0.07 %). Reported global coal reserves at the end of 2015 were 1,029 Gt, of which 712 Gt hard coal and 317 Gt lignite. With respect to reserves, there are changes compared to the previous study (BGR 2015) in terms of hard coal reserves (plus 1.9 %) as well as lignite reserves (plus 10.8 %). The higher lignite reserves are based on new findings and the resulting re-evaluations primarily in the state of Victoria/Australia (Geoscience Australia 2016, pers. com. Roberts/Geoscience Australia).

Global coal production declined compared to the previous year, and therefore for the second time in the new millennium, and totalled around 7,713 Mt in 2015. This represents a decline of 3.2 % year-on-year. This comprised 6,702 Mt (minus 3.5 %) hard coal, whereby the decline in coking coal is much higher than the decline in power plant coal according to the Association of Coal Importers (VDKI 2016b). The remaining 1,011 Mt (minus 1 %) was accounted for by lignite.

Unlike conventional crude oil and natural gas, coal deposits and their production is spread over many companies and countries. Tables 27 to 38 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 20. The Austral-Asia region has the largest remaining hard coal potential with 7,533 Gt, followed by North America with 6,872 Gt, and the CIS with around 3,003 Gt. The world‘s largest hard coal reserves are in the United States with 221 Gt (31.1 % global share). The People‘s Republic of China comes next with around 126 Gt (17.7 %), ahead of India with around 90 Gt (12.6 %). These countries are followed by the Russian Federation (9.8 %), Australia (9.6 %), and the Ukraine (4.5 %). The volumes (reserves) of subsidised production producible in Germany until the end of 2018 amount to around 0.01 Gt hard coal. In terms of resources, the USA alone with 6,458 Gt has 36.5 % of global hard coal resources, followed by China (30.1 %), and the Russian Federation (15 %).

The three largest hard coal producers in 2015 (Fig. 21) were China with a share of 50.5 % (3,387 Mt), the USA (11.2 %), and India (9.5 %). Whilst India was able to boost its production by 4.2 %, production declined in China (minus 3.4 %), as well as in the USA (minus 10.3 %). With respect to the European Union (EU-28), its share of global hard coal production is 1.5 %, corresponding to a production of 89 Mt.

Around 19 % of the hard coal produced world-wide, and amounting to 1,260 Mt, was traded in 2015, of which 1,104 Mt by sea (VDKI 2016a). This corresponds to a year-on-year decline in the globally traded volume of hard coal of around 6 %. Australia dominated the hard coal world market with exports totalling 388 Mt (30.8 %), followed by Indonesia (29.1 %), and the Russian Federation (12 %).

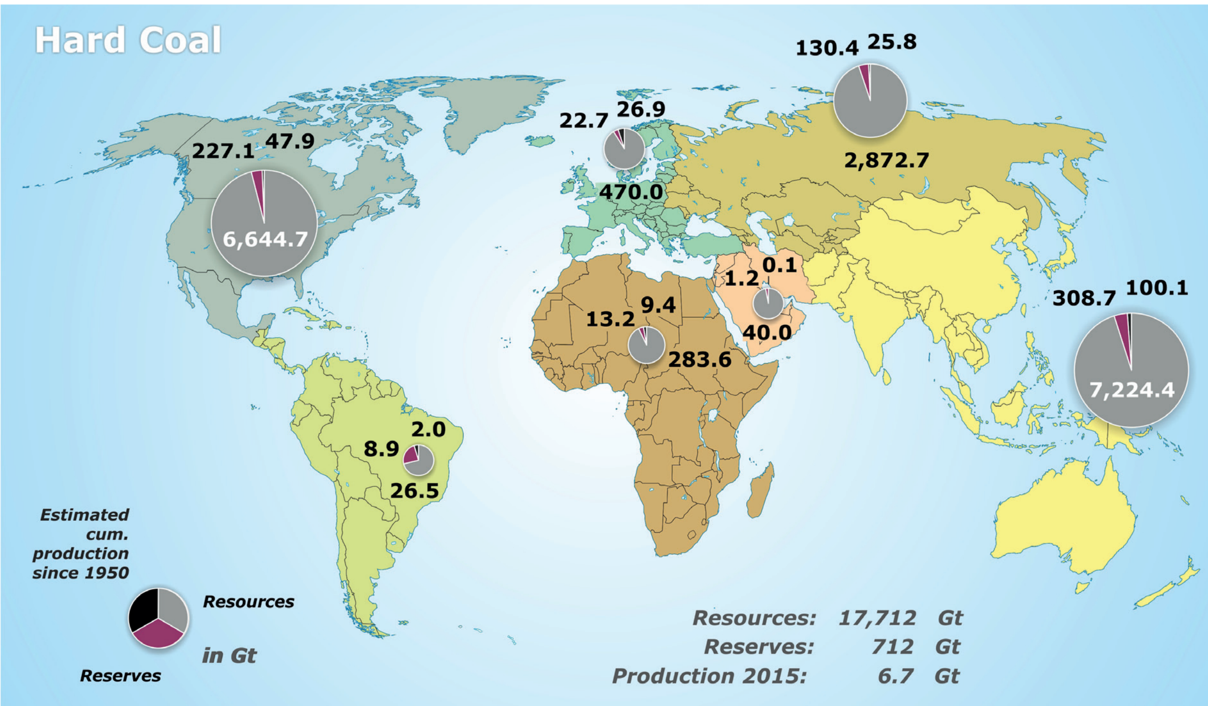

Figure 20: Total hard coal potential 2015 (18,424 Gt): regional distribution.

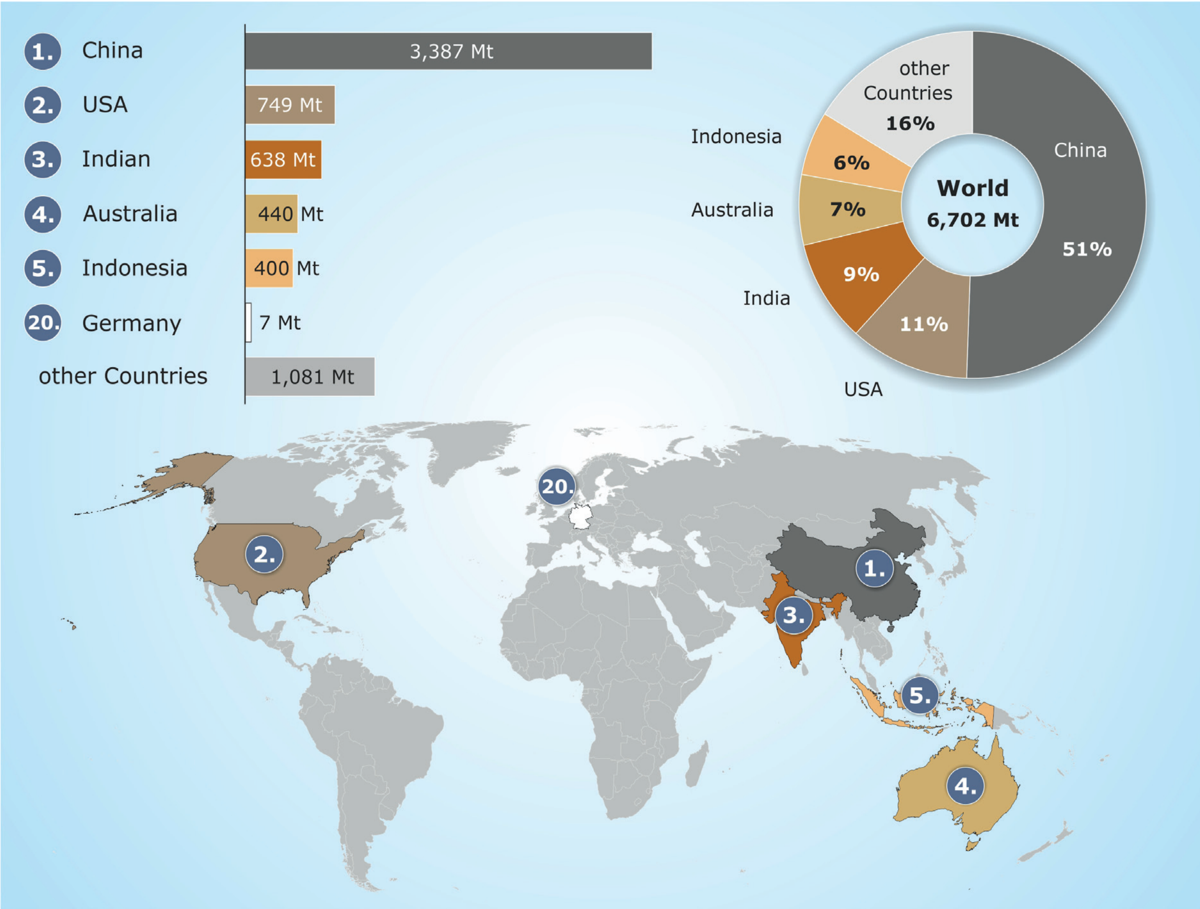

Figure 21: The biggest hard coal producing countries 2015.

The largest hard coal imports were reported by China, India and Japan, with a total volume of around 595 Mt (47.5 %). Compared to the previous year, China again significantly reduced its imports in 2015 (291 Mt) by almost 30 % to 204 Mt. This means that around one sixth of total global hard coal imports were accounted for by China in 2015. India, which had expanded its imports significantly by around a quarter to 215 Mt in 2014, imported almost 7 % less hard coal in 2015 (around 200 Mt). Japan marginally increased its imports by 1.2 % compared to the previous year to around 191 Mt. As in previous years, Asia dominated the global hard coal import market with a share of around 71 %. With 195.7 Mt, only around one sixth of global hard coal imports were accounted for by the European Union (EU-28), which was able to cover more than 70 % of its hard coal demand in this way.

The north-west European annual average spot prices for steam coal (port of Amsterdam, Rotterdam and Antwerp; cif ARA), declined by around 20 USD/tce (minus 23 %) from 87.83 USD/tce in 2014 to 67.45 USD/tce in 2015 (VDKI 2016a). This trend continued almost continuously until April 2016, with the price falling as low as 52.61 USD/tce. However, by September 2016, the spot price had again risen by almost 20 USD/tce to 71.12 USD/tce, primarily driven by price rises in the Asian (Chinese) coal market. As in the previous year, preliminary assessments indicate that European coal imports declined significantly by around 7 % in 2015. This decline is almost exclusively attributable to lower imports into the United Kingdom. Here, the competitiveness of hard coal as a fuel for power generation has declined significantly because of a carbon price support rate introduced in 2013, which was increased to 18 £/t CO_2 on 1 April 2015, and which must be added to the costs for a CO_2 certificate from the European emissions trading system (Scottish Government 2016).

The decline in coking coal prices also continued through 2015 to the beginning of 2016. The prices dropped from around 114 USD/t in January 2015 to around 77 USD/t in December 2015. Coking coal prices recovered again steadily from March 2016: and the prices „exploded“ from the middle of August (Fig. 22), when the spot price for high quality Australian coking coal at the beginning of November 2016 was up to 310 USD/t, corresponding to a tripling of spot prices since June 2016 (IHS Energy 2016, VDKI 2016a, b). These price rises are primarily attributable to the consequences of production cut-backs in China and the USA.

As a result of the further decline in coal world market prices up to the beginning of 2016, mines with high production costs were closed around the world in 2015 as well. The biggest cut-backs were in the US-American coal sector. Coal production in the USA dropped by around 10 % in 2015. After three major US-American coal companies (Alpha Natural Resources, Arch Coal and Walter Energy) had already gone into liquidation during the course of 2015, the world‘s largest private coal company Peabody Energy also had to announce insolvency for most of its US-American activities in April 2016. These changes in the US coal sector were also reflected in other metrics:

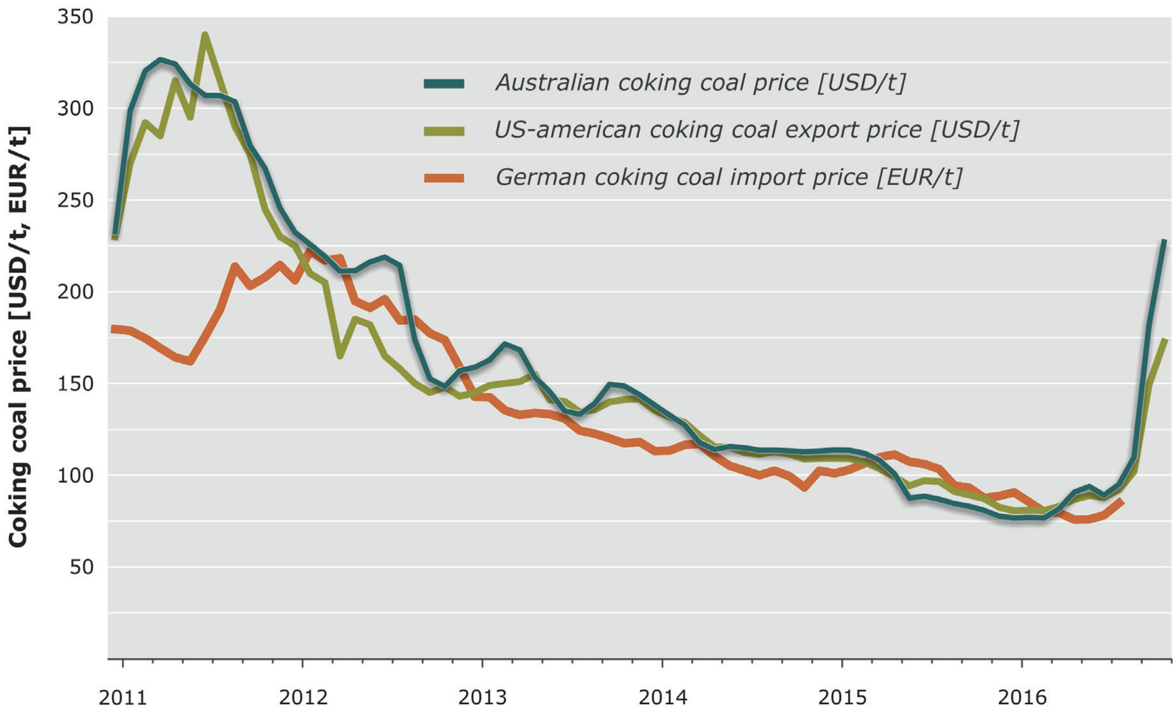

Figure 22: Development of Australian (prime hard coking coal) and US American (low vol coking coal) export prices, and German cross-border prices for coking coal from Dec. 2010 to Oct. 2016 (IHS Energy 2016, VDKI 2016a, b).

during the period from 2008 to 2015, the number of active coal mines declined by around two fifths (605 mines), to 853 (EIA 2015, EIA 2016g), and the size of the workforce in coal mining has almost halved since 2011 from 91,611 (EIA 2013), to around 52,000 in summer 2016 (NCA 2016). The reduction in production capacities associated with the decline in coal demand is due to growing competition, and in particular, to cheap domestic natural gas (shale gas), not to mention more stringent environmental limits for coal power plants such as the Mercury and Air Toxics Standards (EPA 2016) and the Clean Power Plan (White House 2015).

Preliminary estimates for 2016 indicate another significant reduction in US-American coal production in the order of around 20 % compared to 2015 (EIA 2016h). In which case, the USA would already have been overtaken by India in 2016 as the second largest coal producer.

Although the USA was known as a so-called swing supplier in the past on the global hard coal market, it was hardly able to make larger volumes available on the world market at short notice in response to the rise in world market prices in late summer 2016 (in particular for coking coal). The US coal industry has been exposed to a difficult economic environment in recent years (see above) and is therefore undergoing a restructuring phase, which means that no corresponding production capacities are currently available. Moreover, US producers are reacting cautiously to an expansion in production because of the difficulty in predicting the duration of the current global bull market for coal prices (China Coal Resource 2016a).

China, whose coal production capacities had more than tripled in the last 15 years, again cut back its hard coal production by around 3 % in 2015 compared to the previous year in response to the weaker demand. According to the China National Coal Association (CNCA), 43 coal companies in total – and thus nine fewer than in the previous year, each produced more than 10 Mt coal in 2015 (China Coal Resource 2015, 2016b). Nine of these 43 coal companies produced more than 100 Mt each in 2015 (Tab. 3).

Table 3: The largest Chinese coal companies in terms of production volumes (after CNCA, China Coal Resource 2015, 2016b)

Ranking (2015)	Company	Production 2015 [Mt]	Production 2014 [Mt]
1	Shenhua Group	433.26	473.51
2	Datong Coal Mine Group	173.51	167.54
3	China National Coal Group	166.68	183.04
4	Shandong Energy Group	133.68	139.26
5	Shaanxi Coal & Chemical Industry Group	127.11	127.12
6	Shanxi Coking Coal Group	105.35	107.00
7	Yankuang Group	109.02	102.12
8	Jizhong Energy Group	101.75	102.00
9	Henan Coal Chemical Industry Group	101.63	101.86
10	Kailuan Group	91.70	89.64

China is pushing ahead with the restructuring of its coal sector, and particularly the closure of small mines with low production capacities (< 90 Kt/a) and relatively high numbers of (fatal) accidents. Because these measures are only leading to a slow decline in the existing overcapacities in the Chinese coal sector, the Chinese government decided to implement additional measures at the beginning of 2016 to reduce the annual production by more than 250 Mt in 2016 (China Coal Resource 2016c). Measures that came into force on 1 May 2016 included reducing the number of working days in Chinese coal mines from 340 to 276 per year. This enabled Chinese coal production to be cut back by almost 10 % in the first half of 2016 compared to the same period the previous year (China Coal Resource 2016d). Reducing the number of working days was suspended again for more than 800 coal mines in September 2016 because this gave rise to a significant increase in the price of coal, firstly in China, and shortly afterwards also in world hard coal trading. The rise in Chinese coal prices, which led to a near doubling in the price of steam coal between June 2016 and the beginning of November 2016 (in RMB), is, however, not solely attributable to the cut-backs in domestic production. Other causes are the higher demand for power because of higher than expected industrial production, as well as the hot summer in 2016 (higher electricity demand for air conditioning systems), alongside the lower rainfall and the associated lower amount of power generated by hydroelectric plants (IHS Energy 2016). Against the background of these events, it remains to be seen to what extent the targets formulated in summer 2016 for 2020 involving (a) the closure of 500 Mt of coal production capacity and (b) consolidation of an additional 500 Mt of production capacity, will actually be implemented. These plans, including reducing the capacities in the steel sector, would affect around 1.8 million jobs in the next three to five years (China Coal Resource 2016e).

Following the year-on-year reduction in China‘s hard coal imports in 2015 to around 204 Mt, the events described earlier affecting the Chinese coal sector will mean that imports in 2016 will probably be 18 % higher than the previous year according to current estimates.

Lignite

With around 1,519 Gt, North America has the largest remaining lignite potential in the world, followed by Austral-Asia (1,413 Gt), and the CIS (1,389 Gt, including sub-bituminous coal) (Fig. 23). Of the 317 Gt lignite reserves known world-wide in 2015, 90.7 Gt (including sub-bituminous coal) or more than one quarter are in the Russian Federation (28.6 % world 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 %). More than 81 % of global lignite production totalling 1,011 Mt was produced in only 11 of a total of 35 producing countries in 2015. Germany, which had only slightly less domestic production than the previous year (minus 0.06 %), was the world‘s largest lignite producer with a share of 17.6 % (178 Mt), ahead of China (13.8 %), and the Russian Federation (7.2 %).

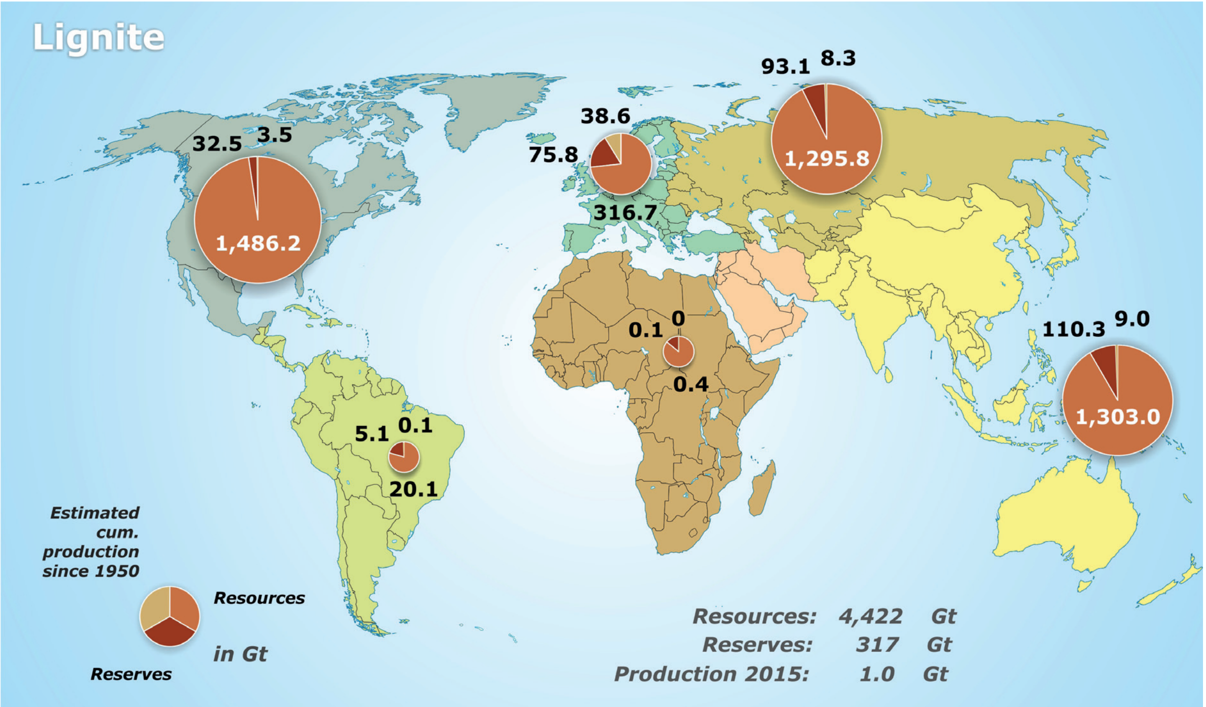

Figure 23: Total lignite potential 2015 (4,739 Gt): regional distribution.

3.5 Nuclear fuels

Uranium

After the government's decision to withdraw from nuclear power, this energy resource continued to decline in significance in Germany, but from a global point of view, it is still an energy resource of high relevance and still in strong demand. The demand for uranium will probably sink further in Europe in future, but a rise in uranium consumption can be expected primarily in Asia and the Middle East. There are already 128 reactors in operation in Southeast Asia, and another 40 are under construction. A moderate rise in uranium demand is also expected in the coming decades in North America, Latin America and Africa (IAEA 2016a; IAEA 2015; OECD-NEA/IAEA 2014).

The global uranium resources[1] at 13.7 Mt are very extensive, and have grown by around 295 Kt compared to the previous year. This is due to changes in only a few countries. Increases primarily in Canada (plus 190 Kt U) and in Kazakhstan (plus 219 Kt U) are reported and are due to the exploration activities which were undertaken in recent years. Both countries are major global uranium production countries (Tab. 43), and regularly re-evaluate their reserves. The transfers of reserves from lower to higher cost categories only had a minor impact on the rise. The main increases are due to renewed evaluations of reasonably assured resources in India and Australia. Declines in resources are primarily attributable to a significant downgrading of uranium reserves in the USA.

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

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 has led to a reduction in the uranium resources in the USA from 2,564 Kt in 2014 to 2,252 Kt in 2015 (minus 12 %). Details on prognosticated resources will no longer be published in the USA in the near future. Argentina, Brazil, Iran, India and Vietnam also stopped providing data for the first time on speculative resources in 2013. Major production countries such as Kazakhstan, the Russian Federation and South Africa stopped providing details on speculative resources in 2009, and Australia stopped providing this data more than 20 years ago. Given these reporting uncertainties, the resource figures presented in this study must be considered as conservative.

With respect to the reporting of uranium reserves, a pure statistical consideration of the economically extractable reserves in the cost category < 80 USD/kg U only partially reflect the real situation (BGR 2014). The production costs of many mines are currently higher than the market price, and around one third of active uranium mines fail to produce economically (WNN 2015). Australia, one of the largest uranium production countries in the world, also produces uranium at higher costs, and only reports uranium reserves above 80 USD/kg U (Tab. 41). In the sense of the conservative approach of this Energy Study (BGR 2014), this means that only uranium deposits in the production class < 80 USD/kg U are counted as reserves. All other reserves with higher production costs are reported within this study as resources, even if they are already being mined.

With respect to uranium reserves, the overall balance shows a rise compared to the previous year. Contrary to the partially considerable reductions in global reserves in recent years (BGR 2014), the large uranium production countries of Canada, Kazakhstan and the Russian Federation in particular are again reporting higher reserves, which is primarily attributable to successful exploration in recent years, and the use of modern production methods. The Russian Federation doubled its reserves in the < 80 USD/kg U cost category from 11,800 Kt U in 2014 to 27,300 Kt U in 2015. Canada and Kazakhstan boosted their reserves by 17 % and 30 % respectively. In the Russian Federation and Kazakhstan, the expansion of uranium mining using in situ leaching was the main reason for the expansion of the reserves figures, because this enables uranium deposits to be mined at lower production costs than was the case with the previous production technology. In addition, reserves also increased as a result of successful exploration, mainly in Canada.

Significant reductions in reserves came about by changes in the estimation of American reserves which, in addition to a significant reduction in the resource figures (see above), also led to the lowering of uranium reserves by almost half. In the < 80 USD/kg U cost category, American reserves therefore declined from 39,064 t U in 2014 to 17,425 t U in 2015. Numerous investigations and projects are currently being implemented by the U.S. Geological Survey (USGS) in the USA (USGS 2007; USURA 2016), and the results of these investigations will steadily flow into the re-evaluation of American reserves in the next few years.

Global uranium reserves in the < 80 USD/kg U cost category total 1.3 Mt (2014: 1.2 Mt). Around 96 % of the reserves are located in only 11 countries, led by Canada, and followed by Kazakhstan and Brazil. According to the current database, more than half of the global uranium reserves are located in these three countries (Fig. 24).

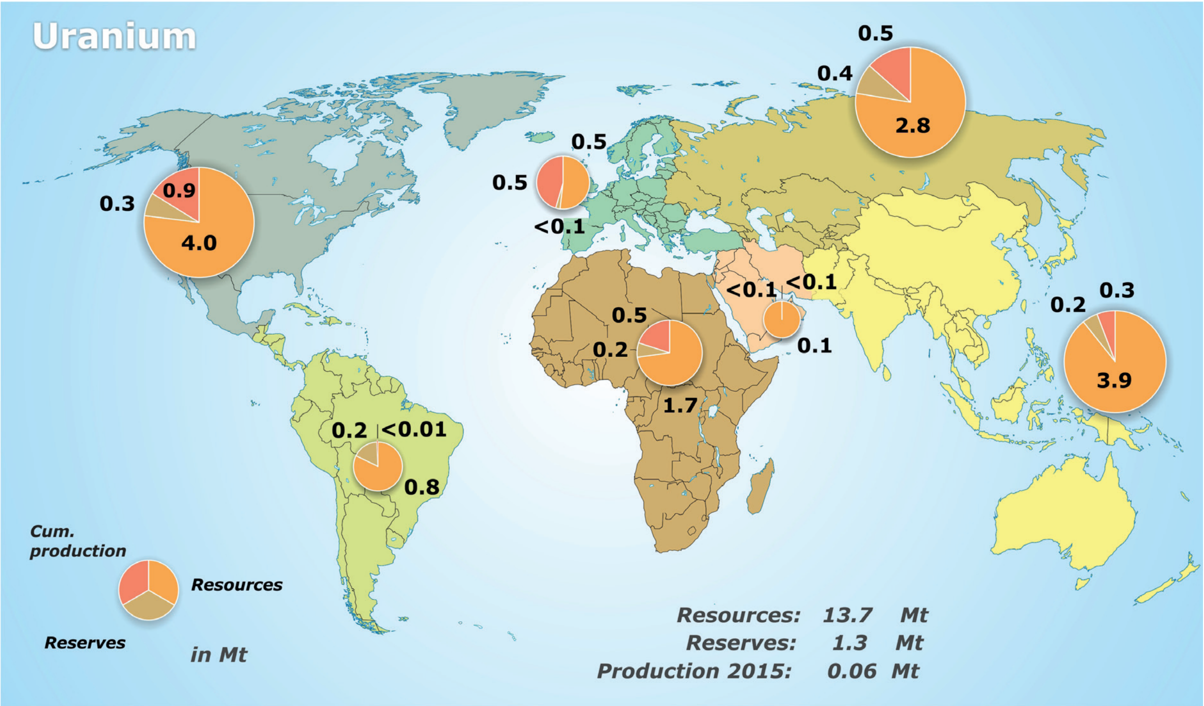

Figure 24: Total uranium potential 2015: regional distribution.

Global uranium production rose in 2015 after a temporary decline the previous year, and rose again to 60,497 t U (plus 8 %). This was primarily due to the renewed increase in production in Kazakhstan by 3 %, and the start of commercial mining in the Canadian Cigar Lake deposit. This conventionally mined deposit produced 4,345 t U during its first year of commercial operations. The largest single production site continues to be McArthur River in Canada (7,345 t U, 12 % of global production), followed for the first time by Cigar Lake, Canada (4,345 t U, 7 %), Tortkuduk and Myunkum, Kazakhstan (4,109 t U, 7 %), Olympic Dam, Australia (3,161 t U, 5 %), and Somair, Niger (2,509 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), and some mines have been forced to shut down (e.g. Kayelekera, Malawi).

Around 87 % of global production was generated by only six countries (Fig. 25). The largest producing country is still Kazakhstan, which with 23,800 t U, boosted its production again (2014: 23,127 t U), and is thus alone responsible for almost 40 % of global uranium production. The annual Kazakh production has risen more than five times in the last ten years. Canada, Australia, Niger, the Russian Federation and Namibia accounted for another 47 % of global production. As in previous years, uranium production is concentrated in only a few major companies. In 2015, around 80 % of global production came from only eight 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 18 %, and Areva (France) with 15 %.

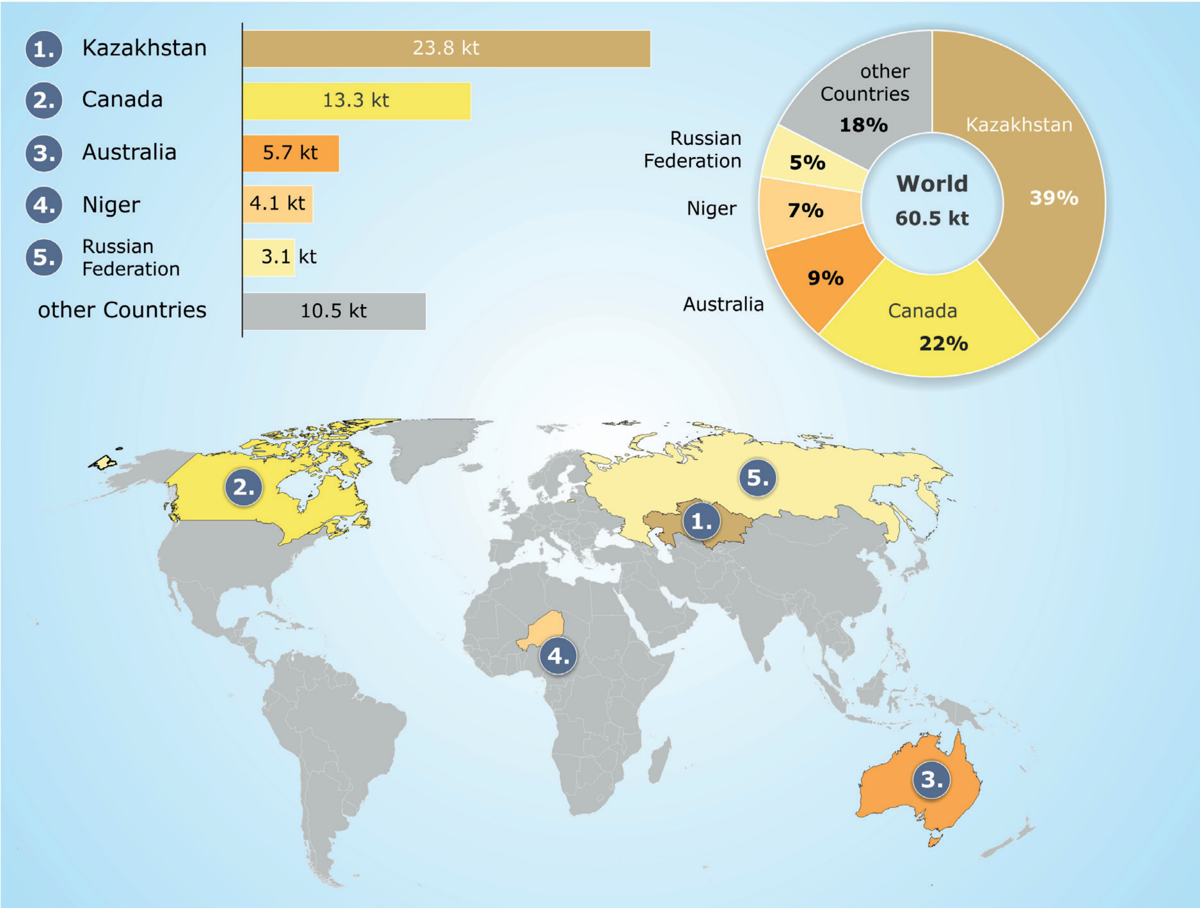

Figure 25: The biggest uranium producing countries 2015.

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 China. The global demand for uranium was 66,880 t U in 2015 (a slight plus of 972 t U compared to 2014). Growth was primarily due to India and Finland (Tab. 44). The start of eight new reactors in China, as well as one in South Korea, and one in the Russian Federation, also contributed to the growth. Uranium demand in Germany reduced with the decommissioning of eight nuclear power plants in Germany in 2011, and was 1,889 t U in 2015, the same level as the previous year (cf. Chap. 2). The decommissioning of the Grafenrheinfeld nuclear power plant in June 2015 has not had any statistical impact on the annual reactor demand so far because the shut-down dates of the still operating nuclear power plants are calculated on a year-end basis.

Uranium is primarily traded world-wide on the basis of long-term supply contracts. Uranium supplies to EU member countries in 2015 totalled 15,990 t U (up 1,239 t U or 8.4 %). The share of supplies arising from spot market contracts was only 5 % (European Union 2016). 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 Jan. 2011: 188 USD/kg U) – initiated by the consequences of the reactor accidents in Fukushima, which directly led to the shut-down of 48 reactors in Japan and eight reactors in Germany – has now also continued into the fourth year. As a result, spot market prices during the course of 2015 declined from 96.2 USD/kg U to 89 USD/kg U, and were therefore around 100 USD/kg U lower than in 2011. No end to the decline in prices is foreseeable in the short term. The downward trend continued in 2016 as well, with a uranium price of 65.65 USD/kg U in August 2016.

Although the uranium price only accounts for a small proportion of the power generation costs (around 14 % of total costs; WNA 2016a), 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 price guarantee.

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 2015). 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, the United Kingdom, Romania, the Russian Federation, Sweden, Slovakia, Slovenia, Spain, Czechia and Hungary, 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.

65 nuclear power plants were in construction in 2015 in 15 countries, including China (24), the Russian Federation (8), India (6), the USA (5), South Korea (4), United Arab Emirates (4), Slovakia (2), Japan (2), Pakistan (2), Taiwan (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 phase. Power plants were decommissioned in Japan (5), Germany (1), the United Kingdom (1), and Sweden (1). Since the start of nuclear power plant utilisation, 156 reactors have been decommissioned world-wide (as at January 2014). Of these, 15 reactors (including research reactors and prototypes) have been completely dismantled (WNA 2016b). In Europe, four decommissioning projects have been completely finished, of which three alone in Germany (BfS 2015). New nuclear power plants were commissioned in China (8), and one each in South Korea and the Russian Federation. The 441 nuclear power plants operated in 2015 with a total net capacity of 382 GW (IAEA 2016b) used around 66,880 t of natural uranium. Most of this (60,497 t) came from mine production.

The world mine production of uranium in the last five years lay between 54,610 and 60,497 t U, compared to an annual consumption of over 65,000 t U. The gap between annual demand and primary production is covered by civil and military inventories, in particular in the Russian Federation and the USA. These inventories were derived from the overproduction of uranium in the period from 1945 to 1990 in the expectation of a growth in civilian demand, as well as for military reasons. The military inventories in particular were successively reduced. The basis for this reduction 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 2016c). 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 2014).

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 50 %. 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 to 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 within the earth's interior is negligible on human time scales. It is therefore looked at separately from the other renewable energy (Chapter 3.7).

At the end of 2015, geothermal electricity was generated in 24 countries on four continents. The installed global capacity amounts to 13.2 GW_e (GEA 2016), producing 75 TWh of electric energy. This corresponds to a share of 0.3 % of around 24,000 TWh, the total energy production in 2015 (Enerdata 2016). Despite the growth of around 2.5 % compared to the previous year, the relative proportion of geothermal energy in global power supplies declined because of the strong growth in other energy sources. The non-renewable energy resources continue to cover the largest share of energy production, i.e. accounting for around 76.3 % (REN21 2016).

With respect to the development of greenhouse gas emissions, and carbon dioxide (CO_2) in particular making a major contribution to global warming, the current Paris Climate Treaty (Chap. 3.7) means „net zero emissions" in the second half of this century. Net zero emissions in the Paris Treaty (UNFCCC 2015) is understood as an „equilibrium between anthropogenic emissions of greenhouse gases from sources and the removal of such gases in sinks" (Bundesrat 2016). Geothermal energy is to make a contribution here. As a renewable energy, it has relatively low emissions of greenhouse gases averaged across the whole process chain („life cycle"). At the climate conference in Paris, the 28 members of the „Global Geothermal Alliance", including some leading countries in the geothermal energy sector such as Indonesia, Italy, Kenya, and the USA, issued a communiqué for global growth in geothermal power production aimed for an increase in production by a factor of five (Fig. 26). The geothermal capacity in the heat sector is to double by 2030. The aforementioned expansion targets are based on the strategy plan „Remap 2030" issued by the International Organisation for Renewable Energy (IRENA 2014).

The aimed growth contrasts with the reality and/or today's status quo. In 2015, the new installed global capacity totalled 313 MW_e. This value reaches approximately only half the increase achieved in 2014 (610 MW_e), even though a similar number of new power plants were added, i.e. 18 plants in 2015 compared to 21 the preceding year (GEA 2016). Almost half of the plant capacity was commissioned in Turkey, followed by the USA, Mexico, and Kenya. Unfortunately, the global data for 2015 is currently incomplete. Country-specific data available for this report is based on EGEC (Antics et al. 2016) and REN21 (2016). In terms of energy production, the leading countries worldwide continue to be the USA with installed capacities of 3567 MW_e, followed by the Philippines with 1,930 MW_e, Indonesia with 1404 MW_e, and Mexico with 1069 MW_e. Geothermal electricity is produced in Europe in eight countries (six of them in the European Union). The three largest producers and their installed capacities are Italy (915 MW_e), Iceland (661 MW_e), and Turkey (624 MW_e). Italy is the sixth largest producer world-wide. Figure 27 provides an up-to-date overview of the countries, which use deep geothermal energy for electricity production.

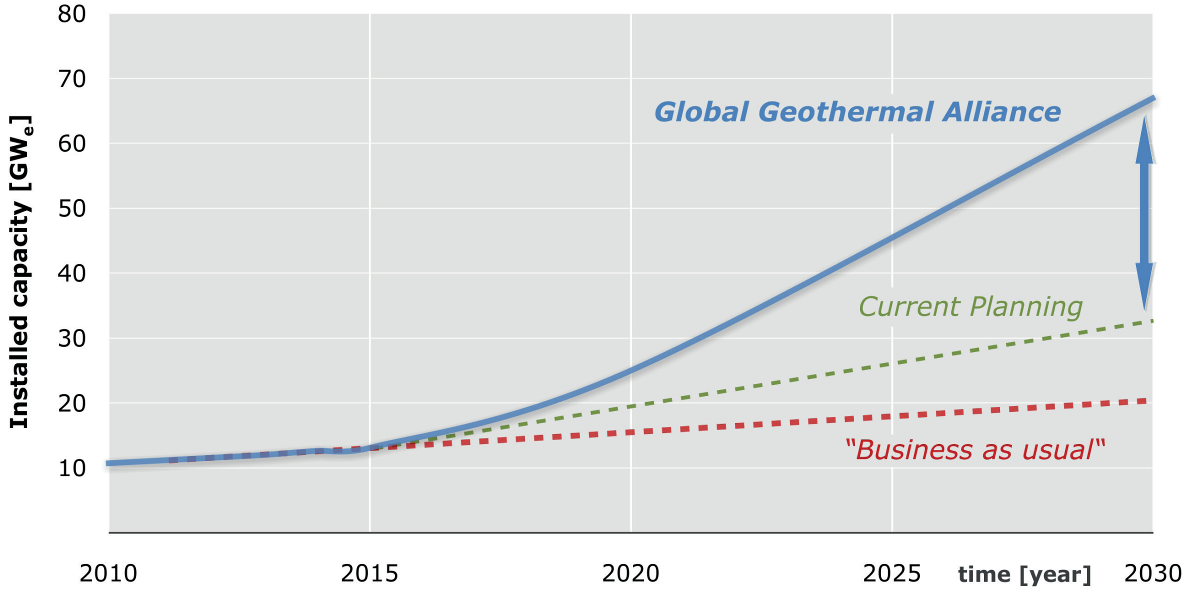

Figure 26: Global expansion targets for the geothermal energy power sector to 25 GW_e in 2020 and 67 GW_e in 2030 (blue dots) issued by the „Global Geothermal Alliance". The red dots correspond to the current figures (installed capacity in GW_e) between 2010 and 2015. The „business as usual" expansion curve (dashed red line) would lead to a doubling of installed capacities by 2030 (with respect to 2010). If current planning is implemented (dashed green line), this could expand the global market to 32 GW_e by the early 2030s (GEA 2016).

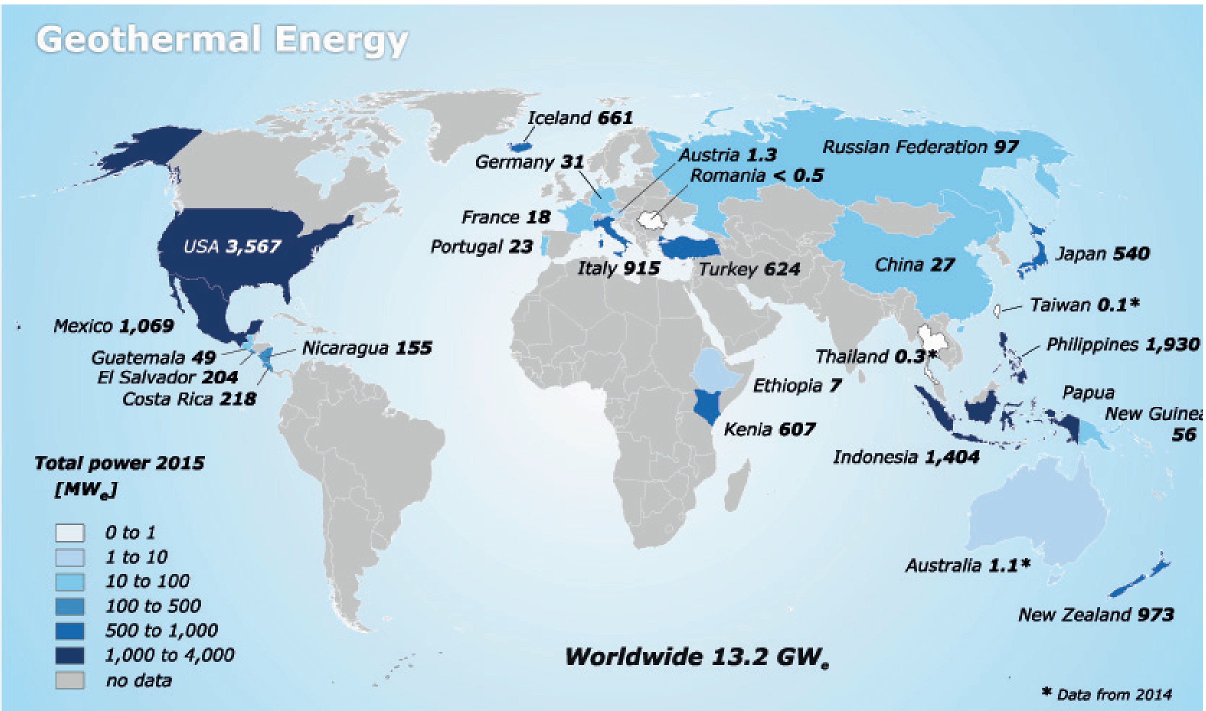

Figure 27: Countries which used deep geothermal energy to generate electricity: At the end of 2015, the global installed capacity reached 13.2 GW_e (GEA 2016).

No comprehensive global, country-specific data is available for heat utilisation in 2015. An exception is Europe where data was collected by the European Geothermal Energy Council (EGEC) and subsequently published at the European Geothermal Energy Congress 2016 (Antics et al. 2016). In 2015, the database differentiates according to various uses for the first time in 2015. In addition, applications involving shallow geothermal energy with heat pumps are listed. Hence, a clear differentiation between shallow and deep geothermal energy with respect to the use of geothermal heat is feasible. One example is Poland: Here, the heat use compared to 2014 rose by an amount of 115 MW_{th} to 605 MW_{th} in 2015. Installed capacity is divided up amongst deep geothermal energy (105 MW_e) and shallow geothermal energy (500 MW_{th}), where the geothermal heat is often harnessed with the help of heat pumps (Tab. 4). Germany has differentiated for many years between shallow and deep geothermal energy applications (deep geothermal energy: wells deeper than 400 m, temperatures exceeding 20 °C). At a global level, an additional capacity of 1.2 GW_{th} (without heat pumps) was installed for geothermal heat utilisation overall. The total installed capacity (without heat pumps) reached 21.7 GW_{th} in 2015 (REN21 2016). This corresponded to a growth of more than 5 % with a total heat use of around 75.5 TWh.

Table 4: Geothermal heat utilisation in Poland in 2015 (Data: Antics et al. 2016)

Total	Deep geothermal energy			Shallow geothermal energy (with heat pumps)
	Heating	Agriculture	Balneology	
	76 MW_{th}	3 MW_{th}	26 MW_{th}	
605 MW_{th}	105 MW_{th}			500 MW_{th}

Geothermal energy projects were also implemented in developing countries by the Clean Development Mechanism (CDM) of the UN. Industrial countries with emission reduction targets pursuant to the Kyoto Protocol can finance projects in this way for greenhouse gas reduction in developing countries and the reductions achieved are credited to their own emission reduction accounts (DEHST 2015). Out of the 35 projects, which were registered as of August 2016 (UNEP 2016), 33 are power generating facilities. Most of the projects (23) are located in the Asia-Pacific region, 14 alone in Indonesia. The five African projects are all undertaken in Kenya. Because of its favourable geological situation with its high enthalpy reservoirs in the Rift Valley, this East African country already generates around half of its power needs from deep geothermal energy. In addition, excess geothermal power was also supplied to the neighbouring countries of Ruanda and Uganda (GEA 2016). Kenya is ranked ninth in the world with an installed capacity of 607 MW_e. A further expansion of more than 1,000 MW_e is planned for the next few years (GEA 2016). Despite the good geological situation, risks still remain, e.g. when a geothermal reservoir fails to produce the expected output. Exploration risks of this kind could be covered, amongst others, by Munich Re (Munich Re 2015). The first geothermal energy insurance in Africa issued by Munich Re covers the Akiira project in the Kenyan Rift Valley.

A crucial factor limiting the further global expansion of deep geothermal energy will be the development of costs compared to other energy resources, as well as the geological and geopolitical situation in each case. The latter includes government targets, energy infrastructure, water availability, the level of technical understanding, the willingness to invest, as well as political and social conditions. The Paris Climate Protection Treaty might have a positive stimulus on the expansion of geothermal energy. One of the arguments in favour of geothermal energy is that it is a low-emissions technology compared to fossil fuels. Up to the year 2050, IEA (OECD/IEA 2011) forecasts that the global growth of geothermal energy will reach an output of 1,400 TWh_e per year for electrical energy and 1,600 TWh_{th} per year for thermal energy. This corresponds in each case to a share of global production of 3.5 % and 3.9 %, respectively. IPCC (2011) publishes similar figures: The panel predicts that geothermal energy could provide 3 % of global power demand and 5 % of global heat demand by 2050. The economic potential for geothermal power in Europe is estimated to total 4,160 TWh_e in 2050. Tables 45 to 47 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.

3.7 Renewable energy

Renewable energy is a globally established energy resource. It includes biomass, geothermal energy[2], marine energy, solar power, hydroelectric power, and wind power. Because it is virtually inexhaustible, or can be renewed relatively quickly, it differs from fossil fuels which require millions of years to regenerate. The proportion of renewable energy rose in 2015 in both the transport sector as well as in the power generation sector, to reach a record share of global primary energy consumption in the Anthropocene.

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 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. 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 13.8 % of global primary energy consumption is covered by renewable energy (IEA 2016a, Fig. 11: Development of PEC). Over three quarters of this 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 primarily still involves the use of wood and charcoal.

2 Geothermal energy is the only geological energy resource classified as a renewable energy and is therefore discussed separately (cf. 3.6 Deep geothermal energy).

After biomass, hydroelectric power is another „classic“ renewable energy resource and accounts for a share of around 2.4 % of global primary energy consumption, making it the second most important renewable energy. „Modern“ renewables such as solar power and wind power still only cover around 1.3 % 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 2015 amounted to around 77 % (2014: 60 %). This means that the annual addition of renewable energy exceeds the new installed capacities of all fossil energies for power generation together, and has therefore reached record levels. One of the reasons for this is the establishment of political conditions in many countries which favour the expansion of renewable energy. There are considerable differences in the expansion of capacities at an international level: investment in Europe, including in Germany, declined in 2015 (REN 21 2016); but there was significant growth (plus 19 %) in the USA and in the BRICS countries.

Renewable energy power generation capacities world-wide are around 1,985 GW, see Figure 28 (IRENA 2016). This compares with the around 409 GW (gross) available globally in terms of nuclear power in 2015. The main type of renewable energy for power generation is hydroelectric power, accounting for around 1,208 GW installed capacity (around 61 %), followed by wind power (433 GW; 22 %), and photovoltaics (227 GW; 11 %). With a quarter of the global installed capacity (520 GW) of renewable energy, China leads the world, with around 321 GW provided by hydroelectric power alone, and another 145 GW by wind power. Another 438 GW of renewable energy is installed in the USA (219 GW), Brazil (114 GW), and Germany (105 GW). These four countries cover almost half of the globally installed capacity for renewable energy (Tab. 49).

The installation of new renewable energy plants in the power sector mainly involves wind power, with the addition of 63 GW in 2015 (2014: 51 GW) to reach a global level of 433 GW. Additional capacities of 50 GW and 28 GW for photovoltaic power and hydroelectric power respectively were also added in 2015.

With an installed capacity of almost 40 GW for photovoltaic power generation, Germany lost its leading position world-wide for the first time. Despite the addition of 1.4 GW of new installed capacity, Germany was exceeded by China which added 15 GW of photovoltaic power capacity in 2015 to reach a total capacity of around 43 GW. China already added 10 GW in new capacity the previous year. Additional capacities were also installed in Japan (10 GW), and the USA (7.3 GW). The globally installed capacity for photovoltaic power generation rose by around 25 % compared to the previous year to 227 GW (2014: 175 GW). 2015 was therefore a record year for the installation of new photovoltaic power generation capacity.

The expansion of wind power and photovoltaic power is making dynamic progress. However, power generation from these sources is still relatively small. Although the total proportion of renewable energy in global power generation is already 23.7 % (2014: 22.8 %), hydroelectric power which accounts for around 16.6 %, is still the leading power source (around 70 % of power production from renewable energy). Wind power (3.7 %), biomass (2.0 %) and photovoltaics (1.2 %) only accounted for almost 7 % of total power generation capacity in 2015 (REN21 2016). The expected further expansion of installed capacities will drive the further increase in the share of renewable energy in power generation capacities in future.

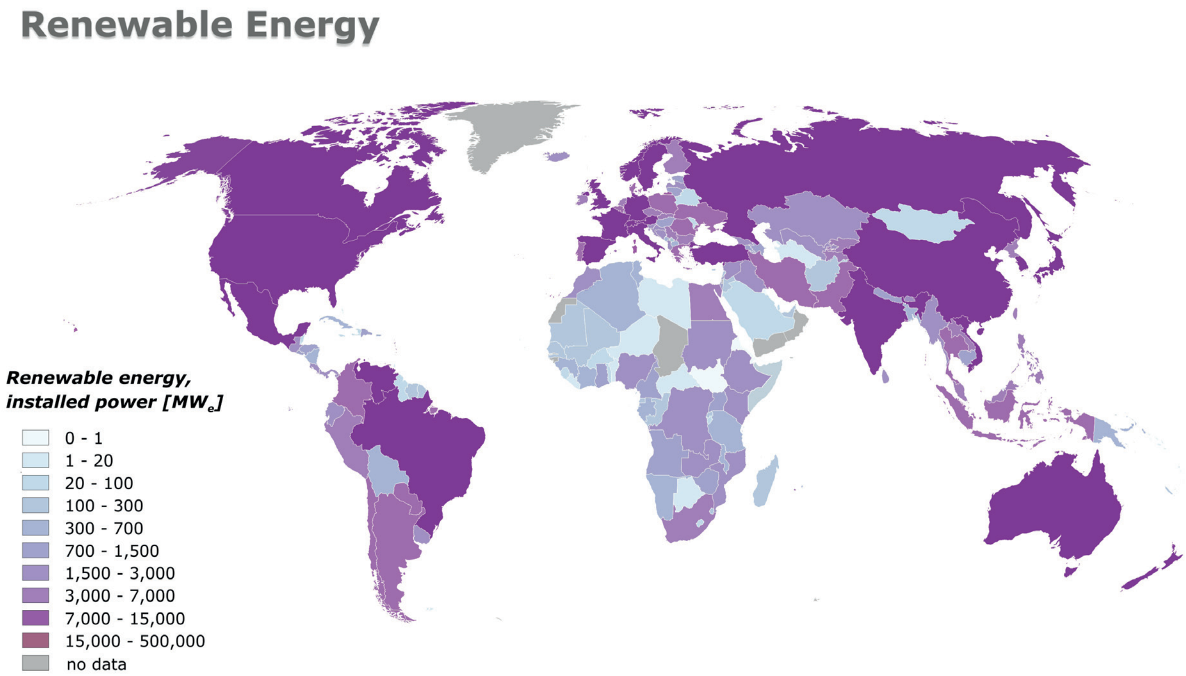

Figure 28: Total potential of the installed capacity of renewables for power generation (1,985 GW): regional distribution (IRENA 2016).

In addition to the geographical conditions, the policies and aims of the governments in question are also crucial for the strategy selected for the expansion of renewable energy. In Denmark, Ireland and Portugal for instance, over 20 % of the power demand is already covered by wind power today (REN21 2016). Iceland covers 100 % of its power demand from renewable energy (73.3 % hydroelectric power; 26.6 % geothermal power; 0.1 % wind power) (IEA 2016d). In Germany, 30 % (2014: 26 %) of power demand was covered by renewable energy for the first time in 2015 (see Germany chapter). Against the global trend, more than half of the power generated in Germany by renewable energy was produced by wind power (88 billion kWh; 14 % of the German power mix), and biomass (44.2 billion kWh; 7 % of the German power mix).

Renewable energy in the form of biofuels (ethanol and biodiesel) is also gaining in importance in the mobility and transport sectors. Biofuels currently account for 0.8 % of global end energy consumption. Global production in the last 10 years has increased several times from around 30 billion litres (2004) to around 133 billion litres (2015) (REN21 2016), and the growth is expected to continue. The leading producers are the USA and Brazil, and both countries account for over 70 % of ethanol and biodiesel. The production of wood pellets for heat generation rose from around 4 Mt (2004) to around 24 Mt (2014). The main producer regions are Europe and North America. Whilst only around 2 Mt of wood pellets were produced in Europe (EU-28) in 2004, this had already grown to around 13 Mt in 2014 (REN21 2015). Demand is growing considerably in Europe as well as in

Asia (IEA 2015) and can hardly be covered any more by domestic production. Today's biggest exporter is North America, and the export of wood pellets from North America to Europe has quadrupled since 2011 (REN21 2015). The domestic demand in Germany alone is estimated to be 1.85 Mt per year and growing (2006: 470 Kt) (DEPL 2016).

The energy generated by renewables is primarily also used where the largest capacities are installed globally (Tab. 49). An international comparison reveals that the dominant consumption countries are the USA (71.75 Mtoe), China (62.72 Mtoe) and Germany (39.95 Mtoe). Almost half of the energy consumed from renewable energy resources world-wide (364.86 Mtoe) was used in these countries (Tab. 48; Fig. 29).

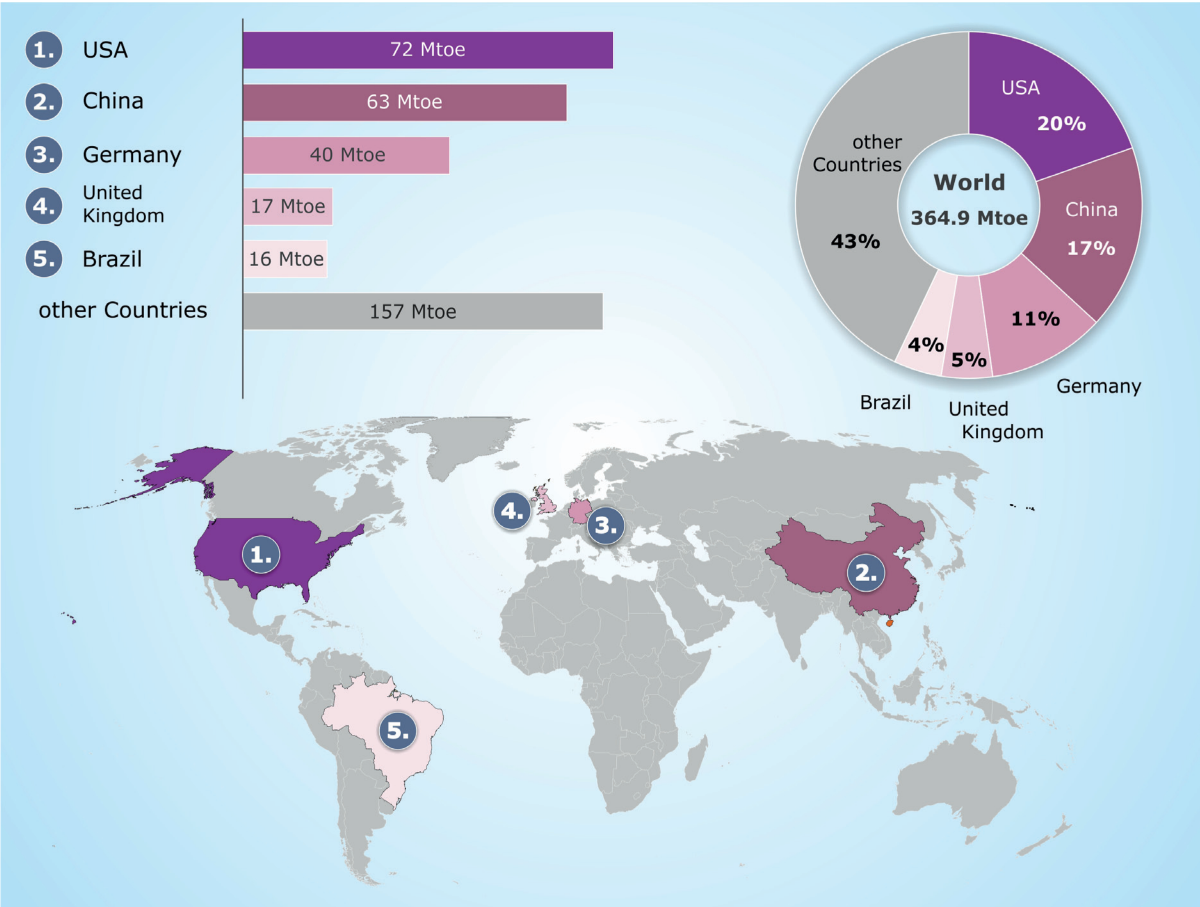

Figure 29: The biggest users of renewable energy 2015.

4 ENERGY RESOURCES IN FOCUS (SPECIAL TOPICS)

4.1 Crude oil and natural gas potential of the countries around the Horn of Africa

For over one hundred years, Eastern Africa was considered to have little potential for crude oil and natural gas. However, significant amounts of crude oil and natural gas were discovered in Uganda in 2006, and Mozambique and Tanzania in 2010. Crude oil has been produced since around the start of the millennium in Sudan and South Sudan lying further to the west. Even though the most recent finds still remain largely undeveloped and unproduced, they are proof of the existence of several independent hydrocarbon plays. The interesting question is therefore whether there is also potential in the region around the Horn of Africa (Fig. 30) in the countries of Ethiopia, Djibouti, Eritrea, Somalia and Kenya, and if so, how much. In addition to the impact on the global oil and gas market, the successful development of new oil and gas fields in these countries – amongst the poorest in the world – could open up an opportunity of using these natural resources for the benefit of the inhabitants, and thus contributing to the socio-economic development of the region.

The study by Falcon-Geoconsulting was carried out in 2016 on behalf of BGR to estimate the petroleum-geological situation. The study was based on published data and information such as geological maps, technical articles, reports by geological surveys, and company presentations. Data from around 350 wells, and 750 potential finds and fields were gathered and analysed. This enabled the mapping of 45 sedimentary basins, and a volumetric estimate of their crude oil and natural gas potential. This involved calculating the crude oil and natural gas resources on the basis of the sedimentary basins defined in the study, and then amalgamating this on a country-by-country basis. The volumes of the analysed prospects were used as the basis for quantitatively estimating the resources in the study area. These values were then used to derive three scenarios: a minimum, a mean, and a maximum case. Values for all onshore, and where relevant, all offshore resource volumes, are calculated separately for crude oil and natural gas for each country.

Reserves in compliance with the BGR definition were not identified in any of the countries involved in the analysis. Although crude oil and natural gas has been found in Ethiopia for instance (Calub field, Hilala field, Kuran field), and in Kenya (Lokichar Basin), these discoveries cannot be produced economically under today‘s market conditions. On the one hand, the discoveries in the Ogaden Basin (Ethiopia) are of natural gas, not of the economically more interesting crude oil, and on the other hand, the discoveries are located in isolated geographical positions. This affects the crude oil discoveries in the Lokichar Basin (Kenya) for instance, which are a long way from pipeline routes. In the case of Djibouti, the very high exploration risks mean that neither reserves nor resources have been identified.

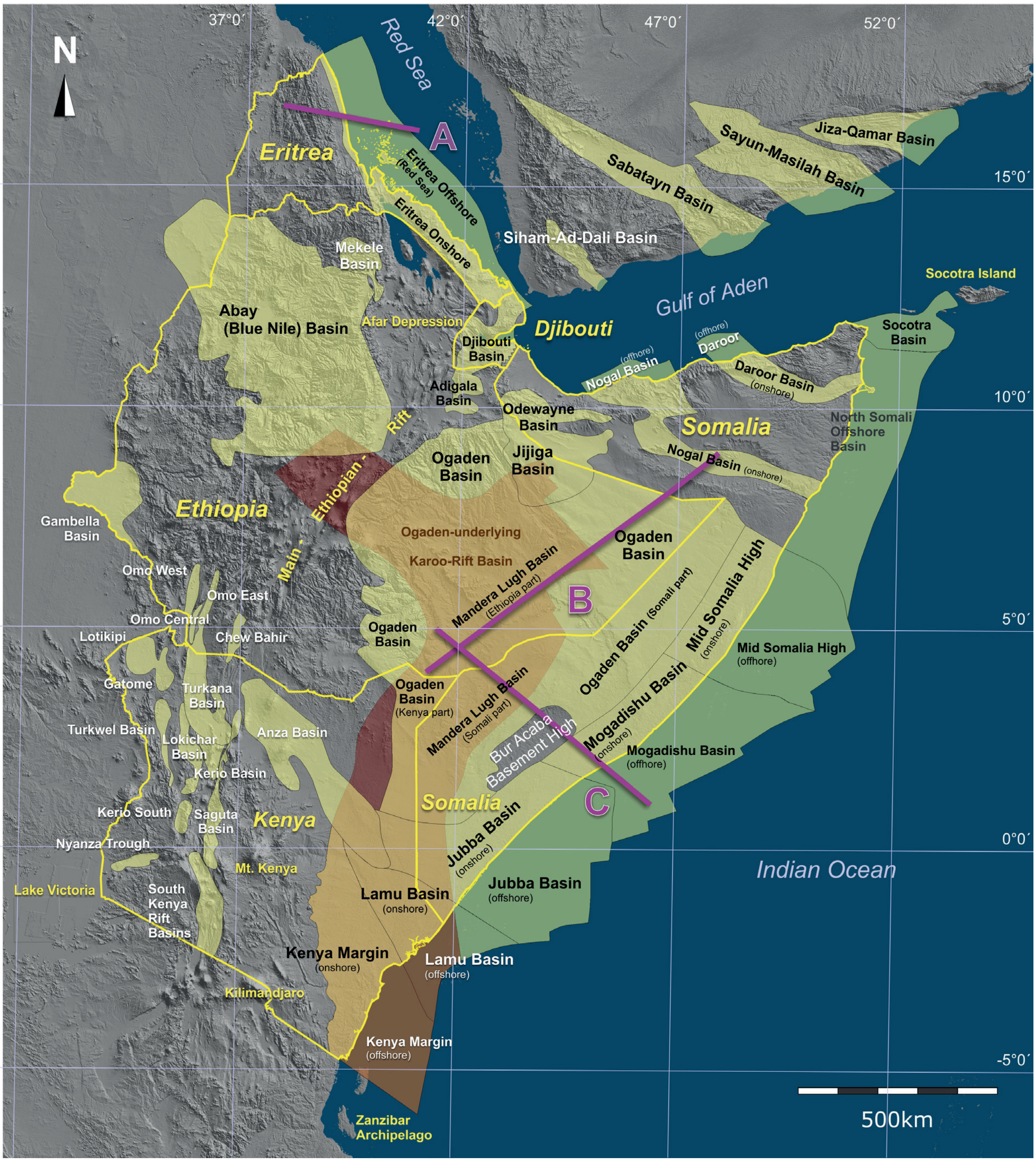

Figure 30: Countries around the Horn of Africa showing the location of the studied sedimentary basins, and the position of the geological cross-sections shown in the text.

Geological overview

Early on in the earth's history (Palaeozoic) the area of investigation was part of the Gondwana supercontinent. It was located for a long time in southern latitudes during this period, and even in the high southern latitudes during the Devonian and Carboniferous periods, so that it was located in a marginal position with respect to Gondwana glaciation during the Permo-Carboniferous. At the end of the Palaeozoic, during the Permo-Triassic, the study area was affected by a lengthy extensional phase during which large-scale rift basins were formed, known as the „Karoo“ Grabens. During this time, the study area moved northwards as a result of plate tectonic movements so that it was already located slightly south of the equator during the end of the Triassic, and the climate was generally warmer with strongly fluctuating amounts of rainfall. When the Neotethys Ocean opened in the Triassic, Gondwana broke into two major fragments during the Jurassic, causing India, Australia, the Antarctic and Madagascar to move away from Africa and the remainder of the western Gondwana fragment. This phase is characterised by geological extension and the formation of the northern Somali Graben and the continental margins of today's western Indian Ocean. The Proto-Horn-of-Africa was still located slightly south of the equator during this period.

Tectonic activity along the central African shear zone in the study area during the Cretaceous period gave rise to the formation of the highly prospective NW-SE striking grabens in Sudan (Muglad and Melut Basins), and in Kenya (Anza Basin). This was followed by the first of two major compression and inversion phases affecting the region during the Upper Cretaceous. The study area drifted over the equator to lie in slightly northern latitudes for the first time during the Cretaceous and into the early Cainozoic. During this period (Palaeogene), the area was affected by a second compression and inversion phase. Extension began again beginning in the Oligocene and led to the separation of the African and the Arabian plate. This led to the formation of the Gulf of Aden and the Red Sea, accompanied by strong volcanism in part. The Horn of Africa was also lifted up above sea level during this period. The region is currently affected by extension causing the widening of the Red Sea and the Gulf of Aden, and extension in the Afar Depression and in the East African Rift.

Separate description of each country

Eritrea is the northernmost country looked at and directly borders the Red Sea. The best developed sedimentary basin in the country is the Eritrea Offshore Basin (Fig. 31), whilst the onshore part of Eritrea is mainly occupied by the crystalline, western rift shoulder of the Red Sea. There is one small strip in the southern onshore part of Eritrea in which the remains of Mesozoic rocks are still preserved. However, this area is considered to be non-prospective in this study because of today's deep level of erosion. This means that the evaluation focused exclusively on the offshore part of the Eritrea Basin.

The Eritrea Offshore Basin formed during the opening of the Red Sea (Fig. 31), which means that structural traps are primarily expected in downthrown faults and various kinds of fault blocks (antithetic, synthetic). The formation of salt structures is also favoured by the proven presence of evaporites.

The estimated crude oil resource potential lies between 8.3 million t and 75.4 million t, with a mean of 14 million t. The values for natural gas lie between 17.5 billion m³ and 124.5 billion m³, with a mean of 29 billion m³ (Fig. 32, Tab. 5).

Profile A *Eritrea*

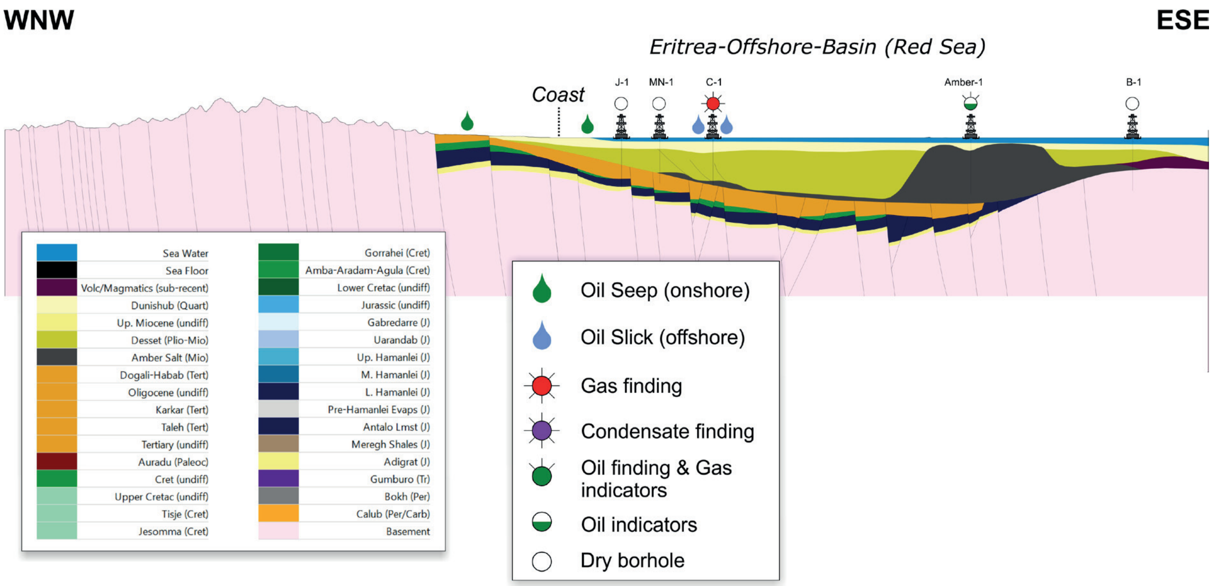

Figure 31: Schematic geological cross-section Eritrea (section A, cf. Fig. 30).

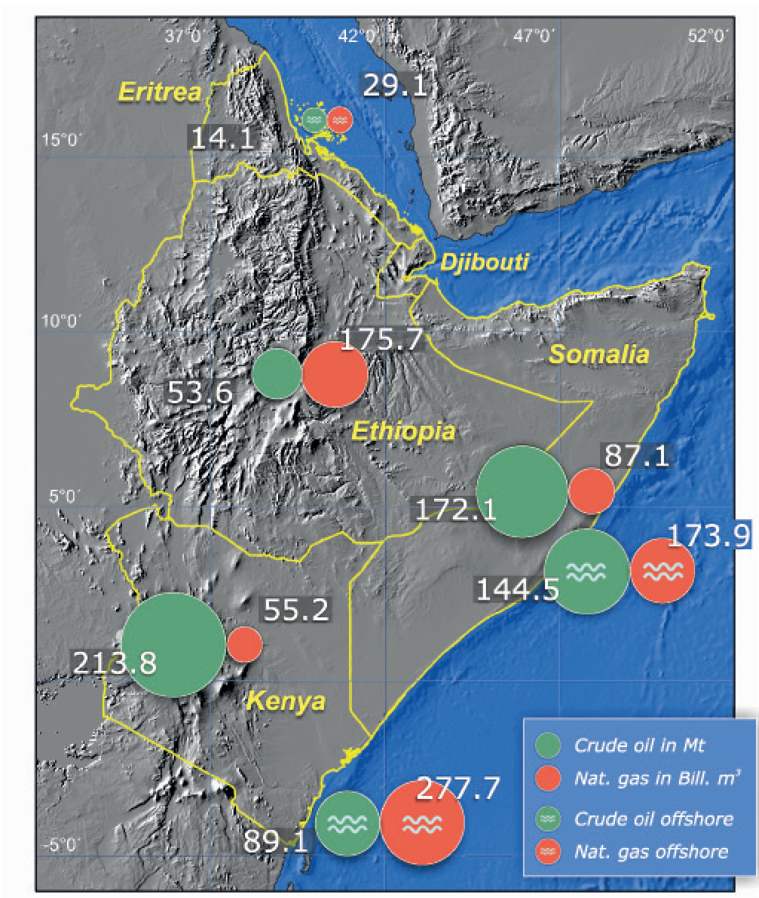

Figure 32: Crude oil and natural gas resources (mean value) of the countries around the Horn of Africa, divided up into onshore and offshore finds.

Establishing a natural gas export market is likely to be problematic because the closest potential market in Egypt has itself developed significant natural gas fields in the meantime. Other markets could exist in Asia, but there is likely to be strong competition from the Persian Gulf and southern East Africa as well. Small natural gas fields located in the vicinity of the coast could be used locally. The crude oil prospectivity is associated with a high level of risk. If it were possible to reduce this risk, for instance by the successful exploration of the pre-rift play along the coast, this could pave the way for successful development of even small fields. Larger volumes would require considerable investment in ports as well as for the establishment of a crude oil and/or natural gas infrastructure.

Table 6: Crude oil and natural gas potential in the countries around the Horn of Africa

Crude oil resources [million t]									
	Onshore			Offshore			Resources (total)		
Country	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Eritrea	–	–	–	8.4	14.1	75.4	8.4	14.1	75.4
Djibouti	–	–	–	–	–	–	–	–	–
Ethiopia	41.4	53.7	356.2	–	–	–	41.4	53.7	356.2
Somalia	97.3	172.1	409.3	81.4	144.5	393.2	178.7	316.6	802.5
Kenya	176.4	213.8	483.8	51.2	89.1	157.5	227.6	302.9	641.3
Natural gas resources [billion m³]									
	Onshore			**Offshore**			**Resources (total)**		
Country	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Eritrea	–	–	–	17.4	29.1	124.5	17.4	29.1	124.5
Djibouti	–	–	–	–	–	–	–	–	–
Ethiopia	147.9	175.7	328.6	–	–	–	147.9	175.7	328.6
Somalia	48.7	87.1	215.1	100.0	173.9	528.1	148.7	261.0	743.2
Kenya	34.7	55.2	230.7	159.2	277.7	449.0	193.9	332.9	679.7

Evaluation of gravimetric data indicates that a sedimentary basin may be preserved in **Djibouti** beneath the thick volcanites occurring in the central part of the country. Because of the tectonic position of the area which is affected by three rift arms, and because of the relatively well documented stratigraphy of the neighbouring regions (Eritrea and Somalia), there is a strong probability that this active subsidence area also contains Mesozoic basin sediments. Because of its location in a highly active tectonic region (triple junction) with very high geothermal gradients, it is probable that any potential Mesozoic source rocks will be over mature, and this means that the basin is therefore classified as non-prospective.

Prospective areas in **Ethiopia** are concentrated in two Mesozoic sedimentary basins, the Abay Basin in the north-west, and the Ogaden Basin in the south-east of the country (Fig. 30 and Fig. 33). Both of these structures were formed as intracontinental Karoo rift basins and are filled with thick Mesozoic sediments. These basins are associated with a series of smaller neighbouring satellite basins. These include the Mekele Basin, the Adigala Basin and the Jijiga Basin (Fig. 30). The Gambella Basin in the extreme west of the country is a separate basin which is stratigraphically and tectonically associated with the Cretaceous grabens in Sudan. Moreover, there are a number of smaller rift grabens located in the south-west of Ethiopia (Omo West, Omo Central, Omo East Basin, Chew-Bahir Basin), which are however seen as being either non-prospective or only having limited prospectivity.

Oil and gas fields were discovered in a thick Karoo graben at the southern end, located below the northern part of the Ogaden Basin. Three fields – Calub and Hilala (natural gas) and El Kuran (crude oil) – were discovered in the Ethiopian part of the basin. This indicates that a Karoo source rock with natural gas potential (Bokh Claystone) is present, as well as an Upper Jurassic source rock, which is considered responsible for the shows of crude oil. The Permo-Triassic Bokh Claystone is probably over mature in the central part of the Karoo Graben, whilst the Jurassic source rock in the southern part of the Ogaden Basin is considered to be immature, which means that only the central part of the Ethiopian Ogaden Basin is rated as prospective. The reservoir rocks of interest are Permian sandstone (Calub) and Triassic/Jurassic sandstones (Adigrat).

Profile B *Ethiopia-Somalia*

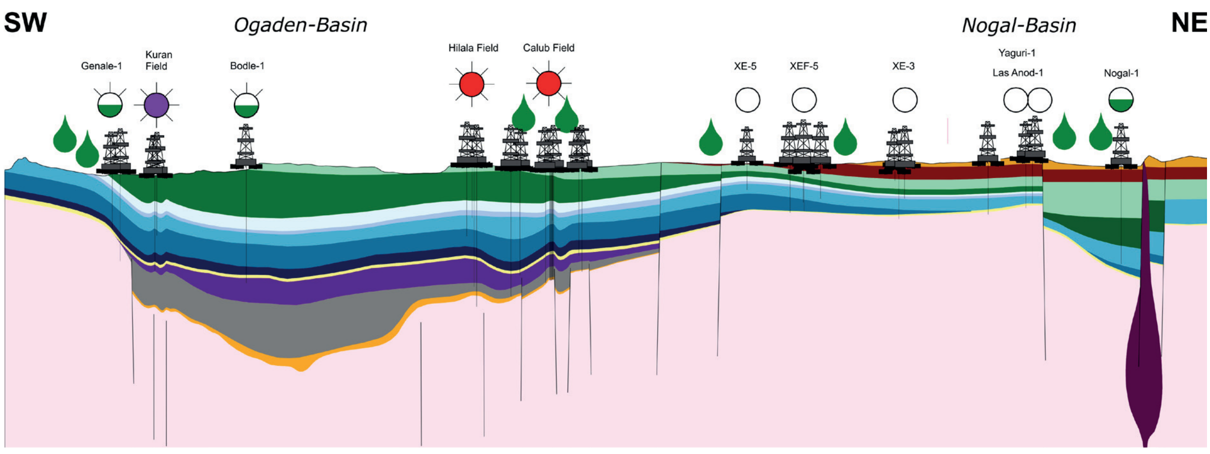

Figure 33: Schematic geological cross-section Ethiopia/Somalia (cross-section B, cf. Fig. 30, legend cf. Fig. 31).

The Jijiga-Basin is the Ethiopian extension of the Somali Odewayne Basin. No natural oil seeps are known here, which either indicates the presence of a tight cap rock or a risk associated with the source rock and/or the timing of hydrocarbon generation. A Karoo graben is located below the western edge of the basin. The situation with respect to source rocks and reservoir rocks is similar to that in the Ogaden Basin.

The Abay (Blue Nile) Basin is a very large basin which, although clearly defined gravimetrically, has not yet been the focus of any oil and gas exploration drilling. Although originally a part of the Ogaden Basin, it was separated off during the Miocene by the East African rift system. Large parts of the basin are covered by young basalt lava today. It is not clear whether an arm of the Ogaden-Karoo Graben is located beneath the Abay Basin, a situation which would strongly enhance its prospectivity. Only one seep of crude oil is known. Crude oil and natural gas plays similar to those in the Ogaden Basin are feasible.

The two wells drilled to date in the Omo-East Basin revealed very good shows of crude oil, and good shows of natural gas, and document the existence of an active hydrocarbon system. However, the well data indicate that there is a cap rock risk in this basin. The spatially limited extent of the prospective area is revealed by seismic and gravimetric data. Mio-Pliocene lacustrine sandstones are considered to be potential reservoir rocks.

The crude oil resource potential in the four basins lies between 41.4 million t and 356.2 million t, with a mean of 53.7 million t. The values for natural gas lie between 147.9 billion m^3 and 328.6 billion m^3, with a mean of 175.7 billion m^3 (Fig. 32, Tab. 5).

Despite the larger natural gas discoveries (around 110 billion m^3) in the Calub and Hilala fields of the Ogaden Basin, developing these fields is difficult because the absence of any suitable infrastructure means it is unclear how the produced natural gas could be transported. Ongoing conflicts with Somalia and Eritrea, as well as the very recent extremist attacks in the Gambella province, also make future oil and gas activities in various parts of the country difficult.

A number of NW-SE-oriented rift basins are located in North **Somalia** in the form of the Odewayne, Nogal and Daroor Basins. The Socotra and North-Somali offshore basins are located along the east coast. The Somali part of the Ogaden Basin is located in central and southern Somalia (Fig. 34), and these areas are also the location of the Mid-Somali-High Basin (onshore and offshore part), the Mogadishu Basin (onshore and offshore part) as well as the Jubba Basin (onshore and offshore part) located in the far south (Fig. 30).

Of the 15 mapped sedimentary basins, 12 were subject to a petroleum-geological evaluation (divided into onshore and offshore areas), 6 of which looked at the offshore areas. In the northern offshore area (north Somalia to Socotra) the potential reservoir rocks range from Upper Jurassic (Gabredare Sandstones) to the Cretaceous, and the source rocks are primarily of Jurassic to Cretaceous age. A potential crude oil and natural gas play may be present along the east coast of Somalia and consisting of Bokh Claystone as the source rock and Calub and Adigrad sandstones and/or Cretaceous turbidites as reservoir rocks. The Somali extensions of the Yemeni Say'un Masilah and Sab'atayin basins (the most important crude oil basins in Yemen) form the Daroor and Nogal Basins (Fig. 30).

Profile C *Ethiopia-Somalia*

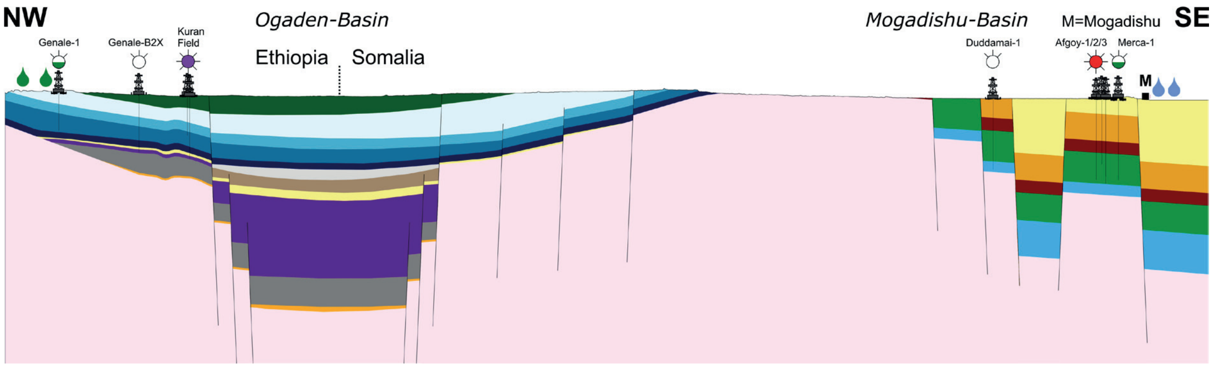

Figure 34: Schematic geological cross-section Ethiopia – Somalia (cross-section C, cf. Fig. 30, legend cf. Fig. 31).

In analogy with Yemen, the petroleum play primarily consists of Jurassic source rocks, and Upper Jurassic limestones and Lower Cretaceous Jesomma Sandstones as the reservoir rocks. Adigrat Sandstones could represent an additional oil and gas play, particularly in structurally high positions along fault blocks.

The crude oil resource potential in the evaluated basins lies between 178.7 million t and 802.5 million t, with a mean value of 316.6 million t. The values for natural gas lie between 148.7 billion m³ and 743.2 billion m³, with a mean of 261 billion m³ (Fig. 32, Tab. 5).

The situation in Somalia is currently dominated by the civil war which has already lasted several decades. There is currently no infrastructure for the crude oil and natural gas industry. The most important sedimentary basin in the country (Nogal and Daroor onshore), as well as the passive continental margin of the Indian Ocean, are affected by „force majeure“. There are signs of a slow normalisation of conditions in Somalia, but new problems could arise with the secession efforts of Somaliland and Puntland. Exploration activities offshore Somalia could in principle be able to start up again, although this is conditional on the associated „force majeure“ status of the previous permit holders. Whilst the southern offshore area has clear potential for natural gas, the mid-Somali High and possibly also the offshore NE-Somali Basin may also have a chance of being prospective for crude oil, just as the shelf of the Gulf of Aden. The situation onshore remains critical, especially in Ogaden, where there are continuing border conflicts with Ethiopia.

Kenya has a wide range of basin types. Whilst the west of the country is dominated by Cenozoic rift basins (Turkana, Lotikipi-Gatome, Turkwel, Lokichar, North-Kerio, South-Kerio, Saguta, Nyanza, South-Kenya Rift Basin), the Anza Basin is a Cretaceous rift basin. Outliers of the Ogaden Basin (Mesozoic and Karoo parts) are located in the north-eastern part of the territory. The south-east of Kenya is the location of the Lamu Basin (onshore and offshore part), as well as the Kenya-Margin Basin (onshore and offshore part), which are both passive continental margin basins.

Ten basins (onshore and offshore) were evaluated in Kenya. The most interesting are the, in some cases, small-scale basins along the East African Rift System, which include the Lokichar Basin, which boasts a large number of crude oil discoveries. The Anza Basin lies to the east of this and contains the Bogal natural gas discovery. The Anza Basin was originally an extension of the South Sudanese Lower Cretaceous Rift Basin with Lower Cretaceous source rocks, which was later broken up by the Oligo-Miocene East African Rift. This restructuring probably led to the fragmentation of the existing oil fields which means that although many shows of crude oil have been discovered today, hardly any accumulations of oil have been found so far. The sedimentary column thickens to the south-east in the direction of the Lamu Basin which therefore also increases the potential prospectivity for natural gas. Three sub-economic fields have been discovered so far (two natural gas finds, one crude oil find). The existing data on the Cretaceous sandstones indicate the presence of low porosity, which means that the main reservoir rock is probably in Eocene sandstones.

The resource potential for crude oil in the evaluated basins is between 227.7 million t and 641.3 million t, with a mean of 302.9 million t. The values for natural gas range from 193.9 billion m³ to 679.7 billion m³, with a mean of 332.9 billion m³ (Fig. 32, Tab. 5).

Kenya is one of the politically more stable countries in East Africa, but is nevertheless also affected by ethnic conflicts. The Somali Al Shahab militia also causes unrest in the country. The development of around 100 million t crude oil resources in the Lokichar Basin is still unclarified because of the current absence of any transport infrastructure. Like all lacustrine type-1 crude oils, this crude oil contains a high proportion of wax, which means that transport requires additional investment in heating facilities for pipelines, or for rail tank cars. Kenya has a large natural gas potential and minor crude oil potential in the offshore area.

Summary and conclusions

The 45 mapped and evaluated sedimentary basins in the countries of Ethiopia, Djibouti, Eritrea, Somalia and Kenya, indicate a potential totalling 687 million t crude oil and almost 800 billion m³ natural gas resources (the mean figure in each case). This is of a similar size to the crude oil resources in Kuwait (700 million t), Qatar (700 million t), or Yemen (500 million t), and the natural gas resources of Tunisia (750 billion m³), Yemen or Kuwait (each 500 billion m³). Somalia and Kenya have the largest share of the crude oil resources onshore and offshore with 317 million t. and 303 million t respectively. In terms of natural gas resources, the principle areas are the offshore zones of Somalia and Kenya with 174 billion m³ and 278 billion m³ respectively, as well as the Ogaden Basin in Ethiopia with 278 billion m³.

If the calculated crude oil and natural gas resources are grouped separately according to reservoir lithology or stratigraphic age of the reservoir, this reveals that around 30 % of the crude oil resources are held in carbonate reservoirs, and around 70 % in clastic reservoirs. The natural gas resources are found to around 94 % in clastic reservoirs, with only around 6 % in carbonate reservoirs.

In terms of their distribution according to stratigraphic age, only a very small proportion (< 50 million t) of the crude oil is stored in Permian reservoirs, whilst the lion‘s share of the total resources is held in Triassic to Miocene reservoirs, of which the Triassic-Jurassic reservoirs account for the largest volume. Natural gas shows a completely different picture: the higher share of natural gas resources in Permian reservoirs (compared to crude oil) is attributable to the influence of the large volumes in the Karoo sediments of the Ogaden Basin. The higher level of resources in the Eocene reflects the numerous potentially prospective natural gas structures in Tertiary clastics in the southern part of the study area (offshore Kenya, southern Somalia).

It is not foreseeable under the current conditions when specific onshore fields could become developed. A lack of infrastructure and continuing political problems, border disputes and rebel and extremist conflicts in numerous regions in these countries make the situation even more complex. Because transport is easier, better chances are seen for the highly prospective and underexplored offshore basins of Kenya and Somalia, where there is even considered to be potential for some giant fields.

4.2 Shale oil and shale gas in Germany – resources and environmental aspects

Shale oil and shale gas deposits have established themselves globally as significant resources for fossil fuels. This was initiated by the commercial development of numerous shale gas deposits in the USA in the last 15 years. The USA will probably be capable of covering its natural gas demand in the medium term from its domestic sources. The shale gas boom was followed a few years later by the shale oil boom, which enabled the USA to become the world‘s largest oil producing country, to even put it ahead of Saudi-Arabia and the Russian Federation.

This was the background against which BGR investigated the potential of shale gas and shale oil in Germany in a project lasting several years (NiKo). The study „Schieferöl und Schiefergas in Deutschland – Ressourcen und Umweltaspekte" (available in German) was published at the beginning of 2016 (BGR 2016b). In addition to conducting a resource assessment, the study also looked at the geoscientific aspects of the potential environmental impacts of the fracking method.

The shale boom in the USA was initiated a public debate on the environmental consequences of the development and exploitation of these deposits. The main concern is about the environmental impact of using hydraulic stimulation (fracking) to develop these resources, in particular with regard to groundwater and drinking water protection. Following the use of fracking in one of the first exploration wells for potential shale gas deposits in Lower Saxony, a controversial debate about fracking technology began in Germany as well. Exploration activity for shale gas deposits in Germany largely came to an end in 2011, and the use of hydraulic stimulation was banned by numerous federal states.

The German Bundestag (parliament) adopted new regulations for the use of fracking in June 2016, and banned it for the development of natural gas and crude oil deposits in shale, claystone and marlstone, as well as coal seams. For research purposes on environmental issues of hydraulic stimulation a limited number of maximum four pilot or demonstration projects are possible provided approval of the federal states governments. The legal amendments completely entered into force in February 2017.

Occurrences and resources in Germany

The non-technical terms shale oil and shale gas refer to crude oil and natural gas occurrences in organic-rich, sedimentary shales, regionally distributed in Germany, there are quite a number of such shale formations, also known as source rocks.

By far the most prospective formation for shale oil in Germany is the Posidonia Shale of the Lower Jurassic. The largest potential exists in the Lower Saxony Basin, with smaller potential in the Upper Rhine Graben and northern north Germany (Fig. 35). Followed by Lower Carboniferous shales, the Posidonia Shale also has the largest shale gas potential. As is also the case with shale oil, this potential is primarily found in the Lower Saxony Basin, as well as to a lesser extent in the Upper Rhine Graben. The main potential in Lower Carboniferous shales is found near the Baltic coast of Western Pomerania. In addition to the aforementioned formations, the Wealden Formation of the Lower Cretaceous in the Lower Saxony Basin also has significant potential for shale oil as well as shale gas. However, this formation is primarily found at shallower depths between 500 m and 1,000 m below ground level. The shale gas potential of the Middle Rheatian shale of Triassic age is also worth mentioning. The other formations analysed only have very minor shale oil and shale gas potential.

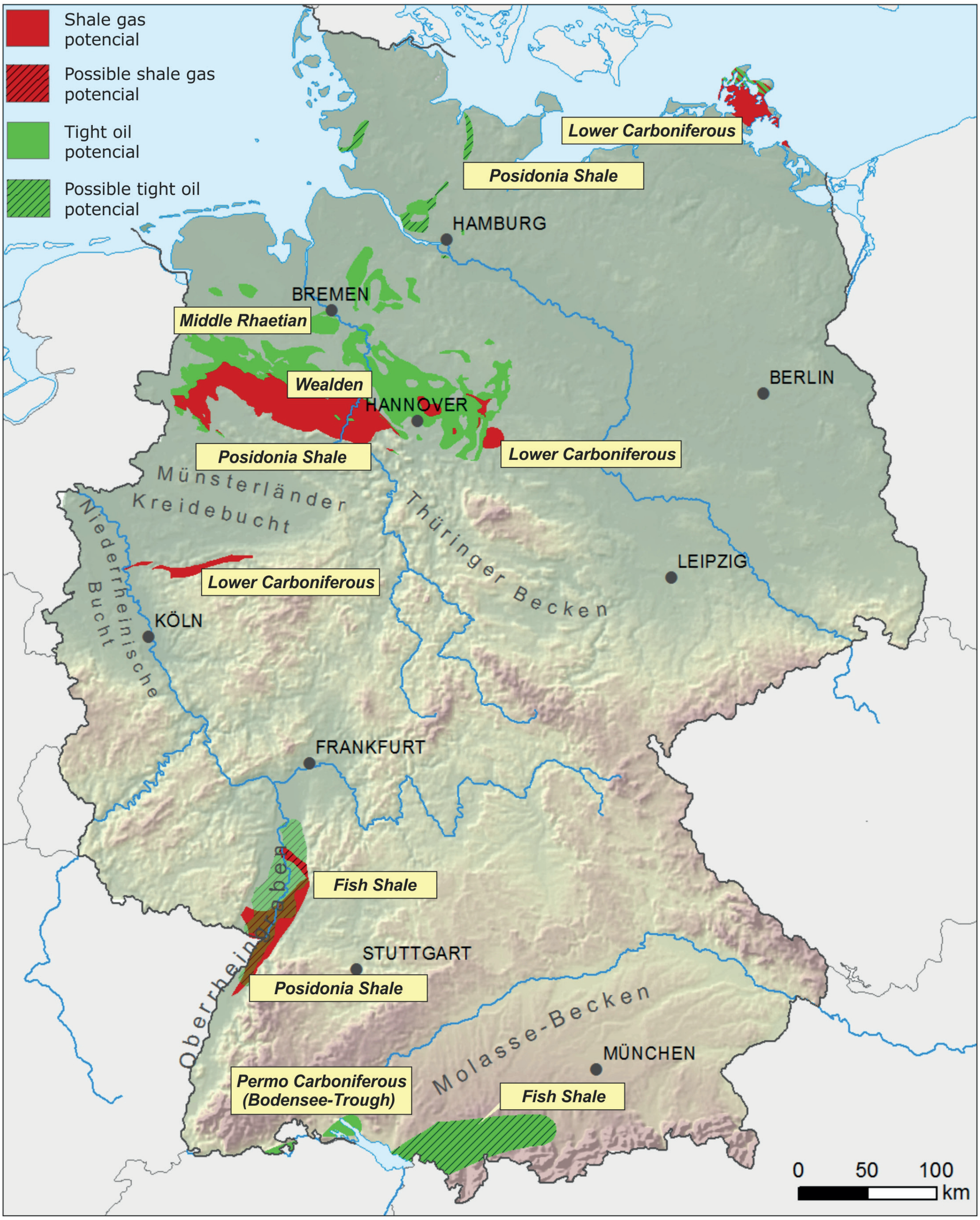

Figure 35: Overview of the areas with shale oil or shale gas potential including the name of the shale formation in each case: hachured areas: areas with possible shale oil or shale gas potential; the potential within these areas only exists in smaller sub-zones which cannot be localised more precisely by the study (BGR 2016b).

Most of the resources of shale oil and shale gas are located at depths shallower than 3,000 m. This applies to almost all of the formations studied. One exception is the Lower Carboniferous formation along the Baltic coast of Western Pomerania, where shale gas potential is also considered to be present at depths greater than 3,000 m.

The technically recoverable shale oil resources at depths between 1,000 m to 5,000 m lie between 13 million t and 164 million t, with a mean of 50 million t (Fig. 36). The potential increases to 70 million t (mean) if shallower occurrences up to depths of 500 m are also taken into consideration. The shale oil resources in Germany are of a similar size as the conventional resources and reserves (LBEG 2016), and therefore smaller than domestic annual consumption (as at 2015).

The technically recoverable shale gas resources in Germany in the 1,000 m to 5,000 m depth range are between 320 billion m³ to 2,030 billion m³, according to the BGR study, with a mean of 800 billion m³ (Fig. 36). The mean rises to 940 billion m³ if potential lying at depths of between 500 m to 1,000 m are also taken into account. This means that the resources in Germany of technically recoverable shale gas are several times larger than the conventional natural gas resources (including tight gas). In comparison: the domestic annual natural gas production in Germany amounts to around 10 billion m³ and the annual consumption to around 90 billion m³.

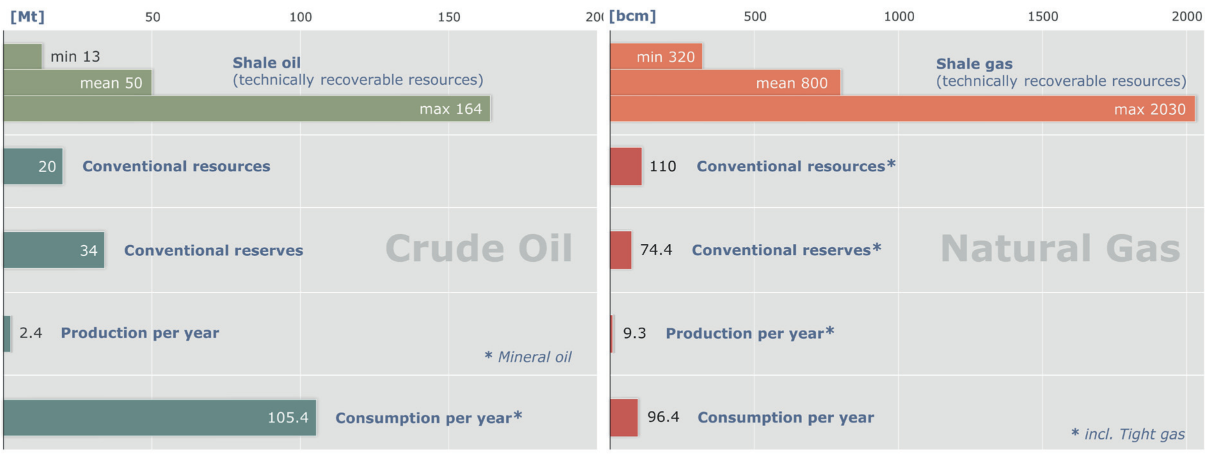

Figure 36: Shale oil and shale gas resources at depths between 1,000 m to 5,000 m; conventional crude oil and natural gas resources and reserves, production and consumption in 2015.

The shale oil resources in Germany are the fifth largest in Europe, which total around 2 million t. In an international ranking, Germany‘s shale oil resources place it in position 35 (Fig. 47). The outstanding positions of the Russian Federation and the USA are followed by China, Argentina and Libya, although their potential is only half as large. However, global estimates are not yet complete, and a number of regions have not yet been assessed comprehensively.

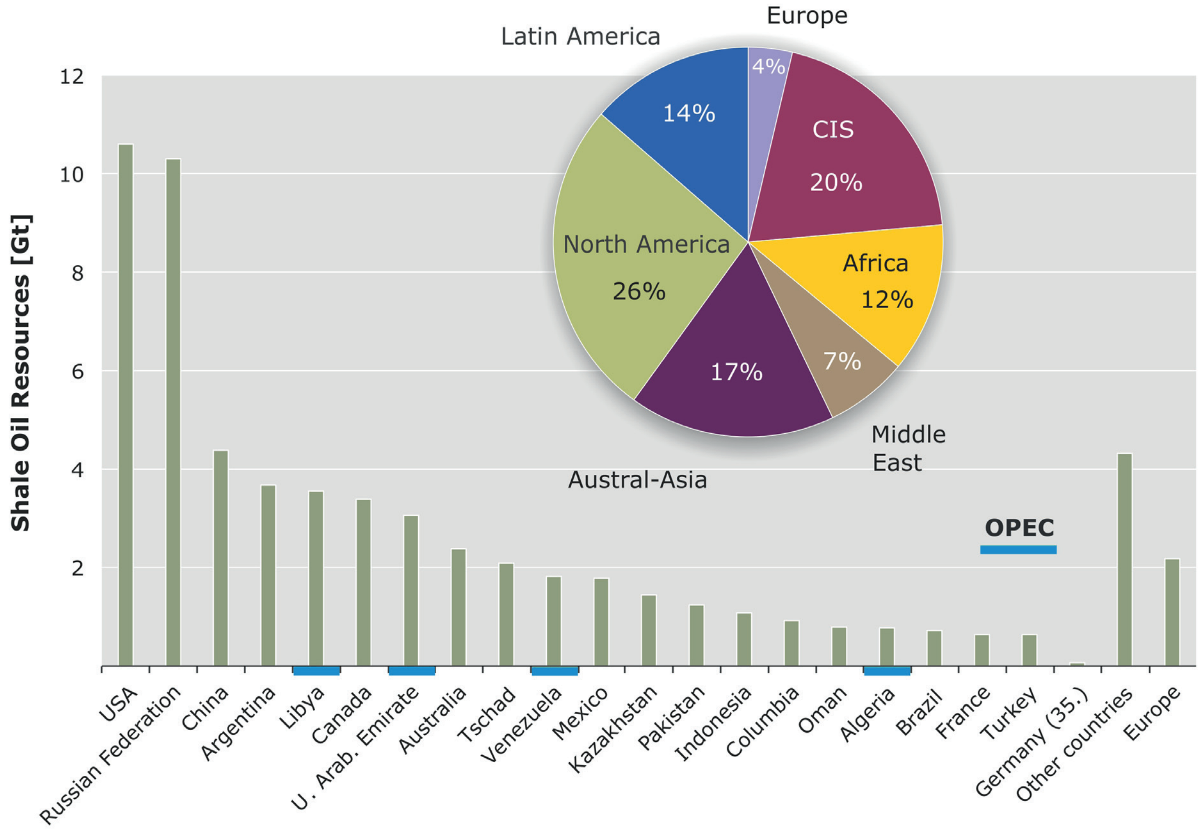

Figure 37: Shale oil resources of the top 20 countries, and Germany, also showing distribution according to regions.

In the European ranking, the Germany's shale gas resources resemble the fourth largest behind France, Spain and Romania. Total reported shale gas resources in Europe are currently estimated to be 12.6 trillion m³, and thus represent half of the European natural gas resources. In an international ranking, Germany's shale gas resources are well below the resources of China, Argentina, Algeria and the USA, and place it in only 30th position (Fig. 38). Compared to the shale oil resources, the world wide shale gas resources are distributed more uniformly, and over a larger number of countries. However, there are still considerable uncertainties associated with the estimated volumes.

Estimates of the technically recoverable resources indicate on the one hand that shale gas in particular represents a significant resource in Germany, and that there is also a limited potential for shale oil. On the other hand, neither a shale gas nor a shale oil boom comparable to that in North America can be expected. The exploitation of shale gas in Germany could, however, help compensate for the decline in natural gas production in Germany, and therefore help to slow down the increasing dependence on natural gas imports.

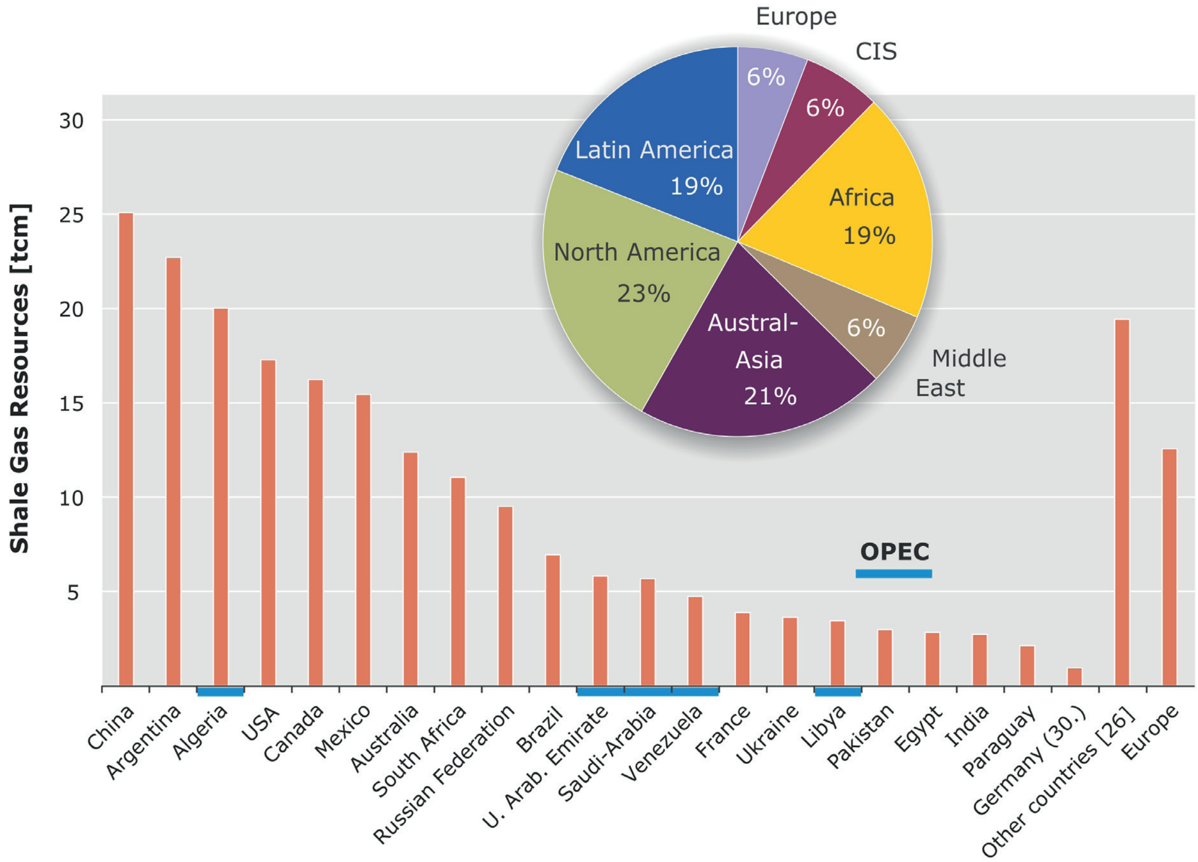

Figure 38: Shale gas resources in the top 20 countries, and Germany, as well as distribution according to regions.

Environmental aspects of fracking

Hydraulic stimulation (fracking) is required to develop shale gas deposits. This technique is subject to a controversial public debate of the potential environmental impacts, particularly with respect to groundwater and drinking water resources, as well as the disposal and handling of produced water from the reservoirs, and the occurrence of induced felt seismic events. Because shale gas and shale oil deposits cover larger continuous areas in the underground, and the reservoir rocks have very low permeabilities, their development requires the drilling of many more wells with multiple frack stages, compared to the development of conventional fields. Aspects such as water consumption, surface and landscape footprint, increased vehicular traffic, air pollution, and greenhouse gas emissions, are all part of the discussion involving the environmental impacts associated with the exploitation of these deposits.

As part of the NiKo study, BGR thus carried out geoscientific investigations and numerical modelling to investigate the processes occurring during the fracking stimulation of underground formations, and thus to assess potential risks to groundwater reservoirs in shallow horizons, as well as the potential for fracking induced earthquakes. The model scenario targeted a hypothetical shale gas play in the Posidonia Shale in the North German Basin –resembling the most prolific basin and formation in Germany. The findings can therefore be employed with regard to environmental risk assessments in the head of potential pilot projects.

Computer simulations were carried out on aspects including the potential upward migration of injected fluids from deep underground formations. The numerical simulations revealed that even in long-term scenarios, and the presence of preferential natural transport pathways (fault zones, open fractures), there was no upward movement into shallow aquifers. In addition, the simulations also modelled the fractures artificially created by fracking. This demonstrates that fracture growth is controlled by the injection parameters, and particularly by the volume of injected fluid, and that the average fracture height in the modelled scenario was around 50 m. According to these findings, adequate safety distances to usable aquifers can therefore be maintained.

Moreover, the numerical modelling study carried out by BGR on the induced seismicity associated with hydraulic fracturing reveals that the maximum moment magnitudes reach M_w 0.5. This is below the level felt at the surface in the vicinity. These numerical findings were corroborated by an analysis of the spatio-temporal correlation between seismicity and conducted hydraulic stimulations in primarily tight gas reservoirs in Lower-Saxony (327). This study revealed that no felt earthquakes (local magnitude (M_L) below 2.0) have been induced by these frac operations. Thus, felt earthquakes induced by hydraulic stimulations are unlikely in large parts of Germany which, like the North German Basin, are at low risk of the occurrence of natural earthquakes.

The study concluded that potential contamination paths associated with the fracking stimulations in the deep underground rock formations are considered unlikely even in the long term. Therefore, by carrying out detailed site-specific investigations, hydraulic stimulations can be designed and conducted in such a way that an uncontrolled migration of fluids into shallow groundwater aquifers can be excluded with a very high degree of probability. As already demonstrated in numerous national and international studies (e.g. EPA 2015), this confirms that the main risk to the contamination of drinking water resources comes from surface operation spills followed by well integrity issues. One of the future challenges will be to improve the technical monitoring of well integrity and the safe site and well closure. Baseline monitoring allowing the evaluation and assessment of deviations from the original conditions are particularly important in this regard. From a geoscientific point of view, the fracking technology can generally be employed in a controlled and safe manner, provided legal regulations and best practices are carefully observed, and the necessary detailed site-specific investigations are conducted.

Outlook

Germany has significant shale gas resources; however, exploration for these resources has barely begun. Let alone from technical reasons developing these resources is not feasible in the short term, but could only take place successively, and over a period of decades. However, according to the new statutory provisions, the further exploration and production of shale gas and shale oil in Germany is prohibited by the ban on using fracking technology in shale formations. It still remains to be seen whether pilot or demonstration projects especially for environmental impact research – as provided by the new legislation – will actually be realised. Numerous federal state governments in Germany have already stated that they will not approve any pilot projects on their respective territory. These projects would be necessary, however, to adapt the fracking technology to the local conditions, and for the further development of environmental standards such as for monitoring measures.

Under the current conditions, any use of shale gas deposits in Germany is considered highly unlikely in the foreseeable future. In the absence of this option, however, there seems to be no way of preventing the further decline of domestic natural gas production and the further rise in the country‘s dependence on imports.

4.3 Underground energy storages for the energy transition

With its energy transition, Germany has decided to completely restructure its energy supplies. The withdrawal from nuclear power by 2022, and the policy to replace fossil energy resources with renewable energy, are aimed at safeguarding the transition to a safe, environmentally-compatible and economically successful future (BMWi 2015). The energy transition should thus make a contribution to achieving the climate protection targets which envisage a reduction in German greenhouse gas emissions of at least 80 % to 95 % by 2050. 80 % of the power supplies are to be covered by renewable energy by the middle of the century. The share of renewable energy in gross end energy consumption is to reach 60 % (German Government 2010).

Quantitative targets of the energy transition (greenhouse gas emissions, as well as renewable energy excluding the transport sector) and current status (2015). Source: BMWi 2015, 2016 (* Figures from 2014, ** heat + cold)

	2015	2020	2030	2040	2050
Greenhouse gas emissions (GGE)					
THG compared to 1990	-27 %	at least -40 %	at least -55 %	at least -70 %	at least -80 to -95 %
Renewable energy					
Share of gross end energy consumption	13,5 %*	18 %	30 %	45 %	60 %
Share of gross power consumption	32,6 %	at least 35 %	at least 50 %	at least 65 %	at least 80 %
Share of heat consumption	13,2 %**	14 %			

Renewable energy in Germany is mainly provided by the fluctuating energy resources wind power and solar power. The strong expansion of fluctuating power generators will be flanked in future by the increasing number of periods when either too little electricity is generated because of unfavourable weather conditions, or too much power is generated during favourable weather conditions – more power than the grids can accommodate and distribute, and/or consumers can use. Even well designed „intelligent“ power grids will not always be able to balance out these fluctuations across regions and borders. Storages for energy and energy resources can make a contribution here to balancing out power generation and power consumption, as well as storing large amounts of excess energy over longer periods of time. The conversion of power from renewable energy into for instance methane (CH_4) or hydrogen (H_2) is considered to have major development potential, because of the ability to use them directly or to store them for long periods of time (SRU 2013).

The size of the future storage demand depends on a number of factors, and is currently difficult to estimate. The meta study „Energy storages“ published by the Fraunhofer Institute (Fraunhofer UMSICHT & Fraunhofer IWES 2014) provides a good overview of the influencing factors and the storage demand. The German Institute for Economic Research assumes that a share of more than 70 % of renewable energy in the power mix will lead to a considerable demand for storage capacity, and will depend on the prevailing conditions, e.g. the composition of the power generation system, as well as the expansion of the power grids (Shill et al. 2015). If renewable energy supplies all of the power, simulations indicate the need for 34 GW power storage capacity. Conventional pumped hydro plants will not be able to satisfy this demand (ZfES 2012). The development and expansion of new storage technologies is therefore required to implement the energy transition.

Energy storages in underground geological formations

Underground geological formations with (1) man-made salt caverns or (2) natural pore storages, offer two different storage options for the storage of large amounts of energy. Gas storages have already played an important role in Germany since the 1960s for the seasonal storage of natural gas. At the end of 2015 in Germany, there were 51 gas storage facilities, comprising 20 pore storages, as well as 31 cavern storages with a total of 260 separate caverns. 103 separate cavern storages are operated to store crude oil, petroleum products and liquefied gas (LBEG 2016). The energy transition gives rise to new areas of application, such as the storage of compressed air and hydrogen. The following sections look at the storage of these two energy resources in caverns and pore storages.

Cavern storages

Cavern storages are artificially created cavities in salt formations which are engineered by the controlled dissolution of the salt by injecting water (solution mining). The caverns created in this way typically have volumes of several 100,000 m³ (Gillhaus & Horvath 2008). Because of its very low permeability, salt has outstanding properties for the storage of liquid and gaseous fuels. The conditions required for the construction of caverns are the presence of salt formations with adequate thicknesses and quality, and the ability to either use the brine which is created or to dispose of it in an environmentally-compatible way. Unlike pore storages, caverns have the advantage of allowing very rapid injection and withdrawal of the stored medium. This means that salt caverns are suitable for both short-term peak shaving applications as well as for medium-term and long-term storage.

Large salt deposits are primarily found in north Germany. Huge salt structures have formed here from the originally horizontally bedded salt formations as a result of upward movement of the salt over the last 250 million years (Fig. 39). These salt structures have a wide variety of different shapes: in addition to simple and relatively flat updomed structures – known as salt pillows – the so-called salt diapirs are particularly of special importance. The latter have broken through the rock overlying the salt and risen up in some cases close to the surface, and can form very thick salt accumulations with thicknesses of up to 7,000 m.

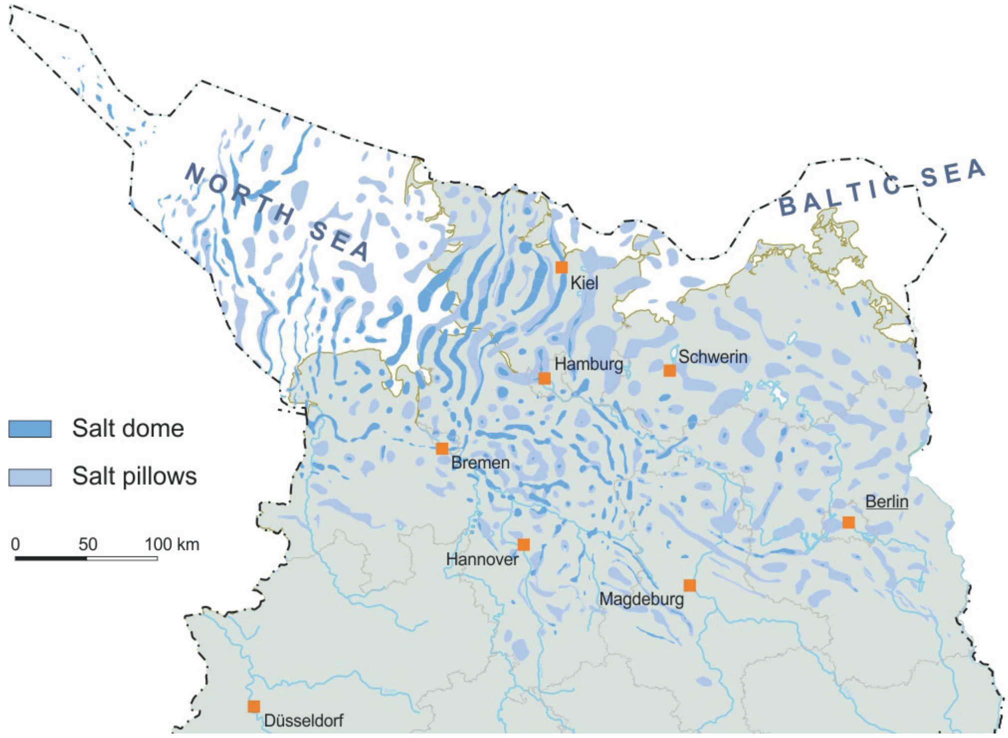

Figure 39: Distribution of salt structures in north Germany (BGR 2008).

Germany has a large potential for cavern storages in salt structures. The energy storage potential in north German salt structures determined by the In-SpEE project (Information system salt structures – planning basis, selection criteria and estimate of the potential for constructing salt caverns for the storage of renewable energy, BGR et al. 2016) is estimated at 4.5 TWh for compressed air, taking into consideration specific criteria (minimum area, minimum thickness, maximum depth, salt quality) as well as existing or future conflicts of interest with mining and housing. In the case of hydrogen, the potential is much higher, totalling around 1,614 TWh, not least because of the higher energy density (Zander-Schiebenhöfer et al. 2015).

The storage of regenerative energies in the form of compressed air (Compressed Air Energy Storage – CAES), has not only already been tested in projects, but also been implemented in practice at a large scale. There are currently two large compressed air energy storage power plants operating around the world, one of which is in Germany: a 330 MW plant has been operating in Huntorf in Lower Saxony since 1978 and has an efficiency of 42 %. Concepts for more efficient adiabatic compressed air energy storages (A-CAES) are currently being developed. These involve the intermediate storage of most of the compression heat so that this can be used again to heat up the air when it is removed from the cavern.

The basic feasibility of storing hydrogen in caverns has been confirmed by the successful operation of storage facilities in the USA and the United Kingdom for many years (Stolzenburg 2014). There is currently no demonstration project in Germany for the underground storage of hydrogen. The higher safety criteria required for hydrogen make further research and development work essential. More research is required in particular to verify the tightness of individual components and their contact surfaces with hydrogen (Stolzenburg 2014).

Independent of their ultimate use, the construction and operation of cavern storages can give rise to surface subsidence. Under certain circumstances, this could damage buildings affected by the subsidence, and in extreme cases, alter the hydraulic conditions. Reliable forecasts of the expected horizontal movements are crucial to avoid mining damage caused by cavern construction, and to effectively plan protective measures. BGR has been carrying out forecasts of this kind for many years on cavern fields for national and international clients.

Pore storages

Pore storages consist of highly permeably, porous or fractured rocks. Whilst the tightness of salt caverns is based on the petrographic properties of salt, porous rocks need to be completely sealed by barrier rocks such as clay, claystone or salt. Storage formations should have trap structures: differentiation is made here between structural, tectonic or stratigraphic traps, where a medium accumulates in a reservoir rock but is prevented from escaping by the structure, faults or the flanks of salt domes, or by a change in petrophysical properties (facies change). Typical porous horizons are brine-bearing sandstones (saline aquifers) as well as oil and gas fields. These hydrocarbon accumulations are associated with trap structures and can be used for the storage of gases when the field has been depleted.

Pore storages have been used in Germany for decades for the storage of natural gas to cover seasonal base loads. 20 pore storages were in operation in the country in 2015, of which eight in saline aquifers, and with a total maximum usable working gas volume of 9,784 million m³ (V_n) (LBEG 2016). When gas is injected, it displaces the water present in the pore spaces and therefore creates an artificial gas field. During the subsequent withdrawal, the previously displaced water pushes the stored gas back towards the wells.

According to the information we have today, pore storages are less suitable for the storage of hydrogen, this is because the reactivity and diffusivity of hydrogen means more chemical reactions can be expected, and therefore the depletion of stored hydrogen. Storage of hydrogen in pore storages has so far not been realised anywhere around the world (EFZN 2013). In the case of the storage of compressed air, research is required to determine to what extent the oxygen in the air reacts with the rock itself and the microorganisms in the rock, because these reactions can deplete the oxygen content or block the pore spaces in the pore storages (ESA 2015).

The storage potential for pore storages in Germany has not been estimated so far. Storage and barrier rocks, which are generally suitable for underground storage, are only present in a few slightly deformed and non-metamorphosed sediments in large sedimentary basins (Fig. 40). The largest sedimentary basin is the North German Basin with a maximum sediment thickness of over 10 km, and which covers the whole of north Germany (Müller & Reinhold 2011). Similar deposits are found in the Molasse Basin of the Alps, the Upper Rhine Graben, and the Thuringian Basin. In addition to the area and the thickness, the quality of an aquifer and/or its potential suitability as a pore storage for gases, also depends on the available porosity and permeability. Information on the regional depositional conditions and the geological development are essential for estimating the properties relevant for storages.

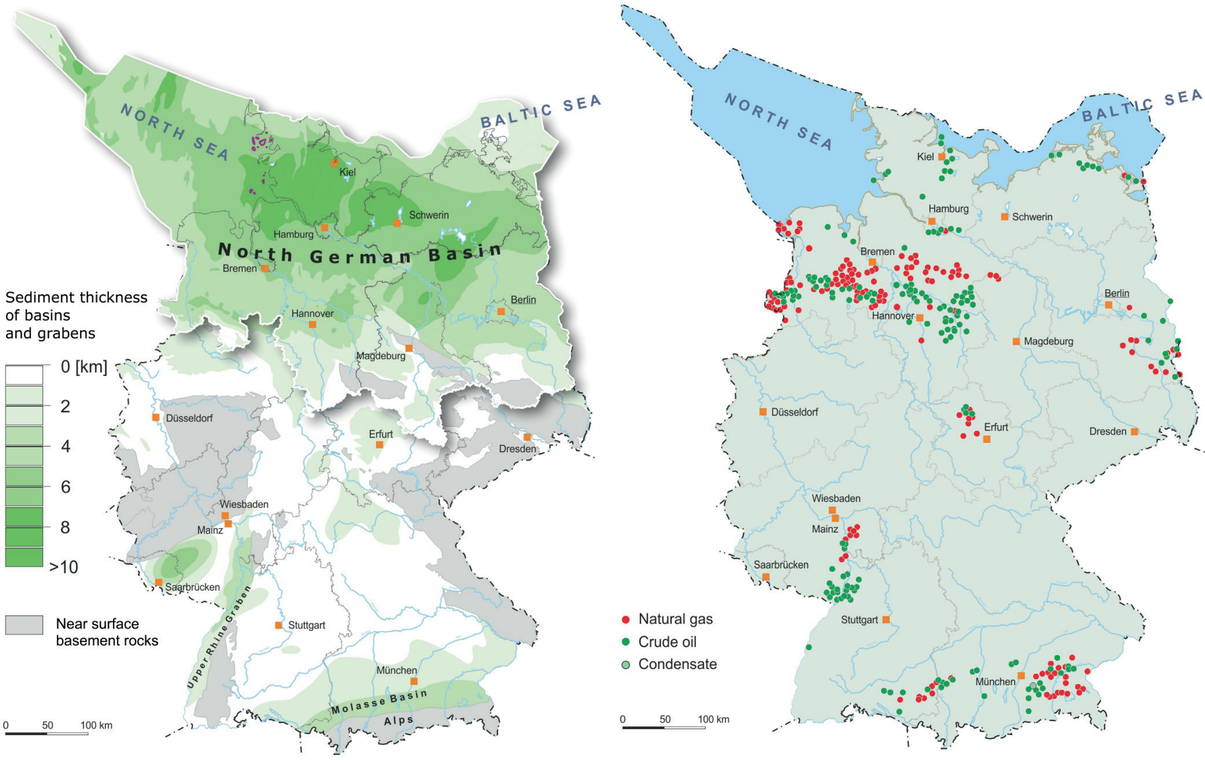

Figure 40: Distribution of sedimentary basins and graben in Germany, as well as the basement (left figure). Location of oil and gas fields in Germany (Müller & Reinhold 2011) (right figure).

An indication of the size of the storage capacities are provided by estimates carried out by BGR geoscientists for carbon dioxide in saline aquifers and oil and gas fields. The storage capacity in oil and gas fields can be determined from the amount of produced oil and gas. For gas fields, this corresponds to around 2.8 Gt, and the figure for oil fields is 150 million t, including known reserves (May et al. 2009). A determination of the storage capacities of saline aquifers is difficult because of the minor amount of information available. Capacity estimates for carbon dioxide (CO_2) lay between 6.3 and 12.8 (median 9.3) Gt CO_2, in a study area covering 75 % of the area of the North German Basin, the Upper Rhine Graben and the Molasse Basin (Knopf et al. 2010). In principle, the potential determined for the storage of CO_2 in saline aquifers can be extrapolated to the storage of methane. If one takes into consideration the possibility of being able to store methane in aquifers at shallower depths than needed for the storage of carbon dioxide, this would give a higher potential for the available pore storage volume (Obst 2008).

This large storage potential in pore storages is restricted by competing uses. Saline aquifers are not only suitable for energy storages, but also for the generation of heat from geothermal energy resources, and also for the generation of electricity at suitable temperature ranges. Assessing the various application options in more detail, and evaluating potential conflicts of use as well as synergies, is essential for the continuation of the energy transition. As the decarbonisation of the energy sector progresses, deep underground rock formations with their saline aquifers can be subject to a wide range of uses. Because the properties of underground rock formations vary strongly from place to place, and can only be influenced to a minor degree technologically, understanding the composition and characteristics of the geological structures is a vital prerequisite for the prudent and optimum utilisation of the limited resources available beneath our feet.

Conclusions

The successful storage of natural gas in underground geological formations for many decades proves that large quantities of gaseous storage media can be safely stored for a long period of time in underground storage spaces such as salt caverns and pore storages. The shift to the use of other storage media such as compressed air, hydrogen or synthetic natural gas will benefit from these many years of practical experience, as well as from the existing infrastructure. Underground geological formations can therefore play a key role as an energy storage as part of the energy transition. Pore storages and cavern storages are suitable for both the short-term as well as the long-term storage of energy. The potential is large but needs to be investigated in more detail taking into consideration potential conflicts of use.

5 FUTURE AVAILABILITY OF FOSSIL ENERGY RESOURCES AND DEEP GEOTHERMAL ENERGY

5.1 Supply situation and future demand

Global energy supplies are characterised by continuous change. Renewable energy is already an integral part of the global energy supply system, and there are even countries which can already cover most of their energy requirements from renewables. However, these are still only special cases from a global point of view, and attributable to specific geological conditions, such as found in Iceland for instance. Despite intense and ambitious efforts to increase the proportion of renewable energy, most countries around the world must still partially if not largely rely on fossil fuels and nuclear power to satisfy their energy requirements in the coming decades. Many industrial countries, and developing and emerging economies in particular, with foreseeable increases in their demand for energy, therefore primarily continue to include crude oil, natural gas, coal and nuclear power in their future energy mixes, in addition to sun, wind 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 (2016b) can be used as the basis for the long-term comparison of supply and demand (Fig. 41). 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 Paris Climate Treaty.

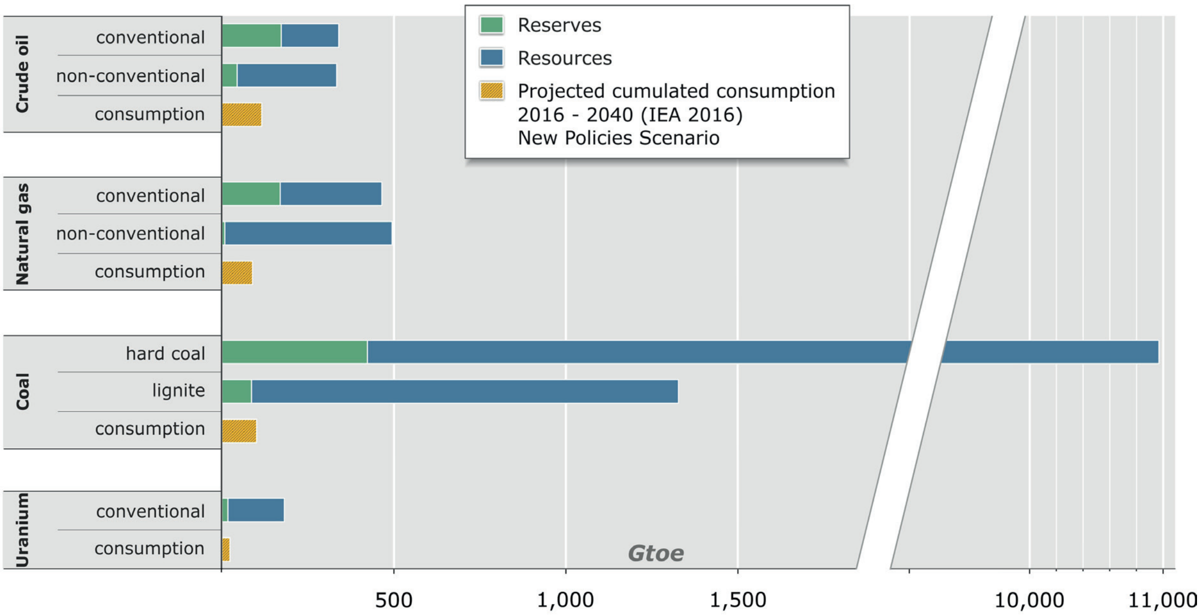

Figure 41: Supply situation for non-renewable energy resources end 2015.

5.2 Summary and outlook

Crude oil

Oil reserves declined slightly in 2015 whilst resources rose. From a geological point of view, the supply of crude oil can be maintained in the next few years even in the face of a continued moderate rise in consumption. The oversupply of crude oil existing since 2014 is the reason for the low crude oil price. A few countries with high levels of production are mainly responsible for the expansion of global crude oil production in recent years thanks to strong increases in production. Despite the increase in diversification of global crude oil production, due to a rising share of production coming from oil sand, shale oil and ultra-heavy oil fields, conventional crude oil production will continue to be the main contributor to the global supply of liquid hydrocarbons.

Cost savings in the oil and gas industry intensified in 2015 and led to the postponement and cancellation of many development projects, particularly in expensive frontier regions such as deep and ultra-deep water, and the Arctic, but also in numerous non-conventional onshore projects (shale oil and oil sand resources). A continuation of the low oil price increases the financial challenges facing companies as well as oil-exporting countries. In the medium term, the cut-back in investments by the oil industry can lead to shortages in production and a rise in prices. Crude oil reserves are only affected in the medium to long term by a cut-back in investments because project development times are typically of the order of around 10 years. A direct consequence of the current relatively low oil price is a decline in US-American shale oil production, because this reacts faster to changing market situations due to a much shorter project realisation time frame.

Natural gas

Natural gas was again the third most important energy resource behind crude oil and hard coal in 2015, with a share of 23.8 % of global primary energy consumption. Because of the high remaining natural gas potential, global supplies of this resource could be maintained for decades to come even in the face of a stronger rise in demand. Although the reserves declined again overall, almost two thirds of the production was compensated for by additions to reserves. The global trade in natural gas increased again overall in 2015. A closer integration of the various natural gas markets due to the generous supplies of LNG, led to a global convergence of prices. Growing quantities of LNG will be available on the market in the next few years, particularly from the USA and Australia, and this will boost competition and further enhance the comfortable supply situation. With an integrated and growing supply grid, Germany and Europe are connected up to a large part of global natural gas reserves via pipelines and LNG import terminals. Despite a decline in drilling activity, the USA increased its shale gas production until the beginning of 2016 thanks to increases in efficiency and technological advances. Although production has declined since then because of the continuing low price of natural gas, the further expansion of production can again be expected in future. Moreover, the first LNG export terminal on the continental United States was commissioned at the beginning of 2016 at Sabine Pass/Texas. In addition to South America and Asia, Europe is now also being supplied with liquefied natural gas from shale gas production. In addition, Australia also shipped its first cargo of liquefied coal bed methane to Asia at the beginning of 2016.

Coal

The global reserves of hard coal and lignite can cover the identifiable demand for many decades from a geological point of view. During the reporting period, global coal production declined year-on-year for the second year in a row in line with the decrease in demand, with a reduction of about 3 % to around 7,713 Mt in 2015. Global trade in hard coal declined year-on-year for the first time since 2009 despite a further decline in coal world market prices, and the continuation of the low freight rates. With respect to its share of global coal imports (Asia: 71 %), the importance of the Pacific market continued to be very high. 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, India might displace the United States as the second largest coal producer, and by that much earlier than previously forecast. This situation is primarily attributable, however, to the cut-backs in production in the United States and only to a minor extent to an increase in production in India. The consolidation phase in the global coal sector which began in 2012 continued unabated in 2016. In 2015, and especially in 2016, this gave rise to massive cut-backs in production in China and the United States, so that global coal production in 2016 will probably be 7 % lower than in 2015. These declines in production already gave rise to shortages by the late summer 2016 and tangible price increases, in particular in the Asian coal market. Because this is causing some producers to already increase their production again, it remains to be seen whether the current rise in prices is only a short-term price peak or reflects a medium-term trend.

Nuclear fuels

The global reserves of uranium are very extensive, which means that no shortage in the supplies of nuclear fuels is expected in the foreseeable future from a geological point of view. Whilst demand for uranium probably continues to decline in Europe in future, a rise in uranium consumption is expected in the emerging economies and developing countries of Asia and the Middle East in particular. A moderate rise in uranium demand is also expected in coming decades in North America, Latin America and Africa. 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. Nevertheless, the expansion in uranium mining in a few countries enabled global mine production to rise again by 8 % compared to the previous year. 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 huge potential, the exploitation of geothermal energy in Germany, as well as worldwide, is developing rather slowly. The challenges affecting geothermal power production in particular are high exploration risk, long planning periods, and high level of investment (BMWi 2015). Forecasts expect a growth in installed capacity to 50 MW_e in Germany for the year 2018 (Weber 2016). Globally, the development is also less dynamic than in previous years. Although a growth of 2.5 % in the installed capacity for power production has been achieved, this increase is only half of the value recorded in the previous year (down from 610 MW_e to 313 MW_e). In addition, it is noteworthy that the increase is accounted for by only a few countries. The Paris Climate Treaty came into force on November 4th. Hereby, a stimulation for the expansion of geothermal energy is expected, because this demands a massive reduction in greenhouse gas emissions in the next decades. The 28 members of the Global Geothermal Alliance have announced a rise in geothermal power production by a factor of five and an increase in the heat sector by a factor of two by 2030.

Renewable energy

„Modern" renewables such as wind power and solar power have also long dropped their niche role and established themselves globally as energy resources. Wind power in particular leads the expansion of renewable energy. The installed capacity of renewable energy for power production world-wide is now around 1,985 GW. The major challenge is the discrepancy between the available potential and the actual generated output, which means that only around 14 % of global primary energy consumption has been covered so far by renewable energy. The further expansion in all energy supply sectors is expected in future associated with the development of major new markets in Africa, Asia and Latin America. Around 173 countries have now formulated targets for the expansion of renewable energy. The global financial investment volume in renewable energy has grown over the last ten years from 73 billion USD/a to over 286 billion USD/a in 2015. Investment here has grown particularly strongly in emerging and developing economies in particular. Their share of the total investment volume grew to over 55 % in 2015, and exceeded the investment volume of western industrial countries for the first time. Investment and expansion of capacities will further increase the global influence of renewable energy in the power sector in particular, whilst the influence in the heat and mobility sector will probably tend to grow moderately in the medium term.

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APPENDIX

- Tables
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Table 6: Reserves of non-renewable fuels 2015: Regional distribution [EJ]

Region	Crude oil		Natural gas		Coal		Uranium	Total	Share [%]
	conventional	non-conventional	conventional [1]	non-conventional	Hard coal	Lignite			
Europe	83	< 0.5	129	–	606	678	13	1,510	3.9
CIS	781	–	2,404	2	3,282	1,354	214	8,037	20.9
Africa	734	–	546	–	309	1	83	1,673	4.4
Middle East	4,581	–	2,992	–	30	–	–	7,602	19.8
Austral-Asia	240	–	533	86	7,570	1,100	102	9,630	25.1
North America	355	958	251	234	5,707	384	170	8,058	21.0
Latin America	397	886	294	–	232	43	81	1,933	5.0
World	**7,171**	**1,844**	**7,148**	**321**	**17,737**	**3,560**	**663**	**38,443**	**100.0**
OECD	457	958	475	278	8,162	1,745	183	12,259	31.9
EU-28	39	–	57	–	582	478	10	1,166	3.0
OPEC	5,428	886	3,580	–	59	1	–	9,953	25.9

[1] including tight gas

Table 7: Ressources of non-renewable fuels 2015: Regional distribution [EJ]

Region	Crude oil		Natural gas		Coal		Uranium	Thorium	Total	Share [%]
	conventional	non-conventional	conventional	non-conventional [1]	Hard coal	Lignite				
Europe	230	94	208	535	12,564	2,958	271	286	17,146	3.2
CIS	1,155	1,027	4,973	1,933	70,292	18,958	1,397	103	99,837	18.5
Africa	1,214	322	1,351	1,814	6,656	4	842	264	12,467	2.3
Middle East	1,254	171	1,607	524	1,008	–	53	–	4,617	0.9
Austral-Asia	1,067	532	1,782	3,339	176,791	12,379	1,930	771	198,590	36.8
North America	1,082	2,803	1,493	2,794	166,883	17,547	1,981	427	195,009	36.1
Latin America	990	2,870	879	1,560	686	173	395	466	8,019	1.5
World	**6,993**	**7,818** [2]	**12,293**	**12,498**	**438,705** [3]	**52,019**	**6,869**	**3,178** [4]	**540,371**	**100.0**
OECD	1,368	3,011	2,113	4,287	220,481	24,013	3,194	1,010	259,476	48.0
EU-28	109	67	118	498	12,524	2,688	270	55	16,330	3.0
OPEC	1,831	2,930	1,756	1,717	1,220	3	18	150	9,625	1.8

[1] without natural gas in gas hydrates and aquifer gas (7,904 EJ)
[2] without oil from oil shale (4,248 EJ)
[3] including hard coal in the Antarctic (3,825 EJ)
[4] including Thorium without country allocation (62 EJ)

Table 8: Production of non-renewable fuels 2015: Regional distribution [EJ]

Region	Crude oil	Natural gas	Hard coal	Lignite	Uranium	Total	Share [%]
Europe	7.3	9.7	2.7	4.5	0.1	24.4	4.7
CIS	28.2	31.6	11.0	1.2	15.2	87.2	16.7
Africa	16.6	7.7	6.3	< 0.05	3.8	34.2	6.6
Middle East	58.9	23.0	< 0.05	–	–	82.0	15.7
Austral-Asia	16.4	20.3	120.5	3.3	3.9	164.4	31.5
North America	38.1	36.8	20.4	0.9	7.3	103.4	19.8
Latin America	16.3	6.6	2.5	< 0.05	< 0.05	25.5	4.9
World	**181.7**	**135.8**	**163.4**	**9.9**	**30.2**	**521.1**	**100.0**
OECD	45.8	49.4	34.9	5.0	10.2	145.2	27.9
EU-28	3.1	5.1	2.6	3.6	0.1	14.5	2.8
OPEC	75.3	26.8	0.1	–	–	102.1	19.6

Table 9: Consumption of non-renewable fuels 2015: Regional distribution [EJ]

Region	Crude oil	Natural gas	Hard coal	Lignite	Uranium	Total	Share [%]
Europe	27.5	18.9	8.3	4.5	10.0	69.2	13.2
CIS	8.0	24.0	7.7	1.2	3.3	44.2	8.5
Africa	8.2	4.9	4.6	< 0.05	0.2	17.9	3.4
Middle East	17.1	18.5	0.3	–	0.1	36.0	6.9
Austral-Asia	63.0	26.1	122.2	3.3	9.2	223.8	42.8
North America	43.6	36.6	18.6	0.9	10.4	110.1	21.0
Latin America	14.3	6.3	1.1	< 0.05	0.3	22.0	4.2
World	**181.9**	**135.3**	**162.8**	**9.9**	**33.4**	**523.4**	**100.0**
OECD	86.6	62.6	36.9	4.9	23.9	215.0	41.1
EU-28	24.7	16.6	7.2	3.5	9.8	61.8	11.8
OPEC	19.4	19.7	0.1	–	0.1	39.3	7.5

– no reserves, resources, production or consumption

Table 10: Germany: Supply of crude oil 2014/2015 [kt]

Country / Region	2014	2015	%	Changes 2014 / 2015	%
Russia	30,025	32,577	35.7	2,552	8.5
Norway	15,183	12,455	13.6	-2,728	-18.0
United Kingdom	9,727	9,953	10.9	226	2.3
Nigeria	7,119	6,691	7.3	-428	-6.0
Kazakhstan	6,777	6,421	7.0	-356	-5.3
Azerbaijan	4,132	5,316	5.8	1,184	28.7
Algeria	3,624	3,468	3.8	-156	-4.3
Egypt	1,487	2,894	3.2	1,407	94.6
Libya	3,194	2,874	3.1	-320	-10.0
Iraq	919	2,392	2.6	1,473	160.3
Saudi Arabia	1,414	1,195	1.3	-219	-15.5
Denmark	273	707	0.8	434	159.0
Colombia	1,275	668	0.7	-607	-47.6
Mexico	432	586	0.6	154	35.6
Tunisia	307	422	0.5	115	37.5
Côte d‘Ivoire	443	364	0.4	-79	-17.8
Netherlands	626	362	0.4	-264	-42.2
Angola	251	340	0.4	89	35.5
Poland	420	254	0.3	-166	-39.5
Italy	222	219	0.2	-3	-1.4
Kuwait	234	192	0.2	-42	-17.9
Estonia	32	175	0.2	143	446.9
Equatorial Guinea	68	163	0.2	95	139.7
United States	0	117	0.1	117	
Venezuela	8	109	0.1	101	1,262.5
Guatemala	109	66	0.1	-43	-39.4
Gabon	0	49	0.1	49	
Latvia	0	15	0.0	15	
Brazil	704	10	0.0	-694	-98.6
U. Arab Emirates	0	9	0.0	9	
France	5	4	0.0	-1	-20.0
South Africa	0	2	0.0	2	
Albania	10	0	0.0	-10	-100.0

continuation of table 10
[kt]

Country / Region	2014	2015	%	Changes 2014 / 2015	%
Pakistan	39	0	0.0	-39	-100.0
Belize	5	0	0.0	-5	-100.0
Turkmenistan	158	0	0.0	-158	-100.0
Cameroon	6	0	0.0	-6	-100.0
Trinidad and Tobago	135	0	0.0	-135	-100.0
Georgia	31	0	0.0	-31	-100.0
Total imports	**89,394**	**91,275**	**100.0**	**1,881**	**2.1**
OPEC	16,763	17,270	18.9	507	3.0
Middle East	2,567	3,788	4.2	1,221	47.6
Africa	16,499	17,267	18.9	768	4.7
CIS	41,123	44,314	48.5	3,191	7.8
Europe	26,498	24,144	26.5	-2,354	-8.9

Table 11: Germany: Origin of consumed natural gas [bcm]

Country of origin	2014	%	2015	%
Russia	36.4	34.2	38.8	31.1
Netherlands	26.0	24.4	37.1	29.7
Norway	30.2	28.4	37.0	29.6
Others	3.7	3.5	2.6	2.1
Domestic production	10.1	9.5	9.3	7.5
Total	**106.4**	**100.0**	**124.8**	**100.0**
re-export	21.4	20.1	31.2	25.0
storage change	-0.4	-0.3	2.8	2.2
Total consumption	**84.7**	**79.5**	**96.4**	**77.3**

Table 12: Germany: Imports of hard coal and coke by supplying countries [kt]

Country / Region	2011	2012	2013	2014	2015	Changes 2014/2015	%
EU	7,025	6,704	8,364	11,024	8,248	-2,776	-25.2
hard coal	3,524	4,089	5,891	8,817	6,651	-2,166	-24.6
coke	3,501	2,615	2,473	2,207	1,597	-610	-27.6
Non-EU	41,353	41,218	44,502	45,182	49,262	4,080	9.0
hard coal	40,626	40,858	44,228	44,854	48,894	4,040	9.0
coke	727	360	274	328	368	40	12.2
Australia	4,280	4,451	4,739	5,673	5,737	64	1.1
hard coal	4,280	4,451	4,739	5,673	5,737	64	1.1
coke	0	0	0	0	0	0	
Indonesia	34	0	0	0	53	53	
hard coal	34	0	0	0	53	53	
coke	0	0	0	0	0	0	
Canada	1,736	1,516	1,214	1,462	1,316	-146	-10.0
hard coal	1,736	1,516	1,214	1,462	1,316	-146	-10.0
coke	0	0	0	0	0	0	
Colombia	10,826	9,352	9,999	7,381	9,948	2,567	34.8
hard coal	10,764	9,319	9,974	7,381	9,948	2,567	34.8
coke	62	33	25	0	0	0	
Norway	857	395	680	435	561	126	29.0
hard coal	857	395	680	435	561	126	29.0
coke	0	0	0	0	0	0	
Poland	5,139	3,971	4,325	4,389	4,096	-293	-6.7
hard coal	2,659	2,406	3,008	2,931	3,098	167	5.7
coke	2,481	1,565	1,317	1,458	998	-460	-31.6
CIS	11,092	11,546	13,091	13,722	16,724	3,002	21.9
hard coal	10,731	11,227	12,842	13,495	16,528	3,033	22.5
coke	361	319	249	227	196	-31	-13.7
South Africa	2,644	1,972	2,533	5,082	3,400	-1,682	-33.1
hard coal	2,644	1,972	2,533	5,082	3,400	-1,682	-33.1
coke	0	0	0	0	0	0	
Czech Republic	360	323	690	659	832	173	26.3
hard coal	30	7	365	362	566	204	56.4
coke	330	316	325	297	266	-31	-10.4

continuation of table 12
[kt]

Country / Region	2011	2012	2013	2014	2015	Changes 2014 / 2015	%
United States	8,140	9,809	12,044	11,099	10,913	-186	-1.7
hard coal	8,140	9,809	12,044	11,099	10,913	-186	-1.7
coke	0	0	0	0	0	0	
Venezuela, Bolivarian Republic	161	112	59	0	0	0	
hard coal	161	111	59	0	0	0	
coke	0	1	0	0	0	0	
China	196	11	8	124	91	-33	-26.6
hard coal	12	9	8	23	16	-7	-30.4
coke	184	2	0	101	75	-26	-25.7
other Non-EU	1,389	2,054	135	204	519	315	154.4
hard coal	1,269	2,049	135	204	422	218	106.9
coke	120	5	0	0	97	97	
total	**48,378**	**47,922**	**52,866**	**56,206**	**57,510**	**1,304**	**2.3**
hard coal	44,151	44,947	50,119	53,671	55,545	1,874	3.5
coke	4,228	2,975	2,747	2,535	1,965	-570	-22.5

Table 13: Crude oil 2015 [Mt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
EUROPE	Albania	1.4	58	25	23	106	48
	Austria	0.9	124	7	10	141	17
	Bosnia & Herzegovina	–	–	–	10	10	10
	Bulgaria	0.1	9	2	32	44	34
	Croatia	0.8	104	9	20	134	29
	Cyprus	–	–	–	35	35	35
	Czech Republic	0.6	12	2	30	44	32
	Denmark	7.7	355	74	187	616	261
	Estonia	0.8	7	–	–	7	–
	Finland	0.7	5	–	–	5	–
	France	0.8	128	11	710	848	721
	Germany	2.4	304	34	90	428	124
	Greece	0.1	17	1	35	53	36
	Hungary	0.9	102	3	20	125	23
	Ireland	–	–	–	245	245	245
	Italy	5.5	197	82	205	483	286
	Lithuania	0.2	5	2	60	66	62
	Malta	–	–	–	5	5	5
	Netherlands	1.4	148	15	455	619	470
	Norway	94.8	3,728	992	2,791	7,511	3,783
	Poland	0.9	65	14	260	339	274
	Romania	4.0	776	80	200	1,056	280
	Serbia	1.2	47	11	20	78	31
	Slovakia	< 0.05	3	1	5	9	6
	Slovenia	< 0.05	n. s.	n. s.	n. s.	n. s.	n. s.
	Spain	0.2	39	19	34	92	53
	Turkey	2.5	147	49	710	906	759
	United Kingdom	45.7	3,666	566	1,579	5,811	2,145
CIS	Armenia	–	–	–	< 0.5	< 0.5	< 0.5
	Azerbaijan	41.6	1,888	952	1,242	4,082	2,194
	Belarus	1.7	141	27	30	197	57
	Georgia	< 0.05	24	5	51	79	55
	Kazakhstan	79.3	1,784	4,082	12,881	18,746	16,962
	Kyrgyzstan	< 0.05	12	5	10	27	15
	Moldova, Republic	–	–	–	10	10	10
	Russia	533.6	23,278	13,384	35,527	72,190	48,911
	Tajikistan	< 0.05	8	2	60	69	62
	Turkmenistan	12.7	562	82	1,700	2,343	1,782
	Ukraine	1.8	368	54	300	722	354
	Uzbekistan	2.8	202	81	400	683	481

continuation of table 13
[Mt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
AFRICA	Algeria	68.1	3,096	1,660	2,375	7,131	4,035
	Angola	88.7	1,646	1,709	5,095	8,451	6,804
	Benin	–	4	1	70	75	71
	Cameroon	3.8	191	27	350	568	377
	Chad	4.1	78	216	2,365	2,659	2,581
	Congo, DR	1.0	47	24	144	215	169
	Congo, Rep.	14.3	384	218	519	1,120	737
	Côte d'Ivoire	1.0	33	14	300	346	314
	Egypt	35.8	1,658	599	2,233	4,490	2,832
	Equatorial Guinea	13.5	235	149	250	634	399
	Eritrea	–	–	–	15	15	15
	Ethiopia	–	–	< 0.5	60	60	60
	Gabon	11.3	559	272	1,400	2,231	1,672
	Gambia	–	–	–	20	20	20
	Ghana	5.3	28	90	210	328	300
	Guinea	–	–	–	150	150	150
	Guinea-Bissau	–	–	–	40	40	40
	Kenya	–	–	–	300	300	300
	Liberia	–	–	–	160	160	160
	Libya	20.1	3,831	6,580	4,750	15,161	11,330
	Madagascar	–	n. s.	n. s.	2,130	2,130	2,130
	Mali	–	–	–	128	128	128
	Mauritania	0.3	8	3	184	194	187
	Morocco	< 0.05	2	< 0.5	1,627	1,629	1,627
	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	113.0	4,576	5,042	5,378	14,997	10,421
	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	550	568	552
	South Sudan, Republic of	7.3	–	472	365	837	837
	Sudan	5.2	–	202	365	567	567
	Sudan & South Sudan	12.4	210	675	730	1,615	1,405
	Tanzania	–	–	–	500	500	500
	Togo	–	–	–	70	70	70
	Tunisia	2.9	209	55	300	565	355
	Uganda	–	–	137	300	437	437
	Western Sahara	–	–	–	57	57	57
	Zimbabwe	–	–	–	10	10	10

continuation of table 13
[Mt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
MIDDLE EAST	Bahrain	10.1	262	17	200	478	217
	Iran	182.6	9,916	21,551	7,200	38,667	28,751
	Iraq	197.0	5,330	19,388	6,320	31,038	25,708
	Israel	0.1	2	2	371	375	373
	Jordan	< 0.05	–	< 0.5	39	39	39
	Kuwait	149.1	6,356	13,810	700	20,866	14,510
	Lebanon	–	–	–	150	150	150
	Oman	46.6	1,489	722	1,490	3,701	2,212
	Palestinian territories	–	–	–	60	60	60
	Qatar	79.3	1,750	3,435	700	5,884	4,135
	Saudi Arabia	565.3	20,336	36,618	11,800	68,754	48,418
	Syrian	1.7	745	340	400	1,486	740
	U. Arab Emirates	175.5	4,838	13,306	4,160	22,304	17,466
AUSTRAL-ASIA	Afghanistan	–	–	–	290	290	290
	Australia	16.3	1,049	542	3,480	5,071	4,022
	Bangladesh	0.2	4	4	30	38	34
	Brunei	6.2	526	150	160	836	310
	Cambodia	–	–	–	25	25	25
	China	214.6	6,508	2,521	22,999	32,028	25,520
	India	37.1	1,333	635	1,840	3,808	2,475
	Indonesia	40.0	3,433	489	3,572	7,494	4,061
	Japan	0.6	52	6	24	82	30
	Korea, Rep.	< 0.05	n. s.	< 0.5	n. s.	< 0.5	< 0.5
	Laos	–	–	–	< 0.5	< 0.5	< 0.5
	Malaysia	31.9	1,127	510	850	2,487	1,360
	Mongolia	1.2	5	35	1,010	1,050	1,045
	Myanmar	0.8	57	7	560	624	567
	New Zealand	1.9	62	12	250	324	262
	Pakistan	4.2	108	48	1,390	1,546	1,438
	Papua New Guinea	2.6	70	24	290	385	314
	Philippines	1.1	19	19	270	308	289
	Sri Lanka	–	–	–	90	90	90
	Taiwan	< 0.05	5	< 0.5	5	10	5
	Thailand	12.3	204	94	335	633	429
	Timor-Leste	3.3	50	56	175	280	231
	Viet Nam	17.6	354	595	600	1,549	1,195
NORTH AMERICA	Canada	215.1	5,888	23,212	56,891	85,990	80,103
	Greenland	–	–	–	3,500	3,500	3,500
	Mexico	128.8	6,548	1,321	4,761	12,630	6,082
	USA	567.2	32,447	6,871	27,773	67,091	34,644

continuation of table 13
[Mt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
LATIN AMERICA	Argentina	29.7	1,599	328	4,175	6,103	4,503
	Barbados	< 0.05	2	< 0.5	30	33	30
	Belize	0.1	1	1	15	17	16
	Bolivia	3.3	87	29	280	396	309
	Brazil	125.6	2,276	1,769	13,720	17,765	15,489
	Chile	0.3	63	20	330	413	350
	Colombia	51.3	1,295	272	1,790	3,357	2,062
	Cuba	3.6	70	17	1,008	1,095	1,025
	Dominican Rep.	–	–	–	150	150	150
	Ecuador	27.0	799	1,126	106	2,031	1,232
	Falkland Islands	–	–	–	800	800	800
	(French) Guiana	–	–	–	800	800	800
	Guatemala	0.5	22	13	40	74	53
	Guyana	–	–	–	450	450	450
	Haiti	–	–	–	100	100	100
	Panama	–	–	–	122	122	122
	Paraguay	–	–	–	575	575	575
	Peru	7.4	393	193	1,401	1,986	1,594
	Puerto Rico	–	–	–	75	75	75
	Suriname	–	15	14	700	728	714
	Trinidad and Tobago	5.4	526	99	68	693	166
	Uruguay	–	–	–	275	275	275
	Venezuela	136.3	10,028	26,827	65,320	102,175	92,147
	World	**4,346.2**	**183,573**	**215,665**	**354,317**	**753,555**	**569,982**
COUNTRY GROUPS	Europe	173.7	10,047	1,998	7,770	19,816	9,769
	CIS	673.6	28,265	18,674	52,211	99,150	70,884
	Africa	396.4	16,810	17,555	36,746	71,112	54,301
	Middle East	1,409.0	51,424	109,581	34,090	195,096	143,671
	Austral-Asia	391.9	14,967	5,747	38,245	58,959	43,992
	North America	911.1	44,883	31,404	92,925	169,212	124,329
	Latin America	390.5	17,175	30,706	92,330	140,211	123,036
ECCONOMIC COUNTRY GPG.	OPEC	1,801.8	72,502	151,051	113,904	337,457	264,955
	OPEC-Gulf	1,348.7	48,526	108,107	30,880	187,513	138,987
	OECD	1,096.2	55,159	33,856	104,745	193,761	138,601
	EU-28	73.7	6,066	922	4,216	11,205	5,138

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

Table 14: Crude oil resources 2015 [Mt]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Total	conventional	non-conventional		
				oil sand	extra heavy oil	tight oil [1]
1	Venezuela	65,320	3,000	–	60,500	1,820
2	Canada	56,891	3,500	50,000	1	3,390
3	Russia	35,527	20,000	5,225	2	10,300
4	USA	27,773	15,900	1,237	36	10,600
5	China	22,999	16,200	2,300	119	4,380
6	Brazil	13,720	13,000	–	–	720
7	Kazakhstan	12,881	4,000	7,441	–	1,440
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	4,761	2,980	–	1	1,780
14	Libya	4,750	1,200	–	–	3,550
15	Argentina	4,175	500	–	–	3,675
16	U. Arab Emirates	4,160	1,100	–	–	3,060
17	Indonesia	3,572	2,400	97	–	1,075
18	Greenland	3,500	3,500	–	–	–
19	Australia	3,480	1,100	–	–	2,380
20	Norway	2,791	2,791	–	–	–
	...					
100	Germany	90	20	–	–	70
	...					
	other countries [121]	52,134	40,691	162	81	11,200
	World	**354,317**	**167,282**	**66,635**	**60,740**	**59,660**
	Europe	7,770	5,514	46	30	2,181
	CIS	52,211	27,635	12,666	19	11,890
	Africa	36,746	29,044	276	8	7,418
	Middle East	34,090	30,005	–	1	4,084
	Austral-Asia	38,245	25,522	2,397	119	10,207
	North America	92,925	25,880	51,237	38	15,770
	Latin America	92,330	23,682	13	60,525	8,110
	OPEC	113,904	43,800	173	60,506	9,425
	OPEC-Gulf	30,880	27,600	–	–	3,280
	OECD	104,745	32,719	51,283	66	20,678
	EU-28	4,216	2,603	46	27	1,541

[1] crude oil from tight reservoirs

– no resources

Table 15: Crude oil reserves 2015 [Mt]
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Total	conventional	non-conventional oil sand	extra heavy oil	tight oil [1]
1	Saudi Arabia	36,618	36,618	–	–	–
2	Venezuela	26,827	5,627	–	21,200	–
3	Canada	23,212	560	22,583	–	68
4	Iran	21,551	21,551	–	–	–
5	Iraq	19,388	19,388	–	–	–
6	Kuwait	13,810	13,810	–	–	–
7	Russia	13,384	13,384	–	–	–
8	U. Arab Emirates	13,306	13,306	–	–	–
9	USA	6,871	6,608	–	3	260
10	Libya	6,580	6,580	–	–	–
11	Nigeria	5,042	5,042	–	–	–
12	Kazakhstan	4,082	4,082	–	–	–
13	Qatar	3,435	3,435	–	–	–
14	China	2,521	2,521	–	n. s.	–
15	Brazil	1,769	1,769	–	–	–
16	Angola	1,709	1,709	–	–	–
17	Algeria	1,660	1,660	–	–	–
18	Mexico	1,321	1,321	–	–	–
19	Ecuador	1,126	1,126	–	n. s.	–
20	Norway	992	992	–	–	–
	...					
58	Germany	34	34	–	–	–
	...					
	other countries [83]	10,429	10,426	–	3	–
	World	**215,665**	**171,548**	**22,583**	**21,206**	**328**
	Europe	1,998	1,995	–	3	–
	CIS	18,674	18,674	–	–	–
	Africa	17,555	17,555	–	–	–
	Middle East	109,581	109,581	–	–	–
	Austral-Asia	5,747	5,747	–	–	–
	North America	31,404	8,489	22,583	3	328
	Latin America	30,706	9,506	–	21,200	–
	OPEC	151,051	129,851	–	21,200	–
	OPEC-Gulf	108,107	108,107	–	–	–
	OECD	33,856	10,941	22,583	3	328
	EU-28	922	922	–	–	–

[1] crude oil from tight reservoirs

n. s. not specified
– no reserves

Table 16: Crude oil production 2010–2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2010	2011	2012	2013	2014	2015	Share [%]	
					Mt			country	cumulative
1	USA	339.1	352.3	431.2	485.2	519.9	567.2	13.1	13.1
2	Saudi Arabia	467.8	525.8	547.0	523.6	530.1	565.3	13.0	26.1
3	Russia	505.1	509.0	517.9	522.6	526.7	533.6	12.3	38.3
4	Canada	162.8	165.3	179.2	192.4	208.0	215.1	4.9	43.3
5	China	203.0	203.6	207.5	208.1	211.4	214.6	4.9	48.2
6	Iraq	117.1	134.2	148.1	152.6	160.3	197.0	4.5	52.8
7	Iran	203.2	205.8	185.8	177.7	169.2	182.6	4.2	57.0
8	U. Arab Emirates	128.9	138.4	155.0	165.7	167.3	175.5	4.0	61.0
9	Kuwait	120.3	134.3	151.6	164.7	158.1	149.1	3.4	64.4
10	Venezuela	166.1	166.7	161.7	162.9	157.8	136.3	3.1	67.6
11	Mexico	146.3	145.1	144.8	143.5	137.1	128.8	3.0	70.5
12	Brazil	106.1	114.6	108.2	105.0	118.5	125.6	2.9	73.4
13	Nigeria	101.7	120.2	123.8	118.3	120.4	113.0	2.6	76.0
14	Norway	106.2	92.2	87.5	90.2	93.1	94.8	2.2	78.2
15	Angola	90.7	85.2	86.9	87.4	83.0	88.7	2.0	80.2
16	Kazakhstan	81.6	82.4	79.2	83.8	82.1	79.3	1.8	82.1
17	Qatar	71.0	78.5	83.0	84.2	83.5	79.3	1.8	83.9
18	Algeria	77.7	76.5	76.1	72.6	70.6	68.1	1.6	85.4
19	Colombia	39.9	45.4	46.9	52.9	52.2	51.3	1.2	86.6
20	Oman	41.0	42.1	45.8	46.1	46.2	46.6	1.1	87.7
	...								
57	Germany	2.5	2.7	2.6	2.6	2.4	2.4	0.1	99.4
	...								
	other countries [80]	672.4	586.8	597.6	562.1	542.7	532.2	12.2	100.0
	World	**3,950.6**	**4,007.1**	**4,167.3**	**4,204.2**	**4,240.7**	**4,346.2**	**100.0**	
	Europe	206.4	178.8	165.0	164.8	168.0	173.7	4.0	
	CIS	656.8	656.8	661.6	671.3	671.8	673.6	15.5	
	Africa	461.9	422.1	461.6	430.5	406.9	396.4	9.1	
	Middle East	1,190.0	1,296.1	1,343.0	1,333.5	1,332.9	1,409.0	32.4	
	Austral-Asia	399.0	388.5	387.8	383.6	387.2	391.9	9.0	
	North America	648.2	662.7	755.2	821.1	865.1	911.1	21.0	
	Latin America	388.3	402.0	393.2	399.4	408.9	390.5	9.0	
	OPEC	1,643.7	1,714.2	1,818.0	1,785.4	1,756.8	1,801.8	41.5	
	OPEC-Gulf	1,108.4	1,217.0	1,270.6	1,268.4	1,268.5	1,348.7	31.0	
	OECD	875.4	859.1	935.2	997.1	1,044.9	1,096.2	25.2	
	EU-28	96.5 [1]	82.7 [1]	73.4 [1]	70.0	69.9	73.7	1.7	

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

Table 17: Oil consumption 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Mt	Share [%] country	Share [%] cumulative
1	USA	845.3	19.4	19.4
2	China	559.7	12.9	32.3
3	Japan	208.1	4.8	37.1
4	India	195.5	4.5	41.6
5	Saudi Arabia	164.9	3.8	45.3
6	Brazil	156.9	3.6	49.0
7	Russia	143.0	3.3	52.2
8	Korea, Rep.	113.7	2.6	54.9
9	Germany	109.9	2.5	57.4
10	Canada	100.3	2.3	59.7
11	Mexico	98.4	2.3	61.9
12	Iran	89.2	2.0	64.0
13	France	76.7	1.8	65.8
14	Indonesia	74.2	1.7	67.5
15	United Kingdom	71.6	1.6	69.1
16	Singapore	69.5	1.6	70.7
17	Italy	59.0	1.4	72.1
18	Spain	50.6	1.2	73.2
19	Australia	47.2	1.1	74.3
20	Taiwan	46.0	1.1	75.4
	...			
	other countries [179]	1,072.2	24.6	100.0
	World	**4,351.9**	**100.0**	
	Europe	658.6	15.1	
	CIS	192.0	4.4	
	Africa	197.2	4.5	
	Middle East	410.1	9.4	
	Austral-Asia	1,506.8	34.6	
	North America	1,044.2	24.0	
	Latin America	341.5	7.8	
	OPEC	465.1	10.7	
	OPEC-Gulf	362.0	8.3	
	OECD	2,072.9	47.6	
	EU-28	591.1	13.6	

Table 18: Crude oil export 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Mt	Share [%]	
			country	cumulative
1	Saudi Arabia	352.6	16.7	16.7
2	Russia	241.3	11.5	28.2
3	Canada	159.0	7.5	35.7
4	Iraq	149.3	7.1	42.8
5	U. Arab Emirates	121.3	5.8	48.6
6	Nigeria	105.1	5.0	53.6
7	Kuwait	97.6	4.6	58.2
8	Venezuela	96.9	4.6	62.8
9	Angola	85.0	4.0	66.9
10	Kazakhstan	64.5	3.1	69.9
11	Norway	62.8	3.0	72.9
12	Mexico	62.0	2.9	75.8
13	Iran	53.7	2.6	78.4
14	Oman	39.2	1.9	80.3
15	Colombia	36.6	1.7	82.0
16	Brazil	36.5	1.7	83.7
17	Azerbaijan	35.1	1.7	85.4
18	United Kingdom	33.7	1.6	87.0
19	Algeria	31.9	1.5	88.5
20	Qatar	24.4	1.2	89.7
	...			
60	Germany	0.3	< 0.05	99.9
	...			
	other countries [57]	217.5	10.3	100.0
	World	**2,106.2**	**100.0**	
	Europe	110.0	5.2	
	CIS	346.9	16.5	
	Africa	295.8	14.0	
	Middle East	838.6	39.8	
	Austral-Asia	75.7	3.6	
	North America	243.8	11.6	
	Latin America	195.5	9.3	
	OPEC	1,151.0	54.6	
	OPEC-Gulf	799.0	37.9	
	OECD	368.3	17.5	
	EU-28	47.0	2.2	

Table 19: Crude oil import 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country/Region	Mt	Share [%] country	Share [%] cumulative
1	USA	367.8	16.7	16.7
2	China	334.0	15.1	31.8
3	India	196.9	8.9	40.8
4	Japan	166.0	7.5	48.3
5	Korea, Rep.	139.6	6.3	54.6
6	Germany	91.3	4.1	58.8
7	Spain	64.6	2.9	61.7
8	Italy	63.1	2.9	64.6
9	France	57.6	2.6	67.2
10	Netherlands	52.9	2.4	69.6
11	United Kingdom	50.5	2.3	71.9
12	Singapore	49.4	2.2	74.1
13	Thailand	43.4	2.0	76.1
14	Taiwan	41.6	1.9	78.0
15	Canada	37.0	1.7	79.6
16	Belgium	35.4	1.6	81.2
17	Greece	26.9	1.2	82.5
18	Poland	26.6	1.2	83.7
19	Turkey	25.2	1.1	84.8
20	Australia	21.2	1.0	85.8
	...			
	other countries [66]	313.8	14.2	100.0
	World	**2,204.7**	**100.0**	
	Europe	613.8	27.8	
	CIS	25.2	1.1	
	Africa	10.3	0.5	
	Middle East	34.0	1.5	
	Austral-Asia	1,062.6	48.2	
	North America	405.3	18.4	
	Latin America	53.5	2.4	
	OECD	1,340.1	60.8	
	EU-28	580.0	26.3	

Table 20: Natural gas 2015 [bcm]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
EUROPE	Albania	< 0.05	8	1	50	59	51
	Austria	1.3	99	8	33	140	41
	Bulgaria	0.2	8	6	575	589	581
	Croatia	1.7	74	25	50	149	75
	Cyprus	–	–	–	250	250	250
	Czech Republic	0.4	16	7	130	153	137
	Denmark	4.6	187	31	236	454	267
	France	0.1	229	9	3,984	4,222	3,993
	Germany	9.7	1,029	74	1,500	2,604	1,574
	Greece	< 0.05	1	1	10	12	11
	Hungary	1.8	230	8	347	585	355
	Ireland	0.1	56	10	50	116	60
	Italy	6.2	756	45	405	1,205	450
	Lithuania	–	–	–	380	380	380
	Malta	–	–	–	10	10	10
	Netherlands	51.2	3,571	760	1,135	5,466	1,895
	Norway	121.3	2,102	1,856	2,090	6,048	3,946
	Poland	4.4	265	82	1,028	1,375	1,110
	Portugal	–	–	–	40	40	40
	Romania	11.2	1,308	105	1,611	3,024	1,716
	Serbia	0.6	34	20	10	64	30
	Slovakia	0.1	26	4	10	40	14
	Slovenia	< 0.05	n. s.	1	10	11	11
	Spain	0.1	12	3	2,425	2,440	2,428
	Sweden	–	–	–	280	280	280
	Turkey	0.4	14	5	1,153	1,172	1,158
	United Kingdom	41.3	2,539	333	1,737	4,609	2,070
CIS	Armenia	–	–	–	10	10	10
	Azerbaijan	18.2	579	1,148	1,800	3,527	2,948
	Belarus	0.2	13	3	10	26	13
	Georgia	< 0.05	3	8	102	113	110
	Kazakhstan	21.7	556	1,918	4,180	6,654	6,098
	Kyrgyzstan	< 0.05	7	6	20	33	26
	Moldova, Republic	–	–	–	20	20	20
	Russia	636.0	22,325	47,768	152,050	222,143	199,818
	Tajikistan	< 0.05	9	6	20	34	26
	Turkmenistan	80.2	2,636	9,904	15,000	27,540	24,904
	Ukraine	17.5	2,023	944	7,130	10,097	8,074
	Uzbekistan	58.8	2,312	1,608	1,400	5,320	3,008
	Algeria	82.3	2,390	4,504	26,720	33,614	31,224
	Angola	0.8	23	308	1,200	1,531	1,508

continuation of table 20
[bcm]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
AFRICA	Benin	–	–	–	100	100	100
	Botswana	–	–	–	1,840	1,840	1,840
	Cameroon	0.7	n. s.	135	200	335	335
	Chad	–	–	–	1,450	1,450	1,450
	Congo, DR	n. s.	n. s.	1	10	11	11
	Congo, Rep.	0.2	n. s.	106	200	306	306
	Côte d'Ivoire	2.1	30	16	400	446	416
	Egypt	44.3	870	2,168	10,830	13,868	12,998
	Equatorial Guinea	6.6	54	109	150	313	259
	Eritrea	–	–	–	29	29	29
	Ethiopia	–	–	–	176	176	176
	Gabon	0.3	6	28	600	634	628
	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	11.7	319	1,504	4,650	6,473	6,154
	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	4.0	37	127	5,500	5,664	5,627
	Namibia	–	–	–	350	350	350
	Niger	–	–	–	250	250	250
	Nigeria	43.7	535	5,111	3,200	8,846	8,311
	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	1.0	44	8	12,620	12,672	12,628
	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	3.0	55	65	750	870	815
	Uganda	–	–	–	100	100	100
	Western Sahara	–	–	–	50	50	50
	Zimbabwe	–	–	–	10	10	10

continuation of table 20
[bcm]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
MIDDLE EAST	Bahrain	15.5	296	172	200	668	372
	Iran	183.9	2,563	33,500	10,000	46,063	43,500
	Iraq	7.5	133	3,158	4,000	7,291	7,158
	Israel	8.3	39	199	2,000	2,238	2,199
	Jordan	0.1	5	6	350	361	356
	Kuwait	15.7	352	1,783	500	2,635	2,283
	Lebanon	–	–	–	850	850	850
	Oman	34.3	439	688	3,020	4,147	3,708
	Palestinian territories	–	–	–	380	380	380
	Qatar	171.3	1,606	24,299	2,000	27,905	26,299
	Saudi Arabia	106.4	1,896	8,325	24,664	34,885	32,989
	Syrian	4.5	141	241	300	682	541
	U. Arab Emirates	55.8	1,260	6,087	7,310	14,657	13,397
	Yemen	2.9	49	266	500	815	766
AUSTRAL-ASIA	Afghanistan	0.1	57	50	400	507	450
	Australia	69.9	1,156	3,471	35,085	39,712	38,556
	Bangladesh	25.8	373	233	800	1,406	1,033
	Brunei	12.5	423	263	200	886	463
	Cambodia	–	–	–	50	50	50
	China	138.2	1,640	3,439	67,980	73,059	71,419
	India	29.2	790	1,488	7,039	9,318	8,528
	Indonesia	72.7	2,150	2,775	9,980	14,905	12,755
	Japan	2.7	138	21	10	169	31
	Korea, Rep.	0.2	n. s.	1	50	51	51
	Laos	–	–	–	10	10	10
	Malaysia	68.2	1,330	2,190	1,900	5,420	4,090
	Mongolia	–	–	–	133	133	133
	Myanmar	16.0	201	485	2,000	2,686	2,485
	New Zealand	5.0	165	37	353	555	390
	Pakistan	40.0	881	669	4,570	6,120	5,239
	Papua New Guinea	0.1	3	141	1,000	1,145	1,141
	Philippines	3.5	43	98	502	643	600
	Sri Lanka	–	–	–	300	300	300
	Taiwan	0.4	52	3	5	60	8
	Thailand	39.8	614	207	740	1,561	947
	Timor-Leste	n. s.	n. s.	88	300	388	388
	Viet Nam	10.7	112	617	1,355	2,084	1,972
NORTH AMERICA	Canada	154.8	6,149	1,987	37,901	46,037	39,888
	Greenland	–	–	–	3,900	3,900	3,900
	Mexico	46.0	1,661	324	17,770	19,755	18,094
	USA	768.1	35,051	10,441	53,246	98,738	63,687

continuation of table 20
[bcm]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
LATINAMERICA	Argentina	36.5	1,176	332	23,710	25,218	24,042
	Barbados	n.s.	n. s.	2	100	102	102
	Belize	–	–	–	10	10	10
	Bolivia	20.9	284	281	1,620	2,185	1,901
	Brazil	23.1	312	424	18,446	19,181	18,869
	Chile	1.0	110	98	1,510	1,718	1,608
	Colombia	12.7	269	148	2,282	2,700	2,430
	Cuba	1.2	16	71	400	487	471
	Ecuador	0.5	7	11	20	38	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	12.5	129	414	2,550	3,093	2,964
	Puerto Rico	–	–	–	30	30	30
	Suriname	–	–	–	350	350	350
	Trinidad and Tobago	39.6	669	326	500	1,495	826
	Uruguay	–	–	–	828	828	828
	Venezuela	24.8	1,140	5,617	7,130	13,887	12,747
	World	**3,573.7**	**113,275**	**196,551**	**652,388**	**962,214**	**848,939**
COUNTRY GROUPS	Europe	256.5	12,563	3,395	19,538	35,496	22,933
	CIS	832.5	30,463	63,313	181,742	275,517	245,055
	Africa	201.7	4,367	14,365	83,274	102,006	97,639
	Middle East	606.2	8,781	78,725	56,074	143,579	134,799
	Austral-Asia	535.1	10,129	16,277	134,762	161,168	151,039
	North America	968.9	42,861	12,752	112,817	168,430	125,569
	Latin America	172.8	4,112	7,724	64,181	76,017	71,905
ECONOMIC COUNTRY GRP.	OPEC	704.3	12,226	94,207	91,394	197,828	185,601
	OPEC-Gulf	540.6	7,811	77,152	48,474	133,437	125,626
	OECD	1,298.9	55,601	19,817	168,428	243,846	188,245
	EU-28	134.3	10,404	1,513	16,235	28,152	17,748

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

Table 21: Natural gas resources 2015 [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	67,980	20,000	12,000	25,080	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	South Africa	12,620	1,000	–	11,050	570
13	Egypt	10,830	8,000	–	2,830	–
14	Iran	10,000	10,000	–	–	–
15	Indonesia	9,980	5,500	–	1,300	3,180
16	U. Arab Emirates	7,310	1,500	–	5,810	–
17	Venezuela	7,130	2,400	–	4,730	–
	Ukraine	7,130	500	–	3,630	3,000
19	India	7,039	2,000	–	2,720	2,319
20	Mozambique	5,500	5,500	–	–	–
	...					
46	Germany	1,500	20	90	940	450
	...					
	other countries [123]	100,777	65,111	1,182	30,551	3,933
	World	**652,388**	**323,495**	**62,772**	**214,802**	**51,319**
	Europe	19,538	5,467	312	12,563	1,196
	CIS	181,742	130,880	20,000	13,910	16,952
	Africa	83,274	35,544	5,500	40,820	1,410
	Middle East	56,074	42,280	750	13,044	–
	Austral-Asia	134,762	46,889	20,200	44,700	22,973
	North America	112,817	39,300	16,000	48,946	8,571
	Latin America	64,181	23,135	10	40,818	218
	OPEC	91,394	46,220	5,500	39,674	–
	OPEC-Gulf	48,474	37,000	–	11,474	–
	OECD	168,428	55,611	24,312	72,949	15,555
	EU-28	16,235	3,117	312	11,893	913

– no resources / not specified

Table 22: Natural gas reserves 2015 [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	47,768	47,724	–	44
2	Iran	33,500	33,500	–	–
3	Qatar	24,299	24,299	–	–
4	USA	10,441	4,341	5,655	445
5	Turkmenistan	9,904	9,904	–	–
6	Saudi Arabia	8,325	8,325	–	–
7	U. Arab Emirates	6,087	6,087	–	–
8	Venezuela	5,617	5,617	–	–
9	Nigeria	5,111	5,111	–	–
10	Algeria	4,504	4,504	–	–
11	Australia	3,471	2,307	n. s.	1,164
12	China	3,439	2,632	500	306
13	Iraq	3,158	3,158	–	–
14	Indonesia	2,775	2,775	–	–
15	Malaysia	2,190	2,190	–	–
16	Egypt	2,168	2,168	–	–
17	Canada	1,987	1,934	n. s.	53
18	Kazakhstan	1,918	1,918	–	–
19	Norway	1,856	1,856	–	–
20	Kuwait	1,783	1,783	–	–
	...				
58	Germany	74	74	–	–
	...				
	other countries [76]	16,175	15,895	–	280
	World	**196,551**	**188,104**	**6,155**	**2,292**
	Europe	3,395	3,395	–	–
	CIS	63,313	63,269	–	44
	Africa	14,365	14,365	–	–
	Middle East	78,725	78,725	–	–
	Austral-Asia	16,277	14,027	500	1,751
	North America	12,752	6,599	5,655	498
	Latin America	7,724	7,724	–	–
	OPEC	94,207	94,207	–	–
	OPEC-Gulf	77,152	77,152	–	–
	OECD	19,817	12,500	5,655	1,662
	EU-28	1,513	1,513	–	–

n. s. not specified
– no reserves
1 including tight gas
2 partly data status 2014

Table 23: Natural gas production 2010–2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2010	2011	2012	2013	2014	2015	Share [%] country	Share [%] cumulative
		bcm							
1	USA	611.0	650.9	681.5	687.2	729.1	768.1	21.5	21.5
2	Russia	610.6	629.5	609.7	627.6	610.1	636.0	17.8	39.3
3	Iran	138.5	151.8	158.2	159.1	172.6	183.9	5.1	44.4
4	Qatar	116.7	146.8	157.0	158.5	160.0	171.3	4.8	49.2
5	Canada	159.8	160.5	156.5	154.8	161.3	154.8	4.3	53.6
6	China	96.8	103.1	110.7	119.3	132.8	138.2	3.9	57.4
7	Norway	106.4	101.4	114.8	107.1	108.8	121.3	3.4	60.8
8	Saudi Arabia	83.9	92.3	95.2	103.0	108.2	106.4	3.0	63.8
9	Algeria	83.9	78.0	81.5	79.6	79.7	82.3	2.3	66.1
10	Turkmenistan	42.4	59.5	64.4	62.3	69.3	80.2	2.2	68.3
11	Indonesia	82.8	91.7	76.7	70.4	71.8	72.7	2.0	70.4
12	Australia	50.4	45.4	48.8	50.1	55.3	69.9	2.0	72.3
13	Malaysia	63.9	61.8	63.0	69.1	66.4	68.2	1.9	74.2
14	Uzbekistan	64.7	58.8	57.7	58.7	59.3	58.8	1.6	75.9
15	U. Arab Emirates	51.0	51.7	51.7	56.0	55.6	55.8	1.6	77.5
16	Netherlands	82.9	80.6	80.1	84.5	66.3	51.2	1.4	78.9
17	Mexico	55.3	52.5	47.0	45.8	44.8	46.0	1.3	80.2
18	Egypt	61.3	61.3	60.9	56.1	48.7	44.3	1.2	81.4
19	Nigeria	32.9	35.9	37.9	36.1	40.3	43.7	1.2	82.6
20	United Kingdom	54.6	43.0	41.1	38.5	38.7	41.3	1.2	83.8
	...								
43	Germany	14.2	13.3	12.1	11.1	10.5	9.7	0.3	97.8
	...								
	other countries [69]	575.9	566.9	581.9	586.1	594.3	569.6	15.9	100.0
	World	**3,239.8**	**3,336.7**	**3,388.5**	**3,421.0**	**3,483.9**	**3,573.7**	**100.0**	
	Europe	299.8	278.2	286.8	276.3	258.2	256.5	7.2	
	CIS	790.3	811.4	795.9	817.1	807.6	832.5	23.3	
	Africa	214.9	197.6	210.5	202.2	200.9	201.7	5.6	
	Middle East	461.0	523.5	541.1	566.8	587.6	606.2	17.0	
	Austral-Asia	486.0	492.1	491.9	492.5	515.1	535.1	15.0	
	North America	826.1	863.9	885.0	887.8	935.2	968.9	27.1	
	Latin America	161.6	170.1	177.3	178.3	179.5	172.8	4.8	
	OPEC	565.5	611.1	648.2	655.6	682.3	704.3	19.7	
	OPEC-Gulf	403.4	460.9	482.5	498.0	520.0	540.6	15.1	
	OECD	1,175.5	1,187.1	1,218.7	1,216.3	1,251.7	1,298.9	36.3	
	EU-28	192.5 [1]	175.6 [1]	170.8 [1]	168.0	148.3	134.3	3.8	

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

Table 24: Natural gas consumption 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	bcm	Share [%] country	Share [%] cumulative
1	USA	777.6	21.8	21.8
2	Russia	461.5	13.0	34.8
3	China	191.0	5.4	40.2
4	Iran	182.7	5.1	45.3
5	Japan	114.1	3.2	48.5
6	Saudi Arabia	106.4	3.0	51.5
7	Canada	102.5	2.9	54.4
8	Germany	96.5	2.7	57.1
9	Mexico	83.2	2.3	59.4
10	U. Arab Emirates	69.1	1.9	61.3
11	United Kingdom	68.3	1.9	63.3
12	Italy	61.4	1.7	65.0
13	Thailand	52.9	1.5	66.5
14	India	50.6	1.4	67.9
15	Uzbekistan	48.5	1.4	69.2
16	Egypt	47.8	1.3	70.6
17	Turkey	47.6	1.3	71.9
18	Argentina	47.5	1.3	73.3
19	Qatar	45.2	1.3	74.5
20	Korea, Rep.	43.6	1.2	75.8
	...			
	other countries [90]	863.6	24.2	100.0
	World	**3,561.7**	**100.0**	
	Europe	496.4	13.9	
	CIS	632.5	17.8	
	Africa	129.3	3.6	
	Middle East	486.2	13.7	
	Austral-Asia	687.9	19.3	
	North America	963.3	27.0	
	Latin America	166.1	4.7	
	OPEC	518.0	14.5	
	OPEC-Gulf	430.3	12.1	
	OECD	1,646.3	46.2	
	EU-28	436.4	12.3	

Table 25: Natural gas export 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	bcm	Share [%] country	Share [%] cumulative
1	Russia	196.0	18.6	18.6
2	Qatar	126.1	12.0	30.5
3	Norway	114.8	10.9	41.4
4	Canada	78.3	7.4	48.8
5	USA	50.5	4.8	53.6
6	Netherlands	48.3	4.6	58.2
7	Turkmenistan	45.8	4.3	62.5
8	Algeria	43.4	4.1	66.6
9	Australia	39.8	3.8	70.4
10	Malaysia	34.2	3.2	73.6
11	Indonesia	32.9	3.1	76.7
12	Germany	31.2	3.0	79.7
13	Nigeria	25.2	2.4	82.1
14	Trinidad and Tobago	18.5	1.8	83.9
15	Bolivia	17.6	1.7	85.5
16	Myanmar	15.0	1.4	86.9
17	United Kingdom	13.4	1.3	88.2
18	Uzbekistan	13.2	1.3	89.5
19	Kazakhstan	11.3	1.1	90.5
20	Oman	10.7	1.0	91.6
	...			
	other countries [31]	89.2	8.4	100.0
	World	**1,055.4**	**100.0**	
	Europe	235.7	22.3	
	CIS	275.6	26.1	
	Africa	84.3	8.0	
	Middle East	154.7	14.7	
	Austral-Asia	133.0	12.6	
	North America	128.9	12.2	
	Latin America	43.2	4.1	
	OPEC	217.8	20.6	
	OPEC-Gulf	142.2	13.5	
	OECD	404.1	38.3	
	EU-28	120.3	11.4	

Table 26: Natural gas import 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	bcm	Share [%] country	Share [%] cumulative
1	Germany	115.5	10.9	10.9
2	Japan	111.4	10.5	21.5
3	USA	77.0	7.3	28.7
4	China	59.8	5.7	34.4
5	Italy	56.2	5.3	39.7
6	Turkey	48.2	4.6	44.3
7	Korea, Rep.	43.4	4.1	48.4
8	France	42.5	4.0	52.4
9	United Kingdom	41.8	4.0	56.4
10	Mexico	37.0	3.5	59.8
11	Netherlands	35.9	3.4	63.2
12	Spain	32.4	3.1	66.3
13	Belgium	27.6	2.6	68.9
14	Russia	25.0	2.4	71.3
15	India	21.7	2.1	73.3
16	U. Arab Emirates	20.8	2.0	75.3
17	Canada	19.6	1.9	77.2
18	Brazil	18.1	1.7	78.9
19	Taiwan	17.3	1.6	80.5
20	Belarus	16.8	1.6	82.1
	...			
	other countries [56]	189.3	17.9	100.0
	World	**1,057.3**	**100.0**	
	Europe	474.4	44.9	
	CIS	74.7	7.1	
	Africa	12.2	1.2	
	Middle East	35.2	3.3	
	Austral-Asia	291.8	27.6	
	North America	133.6	12.6	
	Latin America	35.5	3.4	
	OPEC	32.6	3.1	
	OPEC-Gulf	32.2	3.0	
	OECD	762.3	72.1	
	EU-28	420.9	39.8	

Table 27: Hard coal 2015 [Mt]

	Country / Region	Production	Reserves	Resources	Total Resources
EUROPE	Belgium	–	–	4,100	4,100
	Bulgaria	–	192	3,920	4,112
	Czech Republic	8.0	1,103	15,423	16,526
	France	< 0.05	–	160	160
	Germany	6.7	12	82,963	82,975
	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	1.1	2	90	92
	Poland	72.5	18,700	160,917	179,617
	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	3.0	868	3,363	4,231
	Sweden	–	1	4	5
	Turkey	1.4	378	803	1,181
	United Kingdom	8.6	70	186,700	186,770
CIS	Armenia	–	163	154	317
	Georgia	0.4	201	700	901
	Kazakhstan	101.0	25,605	123,090	148,695
	Kyrgyzstan	0.2	971	27,528	28,499
	Russia	300.1	69,634	2,658,281	2,727,915
	Tajikistan	1.0	375	3,700	4,075
	Turkmenistan	–	–	800	800
	Ukraine	39.7	32,039	49,006	81,045
	Uzbekistan	0.4	1,375	9,477	10,852
AFRICA	Algeria	–	59	164	223
	Botswana	2.1	40	21,200	21,240
	Congo, DR	0.1	88	900	988
	Egypt	0.3	16	166	182
	Madagascar	–	–	150	150
	Malawi	0.1	2	800	802
	Morocco	–	14	82	96
	Mozambique	6.6	1,792	21,844	23,636
	Namibia	–	–	350	350
	Niger	0.2	–	90	90
	Nigeria	0.1	287	1,857	2,144
	South Africa	252.0	9,893	203,667	213,560
	Swaziland	0.2	144	4,500	4,644
	Tanzania	0.3	269	1,141	1,410
	Uganda	–	–	800	800
	Zambia	0.4	45	900	945
	Zimbabwe	4.2	502	25,000	25,502
ME	Iran	1.1	1,203	40,000	41,203

continuation of table 27
[Mt]

	Country / Region	Production	Reserves	Resources	Total Resources
AUSTRAL-ASIA	Afghanistan	1.4	66	n. s.	66
	Australia	439.6	68,310	1,542,829	1,611,139
	Bangladesh	0.7	293	2,967	3,260
	Bhutan	0.1	n. s.	n. s.	n. s.
	China	3,387.2	126,003	5,335,123	5,461,126
	India	638.2	89,782	170,715	260,497
	Indonesia	400.0	17,326	93,818	111,143
	Japan	–	340	13,543	13,883
	Korea, DPR	35.0	600	10,000	10,600
	Korea, Rep.	1.7	326	1,360	1,686
	Laos	0.1	4	58	62
	Malaysia	2.6	141	1,068	1,209
	Mongolia	18.2	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	3.1	825	2,350	3,175
	Pakistan	2.2	207	5,789	5,996
	Philippines	8.0	211	1,012	1,223
	Taiwan	–	1	101	102
	Viet Nam	41.5	3,116	3,519	6,635
NORTH-AMERICA	Canada	51.2	4,346	183,260	187,606
	Greenland	–	183	200	383
	Mexico	14.7	1,160	3,000	4,160
	USA	749.0	221,400	6,458,261	6,679,661
LATIN AMERICA	Argentina	0.1	500	300	800
	Bolivia	–	1	n. s.	1
	Brazil	4.5	1,547	4,665	6,212
	Chile	3.2	1,181	4,135	5,316
	Colombia	85.5	4,881	9,928	14,809
	Costa Rica	–	–	17	17
	Peru	0.3	102	1,465	1,567
	Venezuela	1.0	731	5,981	6,712
	World	**6,701.5**	**712,211**	**17,711,955**	**18,424,166**
COUNTRY GROUPS	Europe	101.5	22,737	470,035	492,772
	CIS	442.9	130,362	2,872,737	3,003,098
	Africa	266.5	13,150	283,611	296,761
	Middle East	1.1	1,203	40,000	41,203
	Austral-Asia	4,980.0	308,728	7,224,360	7,533,088
	North America	815.0	227,089	6,644,721	6,871,810
	Latin America	94.5	8,943	26,491	35,434
	Antarctica [1]	–	–	150,000	150,000
ECONOMIC COUNTRY GRP.	OPEC	2.2	2,279	48,002	50,281
	OPEC-Gulf	1.1	1,203	40,000	41,203
	OECD	1,363.9	320,061	8,671,970	8,992,031
	EU-28	98.9	21,814	468,494	490,307

[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 28: Hard coal resources 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Mt	Share [%] country	Share [%] cumulative
1	USA	6,458,261	36.5	36.5
2	China	5,335,123	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	1.1	91.5
6	United Kingdom	186,700	1.1	92.5
7	Canada	183,260	1.0	93.5
8	India	170,715	1.0	94.5
9	Poland	160,917	0.9	95.4
10	Kazakhstan	123,090	0.7	96.1
11	Indonesia	93,818	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]	15,423	0.1	98.5
	...			
	other countries [57]	272,478	1.5	100.0
	World	**17,711,955**	**100.0**	
	Europe	470,035	2.7	
	CIS	2,872,737	16.2	
	Africa	283,611	1.6	
	Middle East	40,000	0.2	
	Austral-Asia	7,224,360	40.8	
	North America	6,644,721	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	8,671,970	49.0	
	EU-28	468,494	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 29: Hard coal reserves 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Mt	Share [%] country	Share [%] cumulative
1	USA	221,400	31.1	31.1
2	China	126,003	17.7	48.8
3	India	89,782	12.6	61.4
4	Russia [1]	69,634	9.8	71.2
5	Australia	68,310	9.6	80.8
6	Ukraine [1]	32,039	4.5	85.3
7	Kazakhstan	25,605	3.6	88.8
8	Poland	18,700	2.6	91.5
9	Indonesia	17,326	2.4	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
	...			
59	Germany [2]	12	< 0.05	100.0
	...			
	other countries [50]	11,736	1.6	100.0
	World	**712,211**	**100.0**	
	Europe	22,737	3.2	
	CIS	130,362	18.3	
	Africa	13,150	1.8	
	Middle East	1,203	0.2	
	Austral-Asia	308,728	43.3	
	North America	227,089	31.9	
	Latin America	8,943	1.3	
	OPEC	2,279	0.3	
	OPEC-Gulf	1,203	0.2	
	OECD	320,061	44.9	
	EU-28	21,814	3.1	

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

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

Table 30: Hard coal production 2010–2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2010	2011	2012	2013	2014	2015	Share [%] country	Share [%] cumulative
		Mt							
1	China	3,115.0	3,471.9	3,532.6	3,601.5	3,505.0	3,387.2	50.5	50.5
2	USA	918.2	920.4	850.5	823.4	835.1	749.0	11.2	61.7
3	India	532.7	539.9	557.7	565.6	612.4	638.2	9.5	71.2
4	Australia	355.4	345.2	374.1	412.3	441.3	439.6	6.6	77.8
5	Indonesia	285.0	364.5	406.3	430.0	410.8	400.0	6.0	83.8
6	Russia	247.9	258.5	276.1	279.0	287.0	300.1	4.5	88.3
7	South Africa	257.2	252.8	258.6	256.3	260.5	252.0	3.8	92.0
8	Kazakhstan	103.6	108.1	112.8	112.9	107.7	101.0	1.5	93.5
9	Colombia	74.4	85.8	89.0	85.5	88.6	85.5	1.3	94.8
10	Poland	76.7	76.4	79.8	77.1	73.3	72.5	1.1	95.9
11	Canada	57.9	57.4	57.0	59.9	60.5	51.2	0.8	96.6
12	Viet Nam	44.8	46.6	42.1	41.0	41.1	41.5	0.6	97.3
13	Ukraine [1]	75.0	81.7	85.6	83.4	65.0	39.7	0.6	97.9
14	Korea, DPR [2]	24.0	31.5	32.2	31.6	33.0	35.0	0.5	98.4
15	Mongolia	18.3	26.1	23.6	27.0	18.1	18.2	0.3	98.6
16	Mexico	11.2	21.0	16.3	15.7	14.8	14.7	0.2	98.9
17	United Kingdom	18.4	18.6	17.0	12.8	11.6	8.6	0.1	99.0
18	Czech Republic [1]	11.2	11.0	10.8	8.6	8.3	8.0	0.1	99.1
	Philippines	7.3	7.6	8.2	7.8	8.0	8.0	0.1	99.2
20	Germany	14.1	13.0	11.6	8.3	8.3	6.7	0.1	99.3
	...								
	other countries [37]	41.2	39.0	41.7	44.8	52.0	44.8	0.7	100.0
	World	**6,289.6**	**6,776.7**	**6,883.4**	**6,984.4**	**6,942.4**	**6,701.5**	**100.0**	
	Europe	136.5	132.5	131.7	117.6	109.5	101.5	1.5	
	CIS	427.3	449.0	475.5	476.6	461.3	442.9	6.6	
	Africa	261.7	257.6	267.6	268.1	276.3	266.5	4.0	
	Middle East	1.0	0.9	0.8	0.9	1.0	1.1	0.0	
	Austral-Asia	4,398.5	4,849.1	4,992.6	5,131.6	5,084.5	4,980.0	74.3	
	North America	987.3	998.7	923.8	899.0	910.4	815.0	12.2	
	Latin America	77.3	88.9	91.3	90.5	99.4	94.5	1.4	
	OPEC	3.7	3.6	2.7	3.3	3.4	2.2	0.0	
	OPEC-Gulf	1.0	0.9	0.8	0.9	1.0	1.1	0.0	
	OECD	1,485.0	1,481.7	1,434.9	1,436.3	1,471.8	1,363.9	20.4	
	EU-28	131.8 [3]	128.2 [3]	128.0 [3]	113.6	105.9	98.9	1.5	

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

Table 31: Hard coal consumption 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Mt	Share [%] country	Share [%] cumulative
1	China	3,586.0	53.6	53.6
2	India	837.4	12.5	66.1
3	USA	692.2	10.3	76.5
4	Japan	190.6	2.9	79.3
5	South Africa	175.8	2.6	82.0
6	Russia	172.7	2.6	84.5
7	Korea, Rep.	136.7	2.0	86.6
8	Kazakhstan	75.9	1.1	87.7
9	Poland	71.6	1.1	88.8
10	Germany	62.0	0.9	89.7
11	Taiwan	61.8	0.9	90.6
12	Ukraine	53.1	0.8	91.4
13	Australia	51.3	0.8	92.2
14	Viet Nam	46.7	0.7	92.9
15	Indonesia	36.0	0.5	93.4
16	Turkey	35.4	0.5	94.0
17	United Kingdom	32.4	0.5	94.5
18	Malaysia	28.9	0.4	94.9
19	Canada	28.4	0.4	95.3
20	Brazil	24.7	0.4	95.7
	...			
	other countries [83]	288.6	4.3	100.0
	World	**6,688.4**	**100.0**	
	Europe	314.8	4.7	
	CIS	305.2	4.6	
	Africa	196.4	2.9	
	Middle East	14.0	0.2	
	Austral-Asia	5,067.4	75.8	
	North America	743.0	11.1	
	Latin America	47.6	0.7	
	OPEC	3.3	0.0	
	OPEC-Gulf	3.1	0.0	
	OECD	1,455.7	21.8	
	EU-28	276.6	4.1	

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

Table 32: Hard coal export 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Mt	Share [%] country	Share [%] cumulative
1	Australia	388.2	30.8	30.8
2	Indonesia	367.0	29.1	59.9
3	Russia	151.4	12.0	71.9
4	Colombia	82.4	6.5	78.5
5	South Africa	77.3	6.1	84.6
6	USA	67.1	5.3	89.9
7	Canada	30.4	2.4	92.3
8	Kazakhstan	25.3	2.0	94.3
9	Korea, DPR	19.6	1.6	95.9
10	Mongolia	14.5	1.1	97.1
11	Poland	9.2	0.7	97.8
12	China	5.3	0.4	98.2
13	Mozambique	5.0	0.4	98.6
14	Czech Republic	4.2	0.3	98.9
15	Philippines	3.1	0.2	99.2
16	Viet Nam	1.7	0.1	99.3
17	Venezuela	1.6	0.1	99.4
18	New Zealand	1.4	0.1	99.6
19	Ukraine	1.2	0.1	99.7
20	Chile	1.1	0.1	99.7
	...			
26	Germany	0.2	< 0.05	100.0
	...			
	other countries [5]	3.0	0.2	100.0
	World	**1,260.4**	**100.0**	
	Europe	15.9	1.3	
	CIS	177.9	14.1	
	Africa	82.3	6.5	
	Austral-Asia	801.6	63.6	
	North America	97.5	7.7	
	Latin America	85.2	6.8	
	OPEC	1.6	0.1	
	OECD	504.2	40.0	
	EU-28	14.8	1.2	

Table 33: Hard coal import 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Mt	Share [%] country	Share [%] cumulative
1	China	204.1	16.3	16.3
2	India	199.9	16.0	32.3
3	Japan	190.6	15.2	47.5
4	Korea, Rep.	135.0	10.8	58.2
5	Taiwan	64.7	5.2	63.4
6	Germany	55.5	4.4	67.8
7	Turkey	34.0	2.7	70.6
8	Malaysia	26.3	2.1	72.7
9	United Kingdom	24.2	1.9	74.6
10	Russia	24.0	1.9	76.5
11	Thailand	21.9	1.7	78.3
12	Netherlands	20.5	1.6	79.9
13	Brazil	20.3	1.6	81.5
14	Italy	19.6	1.6	83.1
15	Spain	19.0	1.5	84.6
16	Philippines	16.7	1.3	85.9
17	Ukraine	14.6	1.2	87.1
18	France	12.5	1.0	88.1
19	Hong Kong	11.2	0.9	89.0
20	Israel	10.6	0.8	89.8
	...			
	other countries [62]	127.4	10.2	100.0
	World	**1,252.8**	**100.0**	
	Europe	232.4	18.6	
	CIS	40.3	3.2	
	Africa	12.2	1.0	
	Middle East	12.9	1.0	
	Austral-Asia	891.8	71.2	
	North America	25.5	2.0	
	Latin America	37.7	3.0	
	OPEC	2.0	0.2	
	OPEC-Gulf	2.0	0.2	
	OECD	599.1	47.8	
	EU-28	195.7	15.6	

Table 34: Lignite 2015 [Mt]

	Country / Region	Production	Reserves	Resources	Total Resources
EUROPE	Albania	< 0.05	522	205	727
	Austria	–	–	333	333
	Bosnia & Herzegovina	6.5	2,264	3,010	5,274
	Bulgaria	35.9	2,174	2,400	4,574
	Croatia	–	n. s.	300	300
	Czech Republic	38.3	2,573	7,146	9,719
	France	–	n. s.	114	114
	Germany	178.1	36,200	36,500	72,700
	Greece	46.0	2,876	3,554	6,430
	Hungary	9.3	2,633	2,704	5,337
	Italy	–	7	22	29
	Kosovo	8.2	1,564	9,262	10,826
	Macedonia	5.9	332	300	632
	Montenegro	1.8	n. s.	n. s.	n. s.
	Poland	63.1	5,461	222,396	227,857
	Portugal	–	33	33	66
	Romania	25.5	280	9,640	9,920
	Serbia	37.3	7,112	13,074	20,186
	Slovakia	1.9	135	938	1,073
	Slovenia	3.2	315	341	656
	Spain	–	319	n. s.	319
	Turkey	50.4	10,975	3,405	14,381
	United Kingdom	–	–	1,000	1,000
CIS	Belarus	–	–	1,500	1,500
	Kazakhstan	6.2	n. s.	n. s.	n. s.
	Kyrgyzstan	1.6	n. s.	n. s.	n. s.
	Russia	73.2	90,730	1,288,894	1,379,623
	Ukraine	–	2,336	5,381	7,717
	Uzbekistan	3.6	n. s.	n. s.	n. s.
AFRICA	Central African Rep.	–	3	n. s.	3
	Ethiopia	< 0.05	n. s.	n. s.	n. s.
	Madagascar	–	–	37	37
	Mali	–	–	3	3
	Morocco	–	–	40	40
	Niger	–	6	n. s.	6
	Nigeria	–	57	320	377
	Sierra Leone	–	–	2	2
	Australia	63.0	76,508	403,382	479,890
	Bangladesh	–	–	3	3
	China	140.0	7,673	324,884	332,557
	India	43.9	4,987	38,054	43,041

continuation of table 34
[Mt]

	Country / Region	Production	Reserves	Resources	Total Resources
AUSTRAL-ASIA	Indonesia	60.0	8,247	32,792	41,038
	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	5.8	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	–	105	912	1,017
	Thailand	15.2	1,063	826	1,889
	Viet Nam	–	244	199,876	200,120
NORTH AMERICA	Canada	10.5	2,236	118,270	120,506
	Mexico	–	51	n. s.	51
	USA	64.7	30,182	1,367,956	1,398,138
LATIN AMERICA	Argentina	–	–	7,300	7,300
	Brazil	3.6	5,049	12,587	17,636
	Chile	–	n. s.	7	7
	Dominican Rep.	–	–	84	84
	Ecuador	–	24	n. s.	24
	Haiti	–	–	40	40
	Peru	–	–	100	100
	World	**1,011.2**	**316,782**	**4,422,153**	**4,738,935**
COUNTRY GROUPS	Europe	511.3	75,776	316,676	392,452
	CIS	84.7	93,065	1,295,775	1,388,840
	Africa	< 0.05	66	402	468
	Middle East	–	–	–	–
	Austral-Asia	336.4	110,333	1,302,957	1,413,290
	North America	75.2	32,469	1,486,226	1,518,695
	Latin America	3.6	5,073	20,118	25,191
ECONOMIC COUNTRY GRP.	OPEC	–	81	320	401
	OPEC-Gulf	–	–	–	–
	OECD	528.8	177,265	2,173,727	2,350,991
	EU-28	401.1	53,007	287,420	340,427

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

Table 35: Lignite resources 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Mt	Share [%] country	Share [%] cumulative
1	USA	1,367,956	30.9	30.9
2	Russia [1]	1,288,894	29.1	60.1
3	Australia	403,382	9.1	69.2
4	China	324,884	7.3	76.5
5	Poland	222,396	5.0	81.6
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	95.5
10	India	38,054	0.9	96.3
11	Germany	36,500	0.8	97.2
12	Indonesia	32,792	0.7	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]	7,146	0.2	99.2
19	Ukraine [1]	5,381	0.1	99.4
20	New Zealand	4,600	0.1	99.5
	...			
	other countries [32]	23,994	0.5	100.0
	World	**4,422,153**	**100.0**	
	Europe	316,676	7.2	
	CIS	1,295,775	29.3	
	Africa	402	0.0	
	Austral-Asia	1,302,957	29.5	
	North America	1,486,226	33.6	
	Latin America	20,118	0.5	
	OPEC	320	0.0	
	OECD	2,173,727	49.2	
	EU-28	287,420	6.5	

[1] Lignite resources contains subbituminous coal

Table 36: Lignite reserves 2015
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	28.6	28.6
2	Australia	76,508	24.2	52.8
3	Germany	36,200	11.4	64.2
4	USA	30,182	9.5	73.7
5	Turkey	10,975	3.5	77.2
6	Indonesia	8,247	2.6	79.8
7	China	7,673	2.4	82.2
8	Serbia	7,112	2.2	84.5
9	New Zealand	6,750	2.1	86.6
10	Poland	5,461	1.7	88.3
11	Brazil	5,049	1.6	89.9
12	India	4,987	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]	2,573	0.8	95.0
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]	6,960	2.2	100.0
	World	**316,782**	**100.0**	
	Europe	75,776	23.9	
	CIS	93,065	29.4	
	Africa	66	0.0	
	Austral-Asia	110,333	34.8	
	North America	32,469	10.2	
	Latin America	5,073	1.6	
	OPEC	81	0.0	
	OECD	177,265	56.0	
	EU-28	53,007	16.7	

[1] Lignite reserves contains subbituminous coal

Table 37: Lignite production 2010–2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2010	2011	2012	2013	2014	2015	Share [%]	
					Mt			country	cumulative
1	Germany	169.4	176.5	185.4	183.0	178.2	178.1	17.6	17.6
2	China	125.3	136.3	145.0	147.0	145.0	140.0	13.8	31.5
3	Russia [1]	76.0	77.6	77.9	73.0	70.0	73.2	7.2	38.7
4	USA	71.0	73.6	71.6	70.1	72.1	64.7	6.4	45.1
5	Poland	56.5	62.8	64.3	65.8	63.9	63.1	6.2	51.3
6	Australia	68.8	66.7	69.1	59.9	58.0	63.0	6.2	57.6
7	Indonesia [1]	40.0	51.3	60.0	65.0	60.0	60.0	5.9	63.5
8	Turkey	70.0	72.5	68.1	57.5	62.6	50.4	5.0	68.5
9	Greece	53.6	58.4	62.4	54.0	48.0	46.0	4.5	73.0
10	India	37.7	42.3	46.5	44.3	47.2	43.9	4.3	77.4
11	Czech Republic [1]	43.9	46.8	43.7	40.6	38.3	38.3	3.8	81.2
12	Serbia [1]	37.8	40.6	38.0	40.1	29.7	37.3	3.7	84.9
13	Bulgaria [2]	27.1	34.5	31.0	26.5	31.3	35.9	3.5	88.4
14	Romania [1]	27.7	32.9	34.1	24.7	23.6	25.5	2.5	90.9
15	Thailand	18.3	21.3	18.1	18.1	18.0	15.2	1.5	92.4
16	Canada	10.3	9.7	9.5	9.0	8.5	10.5	1.0	93.5
17	Hungary [1]	9.0	9.5	9.3	9.6	9.6	9.3	0.9	94.4
18	Kosovo	8.0	8.2	8.0	8.2	7.2	8.2	0.8	95.2
19	Korea, DPR [3]	7.0	7.6	7.0	7.0	7.0	7.0	0.7	95.9
20	Bosnia & Herzegovina [1]	11.0	7.1	7.0	6.2	6.2	6.5	0.6	96.5
	...								
	other countries [15]	39.7	45.0	43.4	43.8	37.5	35.1	3.5	100.0
	World	**1,008.0**	**1,081.5**	**1,099.4**	**1,053.3**	**1,021.7**	**1,011.2**	**100.0**	
	Europe	529.4	566.7	566.9	530.7	511.8	511.3	50.6	
	CIS	87.3	90.8	90.6	84.9	82.6	84.7	8.4	
	Africa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Austral-Asia	304.1	334.6	353.6	349.5	343.1	336.4	33.3	
	North America	81.2	83.3	81.1	79.0	80.6	75.2	7.4	
	Latin America	5.9	6.0	7.1	9.1	3.6 [4]	3.6 [4]	0.4 [4]	
	OECD	560.1	584.4	590.8	556.3	544.9	528.8	52.3	
	EU-28	394.1 [5]	428.4 [5]	436.8 [5]	410.3	398.0	401.1	39.7	

[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)

Table 38: Lignite consumption 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Mt	Share [%] country	Share [%] cumulative
1	Germany	173.7	17.3	17.3
2	China	140.0	13.9	31.2
3	Russia [1]	73.2	7.3	38.4
4	USA	64.7	6.4	44.9
5	Poland	63.1	6.3	51.1
6	Australia	63.0	6.3	57.4
7	Indonesia [1]	60.0	6.0	63.3
8	Turkey	50.4	5.0	68.4
9	Greece	46.0	4.6	72.9
10	India	43.9	4.4	77.3
11	Czech Republic [1]	38.3	3.8	81.1
12	Serbia [1]	37.3	3.7	84.8
13	Bulgaria [1]	35.9	3.6	88.4
14	Romania [1]	25.5	2.5	90.9
15	Thailand	15.1	1.5	92.4
16	Canada	10.5	1.0	93.4
17	Hungary [1]	9.3	0.9	94.4
18	Kosovo	8.2	0.8	95.2
19	Korea, DPR	7.0	0.7	95.9
20	Bosnia & Herzegovina [1]	6.5	0.6	96.5
	...			
	other countries [15]	35.1	3.5	100.0
	World	**1,006.8**	**100.0**	
	Europe	507.0	50.4	
	CIS	84.7	8.4	
	Africa	0.0	0.0	
	Austral-Asia	336.4	33.4	
	North America	75.2	7.5	
	Latin America	3.6	0.4	
	OECD	524.4	52.1	
	EU-28	396.8	39.4	

[1] Lignite consumption contains subbituminous coal

Table 39: Uranium 2015 [kt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
EUROPE	Bulgaria	–	–	–	25	25	25
	Czech Republic	0.2	112	–	342	454	342
	Finland	n. s.	< 0.5	–	37	37	37
	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	–	14	19	14
	Sweden	n. s.	< 0.5	–	10	10	10
	Turkey	–	–	7	2	9	9
CIS	Kazakhstan	23.8	270	309	1,627	2,205	1,936
	Russia	3.1	162	27	780	969	807
	Ukraine	1.2	21	50	313	384	363
	Uzbekistan	2.4	52	42	74	168	116
AFRICA	Algeria	–	–	–	20	20	20
	Botswana	–	–	–	69	69	69
	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	–	15	19	15
	Mali	–	–	–	13	13	13
	Namibia	3.0	124	–	513	637	513
	Niger	4.1	140	15	455	610	470
	Somalia	–	–	–	8	8	8
	South Africa	0.4	160	113	448	721	561
	Tanzania	–	–	38	20	58	58
	Zambia	–	< 0.5	–	54	54	54
	Zimbabwe	–	–	–	26	26	26
MIDDLE EAST	Iran	–	< 0.5	–	17	17	17
	Jordan	–	–	–	90	90	90
	Australia	5.7	199	–	1,912	2,111	1,912
	China	1.6	41	94	113	247	207
	India	0.4	12	–	266	278	266

continuation of table 39
[kt]

	Country / Region	Production	Cum. Production	Reserves	Resources	EUR	Remaining Potential
AUSTRAL-ASIA	Indonesia	–	–	2	32	34	34
	Japan	n. s.	< 0.5	–	7	7	7
	Mongolia	–	1	108	1,444	1,553	1,553
	Pakistan	< 0.05	2	–	–	2	–
	Viet Nam	–	–	–	85	85	85
NORTH AMERICA	Canada	13.3	497	322	1,433	2,252	1,755
	Greenland	–	–	–	271	271	271
	Mexico	n. s.	< 0.5	–	6	6	6
	USA	1.3	375	17	2,252	2,644	2,269
LATIN AMERICA	Argentina	–	3	5	96	104	101
	Brazil	< 0.05	4	155	421	580	576
	Chile	–	–	–	4	4	4
	Colombia	–	–	–	228	228	228
	Peru	–	–	1	41	43	43
	World	**60.5**	**2,574**	**1,326**	**13,738**	**17,638**	**15,064**
COUNTRY GROUPS	Europe	0.2	457	27	542	1,025	569
	CIS	30.4	505	428	2,794	3,726	3,222
	Africa	7.5	480	166	1,685	2,330	1,851
	Middle East	–	< 0.5	–	107	107	107
	Austral-Asia	7.7	254	204	3,859	4,317	4,063
	North America	14.6	872	339	3,962	5,173	4,301
	Latin America	< 0.05	7	162	790	958	952
ECONOMIC COUNTRY GRP.	OPEC	–	< 0.5	–	36	36	36
	OPEC-Gulf	–	< 0.5	–	17	17	17
	OECD	20.4	1,509	366	6,389	8,264	6,755
	EU-28	0.2	457	20	540	1,017	560

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

Table 40: Uranium resources 2015 (>20 kt U) [kt]
The most important countries and distribution by regions and economic country groupings

Country / Region	Discovered		Total	Undiscovered		Total	Share [%]	
	RAR 80–260 USD / kg	inferred < 260 USD / kg		prognosticated < 260 USD / kg	speculative < 260 USD / kg		country	cumu-lative
1	2	3	4 = 2 + 3	5	6	7 = 4 + 5 + 6	8	9
USA	121	n. s.	121	1,273	858	2,252	16.4	16.4
Australia	1,208	704	1,912	n. s.	n. s.	1,912	13.9	30.3
Kazakhstan	132	659	791	536	300	1,627	11.8	42.1
Mongolia	–	33	33	21	1,390	1,444	10.5	52.7
Canada	382	201	583	150	700	1,433	10.4	63.1
Russia	247	421	668	112	n. s.	780	5.7	68.8
Namibia	297	159	456	57	n. s.	513	3.7	72.5
Niger	310	80	390	14	51	455	3.3	75.8
South Africa	121	217	338	110	n. s.	448	3.3	79.1
Brazil	–	121	121	300	n. s.	421	3.1	82.1
Czech Republic	51	68	119	223	–	342	2.5	84.6
Ukraine	116	54	170	23	120	313	2.3	86.9
Greenland	–	221	221	n. s.	50	271	2.0	88.9
India	160	22	182	85	n. s.	266	1.9	90.8
Colombia	–	n. s.	–	11	217	228	1.7	92.5
China	26	79	105	4	4	113	0.8	93.3
Argentina	6	20	26	14	56	96	0.7	94.0
Jordan	–	40	40	–	50	90	0.7	94.7
Viet Nam	1	2	3	81	n. s.	85	0.6	95.3
Uzbekistan	18	32	50	25	–	74	0.5	95.8
Botswana	13	56	69	n. s.	n. s.	69	0.5	96.3
Zambia	10	15	25	30	n. s.	54	0.4	96.7
Peru	–	2	2	20	20	41	0.3	97.0
Finland	2	35	37	–	–	37	0.3	97.3
Indonesia	6	2	9	23	n. s.	32	0.2	97.5
Central African Rep.	32	n. s.	32	n. s.	n. s.	32	0.2	97.7
Hungary	–	14	14	13	n. s.	27	0.2	97.9
Zimbabwe	1	n. s.	1	–	25	26	0.2	98.1
Bulgaria	–	–	–	25	n. s.	25	0.2	98.3
...								
Germany	3	4	7	–	–	7	0.1	99.7

continuation of table 40
[kt]

Country/Region	Discovered		Total	Undiscovered		Total	Share [%]	
	RAR 80–260 USD/kg	inferred < 260 USD/kg		prognosticated < 260 USD/kg	speculative < 260 USD/kg		country	cumu-lative
1	*2*	*3*	*4 = 2 + 3*	*5*	*6*	*7 = 4 + 5 + 6*	*8*	*9*
World	**3,361**	**3,334**	**6,695**	**3,189**	**3,855**	**13,738**	**100.0**	**–**
Europe	91	154	245	284	13	542	3.9	–
CIS	513	1,166	1,679	695	420	2,794	20.3	–
Africa	835	563	1,398	210	76	1,685	12.3	–
Middle East	1	43	44	12	50	107	0.8	–
Austral–Asia	1,408	842	2,251	214	1,394	3,859	28.1	–
North America	505	423	928	1,426	1,608	3,962	28.8	–
Latin America	6	143	150	347	293	790	5.8	–
OPEC	21	3	24	12	–	36	0.3	–
OPEC–Gulf	1	3	4	12	–	17	0.1	–
OECD	1,809	1,278	3,086	1,684	1,618	6,389	46.5	–
EU–28	91	152	243	284	13	540	3.9	–

n. s. not specified
– no resources

Table 41: **Uranium reserves 2015 (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	cumulative
1	Canada	322	24.3	24.3
2	Kazakhstan	309	23.3	47.6
3	Brazil	155	11.7	59.3
4	South Africa	113	8.5	67.8
5	Mongolia	108	8.2	76.0
6	China	94	7.1	83.0
7	Ukraine	50	3.8	86.8
8	Uzbekistan	42	3.1	90.0
9	Tanzania	38	2.9	92.9
10	Russia	27	2.1	94.9
11	USA	17	1.3	96.2
12	Niger	15	1.1	97.3
13	Slovakia	9	0.7	98.0
14	Turkey	7	0.5	98.5
15	Argentina	5	0.4	98.9
16	Italy	5	0.4	99.3
17	Portugal	5	0.3	99.6
18	Indonesia	2	0.2	99.8
19	Slovenia	2	0.1	99.9
20	Peru	1	0.1	100.0
	World	**1,326**	**100.0**	
	Europe	27	2.0	
	CIS	428	32.3	
	Africa	166	12.5	
	Austral-Asia	204	15.4	
	North America	339	25.6	
	Latin America	162	12.2	
	OECD	366	27.6	
	EU-28	20	1.5	

Table 42: Uranium resources 2015 (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	cumulative
1	Australia	1,151.0	30.5	30.5
2	Canada	509.3	13.5	44.0
3	Kazakhstan	342.1	9.1	53.1
4	Niger	325.0	8.6	61.7
5	Namibia	248.2	6.6	68.3
6	Russia	228.4	6.1	74.3
7	South Africa	175.3	4.6	79.0
8	Brazil	155.1	4.1	83.1
9	China	120.0	3.2	86.3
10	Mongolia	108.1	2.9	89.2
11	Ukraine	100.1	2.7	91.8
12	USA	62.9	1.7	93.5
13	Uzbekistan	59.4	1.6	95.0
14	Tanzania	40.4	1.1	96.1
15	Central African Rep.	32.0	0.8	97.0
16	Botswana	12.8	0.3	97.3
17	Argentina	11.0	0.3	97.6
18	Zambia	9.9	0.3	97.9
19	Slovakia	8.8	0.2	98.1
20	Mali	8.5	0.2	98.3
	...			
	other countries [15]	63.3	1.7	100.0
	World	**3,771.6**	**100.0**	
	Europe	38.8	1.0	
	CIS	730.0	19.4	
	Africa	865.1	22.9	
	Middle East	1.0	0.0	
	Austral-Asia	1,394.1	37.0	
	North America	575.1	15.2	
	Latin America	167.5	4.4	
	OPEC	1.0	0.0	
	OPEC-Gulf	1.0	0.0	
	OECD	1,768.4	46.9	
	EU-28	32.0	0.8	

Table 43: Natural uranium production 2010–2015
The most important countries and distribution by regions and economic country groupings

Rank	Country / Region	2010	2011	2012	2013	2014	2015	Share [%]	
					kt			country	cumulative
1	Kazakhstan	17.8	19.5	21.3	22.6	23.1	23.8	39.3	39.3
2	Canada	9.8	9.1	9.0	9.3	9.1	13.3	22.0	61.4
3	Australia	5.9	6.0	7.0	6.4	5.0	5.7	9.3	70.7
4	Niger	4.2	4.4	4.7	4.5	4.1	4.1	6.8	77.5
5	Russia	3.6	3.0	2.9	3.1	3.0	3.1	5.0	82.6
6	Namibia	4.5	3.3	4.5	4.3	3.3	3.0	4.9	87.5
7	Uzbekistan	2.4	3.0	2.4	2.4	2.4	2.4	3.9	91.5
8	China	0.8	1.5	1.5	1.5	1.5	1.6	2.7	94.1
9	USA	1.7	1.5	1.6	1.8	1.9	1.3	2.1	96.2
10	Ukraine	0.9	0.9	1.0	1.1	0.9	1.2	2.0	98.2
11	South Africa	0.6	0.6	0.5	0.5	0.6	0.4	0.6	98.8
12	India	0.4	0.4	0.4	0.4	0.4	0.4	0.6	99.5
13	Czech Republic	0.3	0.2	0.2	0.2	0.2	0.2	0.3	99.7
14	Romania	0.1	0.1	0.1	0.1	0.1	0.1	0.1	99.9
15	Pakistan	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.1	99.9
16	Brazil	0.1	0.3	0.2	0.2	0.2	< 0.05	0.1	100.0
17	France	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	100.0
18	Germany [1]	< 0.05 [1]	0.1 [1]	0.1 [1]	< 0.05 [1]	< 0.05 [1]	< 0.05 [1]	< 0.05	100.0
19	Malawi	0.7	0.8	1.1	1.1	0.4	0.0	0.0	100.0
	World	**53.7**	**54.6**	**58.4**	**59.6**	**56.2**	**60.5**	**100.0**	
	Europe	0.3	0.4	0.4	0.3	0.3	0.2	0.4	
	CIS	24.6	26.3	27.5	29.2	29.4	30.4	50.3	
	Africa	9.9	9.0	10.7	10.5	8.3	7.5	12.4	
	Austral-Asia	7.2	7.9	8.9	8.2	6.9	7.7	12.7	
	North America	11.4	10.7	10.6	11.2	11.1	14.6	24.1	
	Latin America	0.1	0.3	0.2	0.2	0.2	0.0	0.1	
	OECD	17.6	17.0	17.9	17.8	16.3	20.4	33.7	
	EU-28	0.3 [2]	0.4 [2]	0.4 [2]	0.3	0.3	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 44: Uranium consumption 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	kt	Share [%]	
			country	cumulative
1	USA	18.69	27.9	27.9
2	France	9.23	13.8	41.7
3	China	8.16	12.2	54.0
4	Korea, Rep.	5.02	7.5	61.5
5	Russia	4.21	6.3	67.7
6	Japan	2.55	3.8	71.6
7	Ukraine	2.37	3.5	75.1
8	Germany	1.89	2.8	77.9
9	Canada	1.78	2.7	80.6
10	United Kingdom	1.74	2.6	83.2
11	India	1.58	2.4	85.6
12	Sweden	1.52	2.3	87.8
13	Spain	1.27	1.9	89.7
14	Belgium	1.02	1.5	91.2
15	Taiwan	0.97	1.5	92.7
16	Finland	0.75	1.1	93.8
17	Czech Republic	0.57	0.8	94.7
18	Switzerland	0.52	0.8	95.4
19	Slovakia	0.47	0.7	96.1
20	Hungary	0.36	0.5	96.7
	...			
	other countries [11]	2.22	3.3	100.0
	World	**66.88**	**100.0**	
	Europe	20.07	30.0	
	CIS	6.66	10.0	
	Africa	0.31	0.5	
	Middle East	0.18	0.3	
	Austral-Asia	18.38	27.5	
	North America	20.75	31.0	
	Latin America	0.54	0.8	
	OPEC	0.18	0.3	
	OPEC-Gulf	0.18	0.3	
	OECD	47.88	71.6	
	EU-28	19.55	29.2	

Table 45: Geothermal energy 2015[1]

Region	El. Power [MW_e]	El. Energy Consumption [GWh_{th}]	Therm. Power without heat pumps [MW_{th}]	Therm. Energy Consumption [GWh_e]	Total Power without heat pumps [MW]	Total Energy Consumption [GWh]
Albania	–	–	16	21	30	35
Austria	1	2.2	77	1,577	298	2,298
Belgium	–	–	7	277	18	450
Bosnia & Herzegovina	–	–	23	25	83	86
Bulgaria	–	–	106	–	399	–
Croatia	–	–	68	–	131	–
Czech Republic	–	–	7	307	25	457
Denmark	–	–	–	400	–	598
Finland	–	–	–	2,500	–	5,000
France	18	83.0	500	2,300	1,306	4,366
Germany	31	151.0	337	4,237	1,099	6,803
Greece	–	–	83	231	245	442
Hungary	–	–	753	814	1,874	1,996
Iceland	661	5,003.0	2,131	2,132	7,676	7,681
Ireland	–	–	–	191	–	252
Italy	915	5,916.0	1,371	1,902	2,916	3,822
Lithuania	–	–	14	95	34	227
Macedonia	–	–	45	48	123	136
Netherlands	–	–	115	1,275	667	4,067
Norway	–	–	–	1,300	–	2,296
Poland	–	–	105	605	354	1,068
Portugal	23	182.0	20	21	108	109
Romania	< 0.5	0.4	176	195	362	402
Serbia	–	–	111	124	488	516
Slovakia	–	–	148	–	–	–
Slovenia	–	–	66	202	137	340
Spain	–	–	–	225	–	315
Sweden	–	–	48	5,848	140	20,240
Switzerland	–	–	40	1,572	250	2,636
Turkey	624	–	2,844	2,886	12,278	12,545
United Kingdom	–	–	3	373	17	682
Europe	2,273	11,337.6	9,212	31,681	31,057	79,865
EU-28	988	6,334.6	4,001	23,574	10,130	53,934

[1] Reliable actual data for countries outside of Europe covering the year 2015 is not available as of yet
Europe: Data survey EGEC as quoted in Antics et al. 2016

– no data available

Table 46: Geothermal – electricity installed power 2010–2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	2010	2011	2012	2013 MW	2014	2015	Share [%] country	Share [%] cumulative
1	USA	3,102	3,389	3,442	3,525	3,450	3,567	27.1	27.1
2	Philippines	1,904	1,848	1,904	1,917	1,870	1,930	14.6	41.7
3	Indonesia	1,197	1,341	1,333	1,401	1,340	1,404	10.7	52.4
4	Mexico	887	1,017	1,017	834	1,017	1,069	8.1	60.5
5	New Zealand	792	843	895	971	1,005	973	7.4	67.9
6	Italy	772	876	876	916	916	915	6.9	74.8
7	Iceland	665	660	664	665	665	661	5.0	79.8
8	Turkey	114	242	167	368	397	624	4.7	84.6
9	Kenya	169	249	249	590	594	607	4.6	89.2
10	Japan	538	537	537	539	519	540	4.1	93.3
11	Costa Rica	166	207	207	208	207	218	1.7	94.9
12	El Salvador	204	204	204	204	204	204	1.5	96.5
13	Nicaragua	82	150	150	160	159	155	1.2	97.6
14	Russia	82	82	82	82	82	97	0.7	98.4
15	Papua New Guinea	56	56	56	56	50	56	0.4	98.8
16	Guatemala	52	48	48	48	52	49	0.4	99.2
17	Germany	7	29	24	27	27	31	0.2	99.4
18	China	24	27	27	27	27	27	0.2	99.6
19	Portugal	30	23	29	29	29	23	0.2	99.8
20	France	18	17	17	17	16	18	0.1	99.9
	...								
	other countries [6]	40	49	11	10	10	10 [1]	0.1	100.0
	World	**10,901**	**11,893**	**11,938**	**12,594**	**12,636**	**13,178** [1]	**100.0**	
	Europe	1,553	1,848	1,850	1,850	2,133	2,273	17.3	
	CIS	82	82	82	82	82	97	0.7	
	Africa	176	220	200	200	601	614	4.7	
	Austral-Asia	4,512	4,720	4,800	4,800	4,812	4,930	37.4	
	North America	3,988	4,920	5,100	5,100	5,089	4,636	35.2	
	Latin America	534	639	609	620	622	626	4.8	
	OECD	6,927	7,635	7,670	7,894	8,043	8,423 [1]	63.9	
	EU-28	829 [2]	946 [2]	946 [2]	991	989	988	7.5	

[1] Data for Australia, Thailand, and Taiwan as of 2014
[2] including Croatia (cf. economic country groupings)

Table 47: Geothermal energy resources 2015

Region	Theoretical Potential [EJ]	Technical Potential [EJ/year]		
	Total	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 48: Consumption of renewable energy (excluding hydroelectric power) 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	Mtoe	Share [%] country	Share [%] cumulative
1	USA	71.7	19.7	19.7
2	China	62.7	17.2	36.9
3	Germany	40.0	10.9	47.8
4	United Kingdom	17.4	4.8	52.6
5	Brazil	16.3	4.5	57.0
6	India	15.5	4.2	61.3
7	Spain	15.4	4.2	65.5
8	Italy	14.7	4.0	69.5
9	Japan	14.5	4.0	73.5
10	France	7.9	2.2	75.7
11	Canada	7.3	2.0	77.7
12	Sweden	6.2	1.7	79.4
13	Poland	4.6	1.3	80.6
14	Australia	4.5	1.2	81.9
15	Denmark	4.3	1.2	83.0
16	Turkey	3.8	1.0	84.1
17	Mexico	3.5	1.0	85.0
18	Portugal	3.5	1.0	86.0
19	Belgium	3.2	0.9	86.9
20	Finland	3.1	0.8	87.7
	...			
	other countries [47]	44.7	12.3	100.0
	World	**364.9**	**100.0**	
	Europe	139.9	38.3	
	CIS	0.6	0.2	
	Africa	3.8	1.0	
	Middle East	0.5	0.1	
	Austral-Asia	110.9	30.4	
	North America	82.6	22.6	
	Latin America	24.2	6.6	
	OPEC	0.3	0.1	
	OPEC-Gulf	0.2	0.0	
	OECD	246.3	67.5	
	EU-28	136.0	37.3	

Table 49: Renewable energy – installed electrical output 2015
The most important countries (top 20) and distribution by regions and economic country groupings

Rank	Country / Region	MW	Share [%] country	Share [%] cumulative
1	China	519,748	26.2	26.2
2	USA	219,343	11.1	37.3
3	Brazil	114,220	5.8	43.0
4	Germany	104,978	5.3	48.3
5	Canada	93,357	4.7	53.0
6	Japan	90,089	4.5	57.5
7	India	82,117	4.1	61.7
8	Italy	54,790	2.8	64.4
9	Russia	51,960	2.6	67.1
10	Spain	51,451	2.6	69.7
11	France	44,274	2.2	71.9
12	Norway	32,408	1.6	73.5
13	United Kingdom	32,367	1.6	75.2
14	Turkey	31,694	1.6	76.7
15	Sweden	27,142	1.4	78.1
16	Austria	18,477	0.9	79.0
17	Australia	18,046	0.9	80.0
18	Mexico	17,567	0.9	80.8
19	Switzerland	17,450	0.9	81.7
20	Viet Nam	16,882	0.9	82.6
	...			
	other countries [184]	345,757	17.4	100.0
	World	**1,984,118**	**100.0**	
	Europe	520,969	26.3	
	CIS	77,003	3.9	
	Africa	36,255	1.8	
	Middle East	17,487	0.9	
	Austral-Asia	809,904	40.8	
	North America	330,267	16.6	
	Latin America	191,781	9.7	
	OPEC	36,031	1.8	
	OPEC-Gulf	14,726	0.7	
	OECD	957,619	48.3	
	EU-28	428,357	21.6	

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Wirtschaftskammer Österreich – WKO (Austria)
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 Joint Venture), headquarters in Berlin
AGEE-Stat	Arbeitsgruppe Erneuerbare Energien-Statistik (Working Group on Renewables Statistics, headquarters in Berlin
Aquifer	Underground rock formation whose permeability allows 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
BMU	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety), office in Berlin
BMWi	Bundesministerium für Wirtschaft und Energie (Federal Ministry of Economic Affairs and Energy), office 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.
CTL	Coal to liquid; synthetic fuel made from coal
Cumulative production	Total production since the start of production operations
dena	German Energy Agency; office 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
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 energy is made up of the original heat from when the earth was formed, and the heat generated in the interior of the earth by the continuous decay of naturally occurring radioactive isotopes. A differentiation is generally made between shallow geothermal energy down to approximately 400 m depth, and deep geothermal energy from 400 m downwards. Both zones are used for producing heat (direct use), but only deeper zones can be used geothermally for the production of electrical power because of the required higher temperature differences. Geothermal energy is 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 elektricity
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, headquarters in Hannover (State Office of Mining, Energy and Geology)
LEU	Low enriched uranium
LIAG	Leibniz-Institut für Angewandte Geopysik (Leibniz Institute for Applied Geopysics), headquarters 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)
MB	South German Molasse Basin

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)

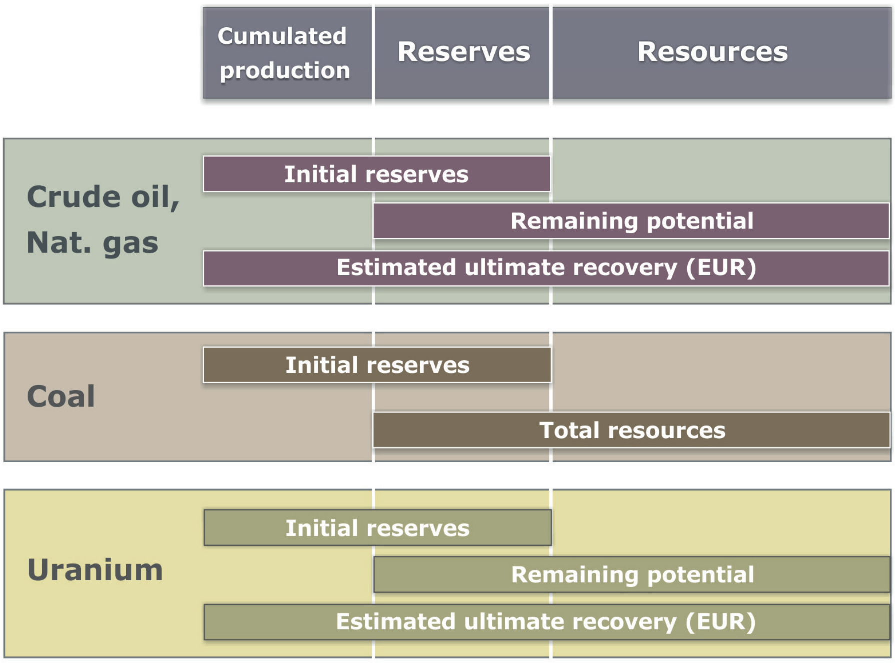
OECD	Organisation for Economic Co-operation and Development, headquarters in Paris; cf. Economic country groupings
OPEC	Organization of Petroleum Exporting Countries, headquarters in Vienna; cf. Economic country groupings
OPEC basket price	Average price of the different qualities of crude oil produced 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 / Nm³ 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
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

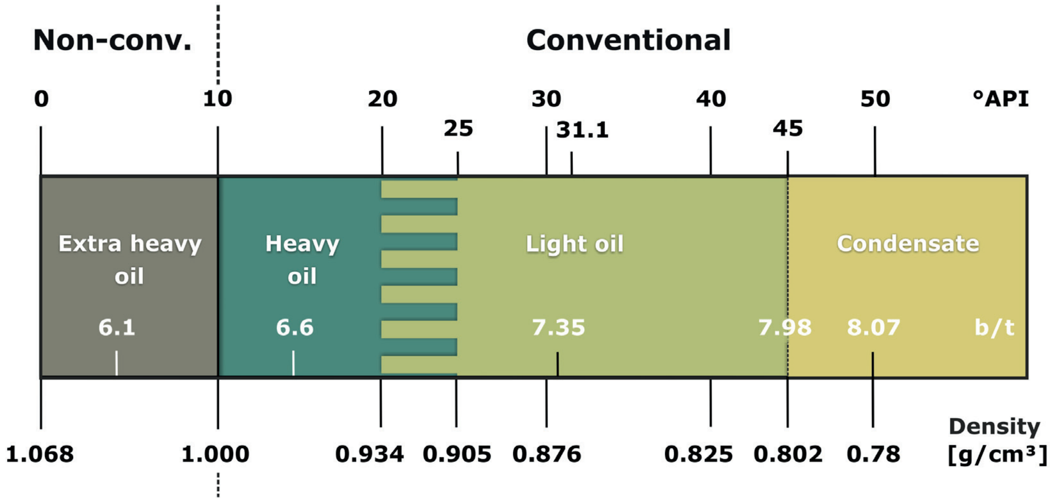
USGS	United States Geological Survey
VDKi	Verein der Kohlenimporteure e.V. (Organisation of Coal Importers); headquarters in Hamburg
WEC	World Energy Council, headquarters in London; organises the World Energy Congress
WGC	World Geothermal Congress: takes place every five years. Discussions on geothermal 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

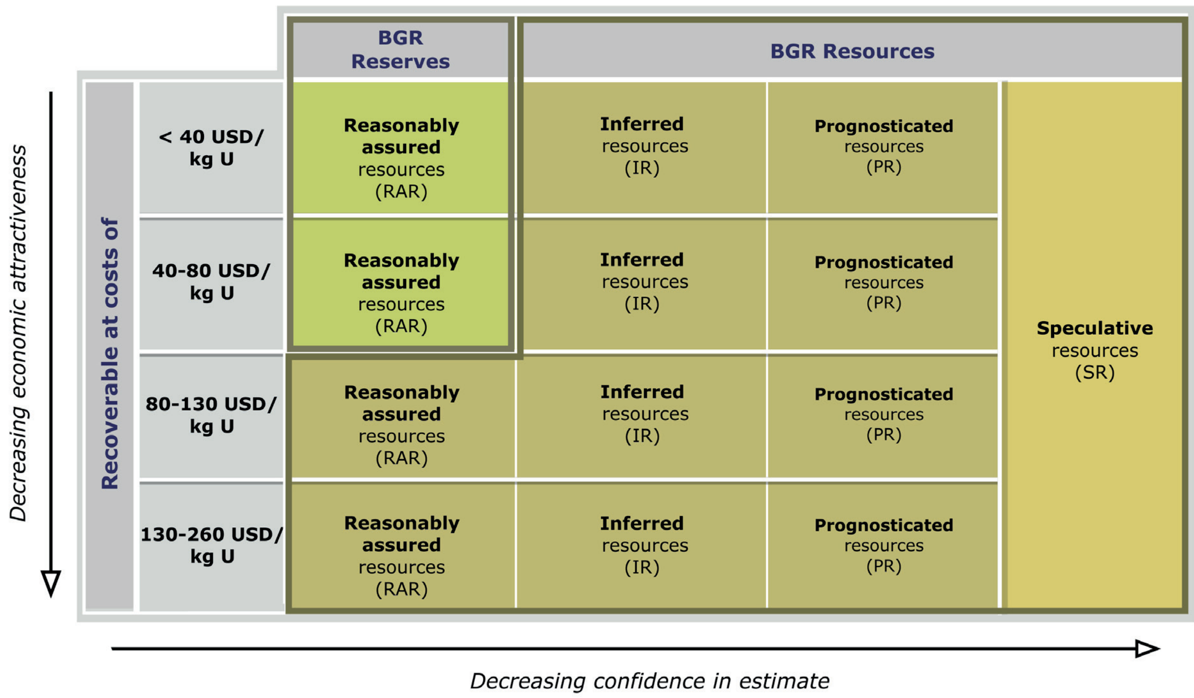


Uranium reserves classification according to cost categories

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 Emirate, 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:2015*

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; 167 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, Turkey, Tunisia, 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; 34 countries)
Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea (Republic), 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; 12 countries)

Algeria, Angola, Ecuador, 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 (Watt second)
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
cm, m^3	cubic meter	
Nm^3	standard cubic meter	Volume of Gas in 1 m^3 at 0° C and 1,013 mbar
mcm	million cubic meter	1 mcm = 10^6 m^3
bcm	billion cubic meter	1 bcm = 10^9 m^3
tcm	trillion cubic meter	1 tcm = 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	ton(s) 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 kW = 3.6 kJ

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 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

Bundesanstalt für Geowissenschaften
und Rohstoffe (BGR)
Federal Institute for Geosciences and
Natural Resources (BGR)
Stilleweg 2
30655 Hannover

E-Mail: energierohstoffe@bgr.de
Web: http://www.bgr.bund.de