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How energy-efficient is Germany?

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Germany is one of the G20 and EU-28 countries with the highest levels of energy efficiency. This is determined and measured using energy intensity as the specific indicator of energy consumption. Between 2000 and 2017 alone, total primary energy intensity for all of Germany – that is, the relation of primary energy consumption to real GDP – dropped by nearly 25 %. A significant part of this reduction is the result of technical efficiency improvements on the energy demand side and the substitution of electricity from nuclear energy and fossil fuels with electricity from renewables.

Despite significantly improved energy intensity, the decline in absolute primary energy consumption in Germany between 2000 and 2017 was relatively modest at -6 %. Efficiency gains achieved were partly offset by higher energy consumption resulting from economic growth, higher traffic volume, changes in lifestyle and consumption patterns, as well as population growth. Germany will have to significantly reduce energy consumption in absolute terms in order to meet its national climate targets.

In addition to the expansion of renewable energies, substantial improvements to energy efficiency are crucial to the success of Germany's energy transition. Primary energy consumption will need to be halved by 2050 if Germany wants to meet its energy and climate policy targets. Improved energy efficiency is also a major prerequisite for cost-efficient decarbonisation of the energy system. It will also strengthen Germany's international competitiveness and contribute to increasing supply security by reducing its dependence on energy imports.[1] How energy-efficient is Germany compared with other countries? And what progress has Germany made in improving energy efficiency and reducing energy consumption in the past? This paper will address these questions.

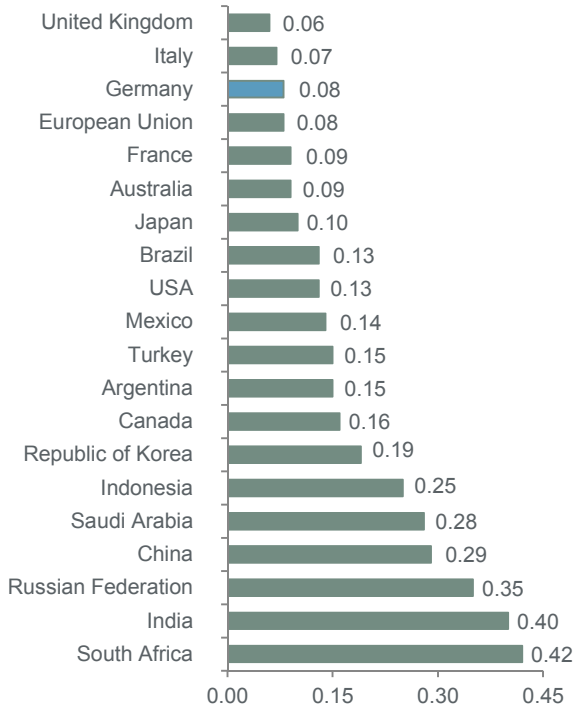
Germany is one of the countries with the lowest energy intensity

With a share of 2 % in worldwide energy consumption, Germany is currently the world's sixth largest energy consumer after China, the United States, India, Russia and Japan.[2] How efficiently a national economy uses energy is typically measured by total primary energy intensity. This is expressed as the ratio of primary energy consumption to real gross domestic product (GDP) and indicates how many physical units of primary energy are necessary to produce one monetary unit of gross domestic product. Primary energy refers to sources of energy that occur naturally, such as lignite, crude oil, natural gas and hydropower, which can be used either directly or converted into what is referred to as final energy (such as electricity, fuels, heating oil) in power plants, refineries, etc.

A comparison of the 20 most important industrialised and emerging market economies in the world (G20 states) shows that Germany is one of the top five countries with the lowest primary energy intensity, along with the United Kingdom, Italy and France (Figure 1). While Germany consumed on average a mere 0.08 kg oil equivalent (OE) of energy to produce one international US dollar[3] of GDP in 2014, the US consumed a 0.13 kg OE and China even 0.29 kg OE, more than three times Germany's energy consumption. Germany's good position in the international arena illustrates that energy efficiency has been regarded as very important here for a long time, mostly because of the country's high dependence on energy imports, relatively high energy prices and state regulation, as well as public subsidy programmes.

Figure 1: Primary energy intensity of the G20 states in 2014

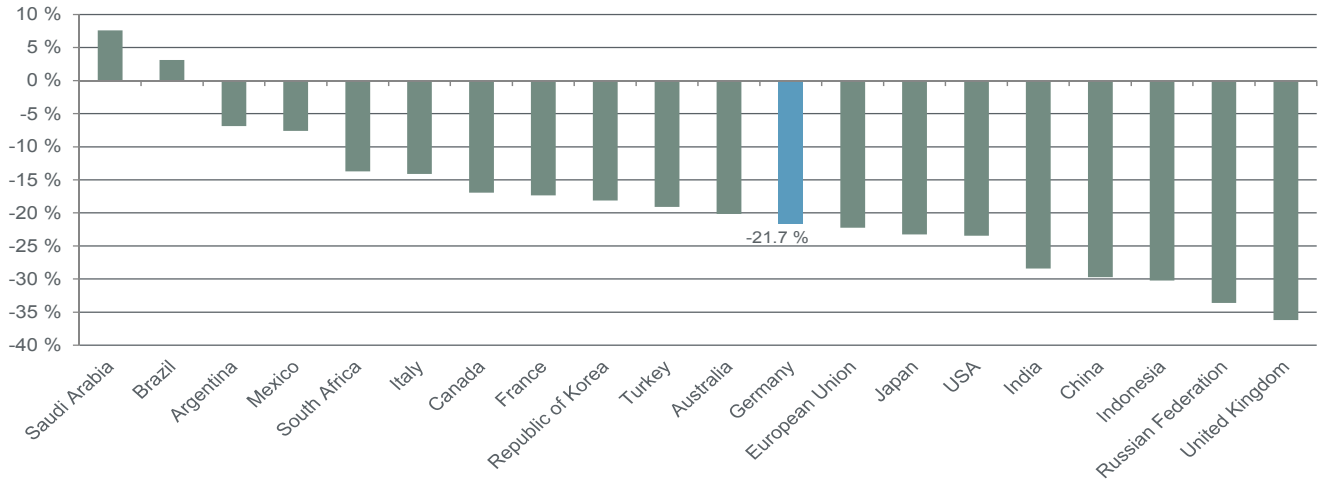
Primary energy consumption in kg oil equivalent (OE) per GDP in international US dollars



Source: Federal Statistical Office, G20 in figures (2017)

Figure 2: Variation in primary energy intensity in the G20 states from 2000 to 2014

In per cent



Source: International Energy Agency (2017), own calculations

Measured by the more recent rate of change in energy intensity, however, Germany now sits in the middle of the G20 states (Figure 2). Between 2000 and 2014 it succeeded in reducing its primary energy intensity by a total of around 22 % but that was a much lower reduction than that of countries such as Russia (-34 %), China (-30 %) and India (-28 %). Energy intensity in these countries, however, dropped from a significantly higher level, so they had much more catching up to do to improve their energy efficiency.

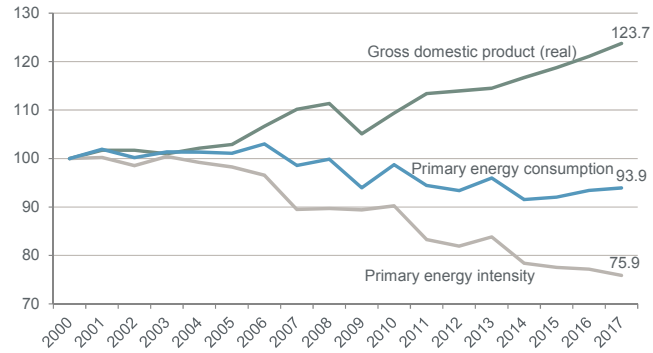
It must generally be noted that total primary energy intensity can only provide a rough idea of how energy efficiency develops within a country and how it ranks in international comparison. A country's energy intensity depends on a number of factors that go beyond technical efficiency improvements and a more sparing use of energy, such as the size of the country, its population density, climatic conditions, economic structure and the import quota of energy-intensive products. A country's energy intensity can thus be improved simply through inter-sectoral structural change – from energy-intensive primary material production to energy-extensive services sectors – without realising technical efficiency improvements.[4] Adjusted data that take into account at least part of these effects are available for total final energy intensity only for the EU-28[5]. The EU project ODYSSEE adjusts the energy intensity indicators of the EU member states with the aid of correction factors that map climatic differences and purchasing power differences, as well as structural industrial and economic differences. The aim is to achieve better comparability of current energy efficiency in the EU member states on the energy consumption side. The current analysis for the year 2015 shows that Germany is among the top positions in this comparison as well. After the United Kingdom, Lithuania and Spain, Germany ranks fourth among the EU-28 countries with the lowest final energy intensity.[6]

Energy transition requires greater reduction in absolute energy consumption

Has improved energy intensity in Germany also translated into a reduction in absolute primary energy consumption? Figure 3 shows that between 2000 and 2017, total primary energy intensity was reduced by nearly 25 % but absolute primary energy consumption in Germany decreased by only a good 6 % in the same period. A considerable portion of the energy savings that were realised through improved energy efficiency was offset again by GDP growth during the period from 2000 to 2017 (+24 %).[7] Nevertheless, it remains to be noted that Germany succeeded to a certain extent in decoupling energy consumption from economic growth. Overall energy consumption has been reduced despite significant economic growth.

Figure 3: Development of primary energy intensity and primary energy consumption in Germany

2000=100



Source: Federal Ministry for Economic Affairs and Energy, Zahlen und Fakten Energiedaten (*Energy facts and figures* – our title translation) (as at: 21 June 2018), in German only

But in order to achieve the German Federal Government's energy and climate targets, absolute primary energy consumption will have to decrease much more. Under the government's energy strategy, Germany's primary energy

consumption is to be reduced by 20 % by the year 2020 and 50 % by the year 2050 compared with 2008. By 2017, however, the decline on the base year 2008 was only around 6 %.[8] To be able to still meet the reduction target for 2020, primary energy consumption would have to drop by an average 5.3 % per year over the remaining period. If we compare this rate with the average annual reduction of 0.6 % achieved thus far since 2008, it becomes clear that this target can now hardly be reached.

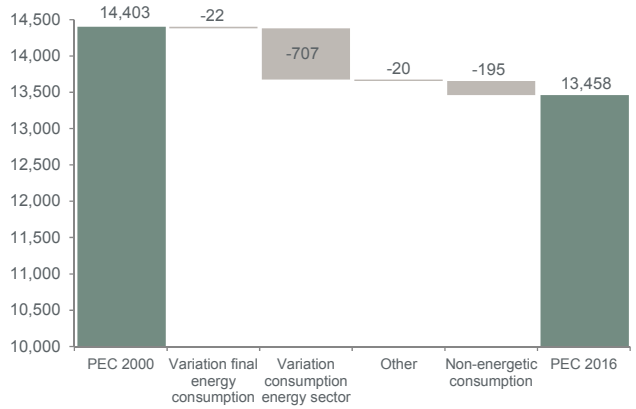
Efficiency gains through technical efficiency improvements are largely offset by quantity effects

What are the main factors influencing primary energy consumption in Germany? How have technical efficiency gains or the structural transformation of the economy influenced energy consumption? Answers to these questions can be found using results of the decomposition tool applied in the above-mentioned ODYSSEE project. This project uses a component analysis to determine the contributions of the most important factors influencing Germany's primary energy consumption during the period from 2000 to 2016.[9]

Between 2000 and 2016, primary energy consumption in Germany was reduced by a total of 945 PJ (Figure 4). The component analysis shows that nearly three quarters of this decline resulted from the reduction in primary energy consumption in the energy sector – i.e. on the energy supply side. Two per cent of the savings was realised in final energy consumption sectors, i.e. on the energy demand side (manufacturing, transport, households, services sector, agriculture). The reduction in non-energetic primary energy consumption (e.g. the use of fossil fuels as a raw material in petrochemical industry) accounted for 21 % of the decline.

The change in the electricity mix had the greatest influence on the reduction of primary energy consumption in the energy sector, caused primarily by the substitution of electricity from nuclear energy and fossil fuels with electricity from renewables. Background information: in the context of energy balancing, renewables are assumed to have significantly higher electrical conversion efficiency than nuclear energy and the use of fossil fuels, thus leading to lower primary energy use.[10] In addition, further primary energy savings in the energy sector could be achieved through technical efficiency improvements in conventional power plants and the expansion of combined heat and power technology.

Figure 4: Components of the variation of primary energy consumption (PEC) in Germany, 2000–2016



Source: **www.indicators.odyssee-mure.eu** (as at 28 May 2018)

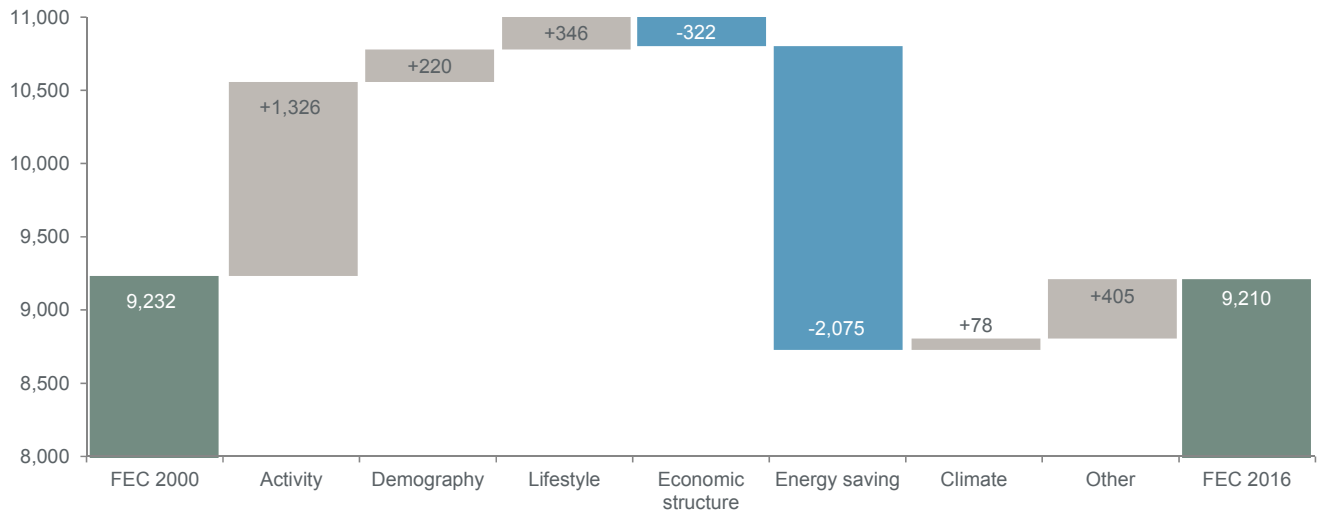
The factors influencing energy consumption in the final energy consumption sectors during the period from 2000 to 2016 are broken down in greater detail in Figure 5. A major impact on reducing consumption came from technical efficiency improvements which led to energy savings of 2,075 PJ and to a lesser extent from the transformation of the economic structure, with a decrease of 322 PJ. These efficiency gains, however, were mostly offset by quantity effects. Energy consumption increases were caused primarily by economic growth and increasing traffic (summarised under the position Activity), which together increased energy consumption by 1,326 PJ. The trend to larger homes and more devices and appliances in private households (summarised under the position Lifestyle) and demographic growth together contributed to a minor increase in energy consumption. On balance, absolute final energy consumption across all final energy consumption sectors was reduced by a mere 22 PJ between 2000 and 2016.

Conclusion

In the past years, Germany has succeeded in significantly reducing its total primary energy intensity. The analysis for the period from 2000 to 2016 shows that technical efficiency improvements in the final energy consumption sectors, but also the expansion of renewables, played an important part in this development. Despite significantly improved energy intensity – as the specific energy consumption indicator –, absolute primary energy consumption in Germany has so far been reduced to a limited extent only. A look at the final energy consumption sectors in particular has shown that the efficiency gains achieved there were just sufficient to offset increased energy consumption from economic growth, rising traffic, changed lifestyle and consumption patterns and population growth. This development impressively illustrates the enormous challenges Germany faces if it intends to halve its absolute primary energy consumption by 2050.

Figure 5: Components of the variation in final energy consumption (FEC) in Germany, 2000–2016

In petajoules (PJ)



Activity: Effects from variations in value added in manufacturing, services and agriculture and from changes in traffic volume
Demography: Effects from the growing number of dwellings
Lifestyle: Effects from greater number of electricity-consuming devices and appliances in private households and larger dwellings
Energy savings: Effects based on technical efficiency improvements

Source: **www.indicators.odyssee-mure.eu** (as at 28 May 2018)

To be able to achieve the national primary energy saving and thus greenhouse gas reduction target (-80 to 95 % compared with 1990) by 2050, the country will have to significantly speed up the current pace of energy efficiency improvements in all sectors of final energy consumption. This is also confirmed by the results of various relevant studies, which use energy scenarios to describe development pathways which Germany could follow to achieve its greenhouse gas reduction targets by 2050. Under these scenarios, average annual total final energy productivity growth rates in the period of 2010 to 2050 would have to be at least 2.1 to 2.7 %.[11] That is significantly more than has been achieved in the recent past. Between 2000 and 2016, total final energy productivity in Germany increased by an average 1.3 % per year. Final energy productivity represents the reciprocal value of final energy intensity and indicates how much economic output (gross domestic product) can be generated per unit of final energy consumed.

Although a variety of technical solutions and economic energy efficiency potentials are available in all sectors of final energy consumption, actual efficiency increases have been significantly below the required levels. Major obstacles include high investment requirements with sometimes long periods of amortisation, stakeholders' financial constraints, information deficits and incomplete internalisation of external environmental costs of using fossil fuels. In this context, policymakers must provide further stimului for necessary investments by creating the proper frameworks and providing targeted incentives. ■

[1] Cf. Deutsche Energie-Agentur (2018): dena-Leitstudie Integrierte Energiewende. Ergebnisbericht und Handlungsempfehlungen (German Energy Agency (2018): *dena Pilot Study on an Integrated Energy Transition. Report on Results and Recommendations for Action - our title translation*) – in German only, p. 21.

[2] Cf. International Energy Agency (2017): World Energy Balances 2017.

[3] The international dollar is a hypothetical currency unit that has the same purchasing power parity as the US dollar in the United States at a particular point in time. It is used in economic and financial statistics for various purposes, especially for comparing the gross domestic product of different countries.

[4] Cf. AG Energiebilanzen e. V. (2017): Ausgewählte Effizienzindikatoren zur Energiebilanz Deutschland. Daten für die Jahre von 1990 bis 2016 (*Selected efficiency indicators of Germany's energy balance. Data for the years 1990 to 2016* (our title translation) – in German only).

[5] Total final energy intensity = final energy consumption per unit of gross domestic product (in real terms). Final energy is defined as the part of primary energy originally used which is available to the consumer after deduction of conversion and transmission losses. Final energy intensity represents a measure of energy efficiency in production areas and energy use of private households (energy efficiency on the demand side). Statements about energy efficiency on the supply side (energy provision) cannot be derived from this.

[6] Cf. **www.odyssee-mure.eu**: Key Publications – Sectoral Profile Overview, downloaded on 28 May 2018.

[7] See also the comments on Figure 5.

[8] Cf. Federal Ministry for Economic Affairs and Energy, Zahlen und Fakten Energiedaten (*Energy facts and figures* – our title translation) (as at: 21 June 2018), in German only

[9] The individual contributions quantify the variation in total energy consumption that would theoretically occur while all other factors are kept constant.

[10] The method used in energy balancing to calculate conversion efficiency in accordance with international conventions assumes that nuclear energy consumes three times more primary energy per megawatt-hour of electrical energy generated (conversion efficiency 33 %). Electricity from the renewables hydropower, wind energy and photovoltaics, on the other hand, enters the primary energy balance only in the amount of electricity generated (conversion efficiency 100 %). Cf. AG Energiebilanzen e.V. (2017): loc. cit., and AG Energiebilanzen- Pressedienst (Nr. 10/2011): Statistische Effekte des Kernenergieausstiegs (*Statistical effects of the nuclear phase-out* – our title translation), in German only.

[11] Cf. Samadi, Sascha, et al.: Vergleich der BDI-Klimapfadestudie mit anderen Energieszenarien für Deutschland. (*Comparison of BDI climate action pathway study with other energy scenarios for Germany* – our title translation, in German only) In: Energiewirtschaftliche Tagesfragen, issue 6/2018, p. 52–57.