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Energy Consumption

in Germany in 2022

Energy Consumption in Germany Drops to the Lowest Level since 1990

Contents

Last Update: March 06, 2023
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(The article on renewable energy is based on the work of AGEE-Stat; last update: February 21, 2023)

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Total Primary Energy Consumption

In 2022, the primary energy consumption in Germany amounted to a total of 11,769 petajoules (PJ) or 401.6 million tons of coal equivalents (Mtce); compared to the previous year, this equals a decrease of 5.4 % (please see Table 1).

In 2022, the level of energy consumption as well as its composition (energy mix) were to a great extent characterized by the consequences of Russia's invasion of Ukraine, the stop of Russian gas supplies to Germany and the associated temporarily drastic increases in energy prices as well as comprehensive preparations for averting the threat of an energy crisis and/or the event of a gas shortage as a result of the German economy's dependence on energy imports from Russia which had been quite substantial until then. At the same time, the increase in population by about 1 million people due to war-related refugee movements from Ukraine also affected energy consumption in Germany. In addition, energy consumption continued to be influenced by political and regulatory requirements.

Significant for the medium-term to long-term development are, for example, the gradual phase-out from nuclear energy until April 15, 2023, the scheduled fossil fuel phase-out (by the end of 2038) as well as the continued promotion and support undertaken to expand renewable energy. Relevant at a European level are, for example, the reduction of the maximum quantity of emissions during the fourth trading period between 2021 and 2030 (linear reduction factor 2.2 % p.a. instead of 1.74 % p.a. as had been the case during the third trading period) within the EU-ETS, the objectives pursued for climate protection in the non-ETS sector, the requirements for improving energy efficiency (for example, the EU Energy Efficiency Directive (EED, Directive 2012/27/EU)), binding targets for the progressive expansion of renewable energy (EU Renewable Energy Directive, Directive (EU) 2018/2001) as well as the Proposal for a Directive of the European Parliament and of the Council Amending Directive (EU) 2018/2001 (Document COM/2021/557).

Table 1

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Primary Energy Consumption in Germany in 2021 and 2022 [1)]

Energy Carrier	2021	2022	2021	2022	Changes in 2022 compared to 2021			Proportions in %	
	Petajoules (PJ)		Million Tons of Coal Equivalents (Mtce)		PJ	Mtce	%	2021	2022
Mineral Oil	4,039	4,156	137.8	141.8	117	4.0	2.9	32.5	35.3
Natural Gas	3,303	2,783	112.7	95.0	-520	-17.7	-15.7	26.6	23.6
Hard Coal	1,112	1,156	37.9	39.4	44	1.5	4.0	8.9	9.8
Lignite	1,127	1,174	38.5	40.1	47	1.6	4.2	9.1	10.0
Nuclear Energy	754	379	25.7	12.9	-375	-12.8	-49.7	6.1	3.2
Renewable Energy	1,949	2,023	66.5	69.0	74	2.5	3.8	15.7	17.2
Electricity Exchange Balance	-67	-101	-2.3	-3.4	-34	-1.2	...	-0.5	-0.9
Other	222	200	7.6	6.8	-22	-0.8	-9.9	1.8	1.7
Total	**12,440**	**11,769**	**424.4**	**401.6**	**-670**	**-22.9**	**-5.4**	**100.0**	**100.0**

1) All data are preliminary; discrepancies in the totals are due to rounding off

Sources: Working Group on Energy Balances (AGEB); Working Group on Renewable Energies-Statistics (AGEE-Stat)

1) In this context, CO_2 pricing was introduced in Germany's heating and transportation sectors in January 2021 within the scope of the Climate Protection Program 2030 (German Fuel Emissions Trading Act – BEHG, Act on National Certificates Trading for Fuel Emissions). Since then, both private and commercial consumers (non-ETS) have had to pay a CO_2 surcharge amounting to € 25 per ton of carbon dioxide content for such energy carriers as fuels, fuel oil, or natural gas. The CO_2 price within this national emissions trading system is to be gradually increased to € 55/t by 2025. The increase in the CO_2 price by € 5 per ton, which had originally been planned for January 1, 2023, was in the meantime postponed by one year to January 1, 2024, in order not to place an additional burden on private households and the industrial economy against the backdrop of the sharp rise in energy prices. In the upcoming years 2024 and 2025 as well, the fixed price is to be reduced by € 10 per ton each when compared to the fixed price that has been planned so far.

In 2022 as well, the most important energy carrier continued to be mineral oil with a share of 35.3 %. It was followed by natural gas with a decreased share of 23.6 % (2021: 26.6 %). Renewables ended up at third place with a share of 17.2 %; in 2021, their contribution had still been 15.7 %. The primary energy consumption of hard coal and lignite in 2022 increased by 4 % and 4.2 % respectively so that lignite covered 10 % and hard coal 9.8 % of the domestic demand for primary energy. Compared to the previous year, the primary energy consumption of nuclear energy declined by about half of the previous value in 2022 (the nuclear power plants Grohnde, Gundremmingen C, and Brokdorf had been shut down in late December 2021). Due to the amendment of the German Atomic Energy Act, the decommissioning of the last three nuclear power plant units (Isar 2, Neckarwestheim 2, and Emsland), which had initially been planned for December 31, 2022, was postponed by three and a half months to April 15, 2023. Thus, nuclear energy covered still about 3.2 % of the demand for primary energy in 2022. The surplus obtained from the flow of electric power to foreign countries increased in 2022 (on balance about 101 petajoules, which translates into 9.5 TWh, more electricity flowed into foreign countries than had been the case in 2021). Consequently, the balance in the electricity exchange had a consumption-reducing effect (by 0.9 percentage points) on primary energy consumption also in 2022.

General Conditions for the Development in Consumption in 2022

The development of primary energy consumption depends on numerous influencing factors. These factors include, in addition to changes in the general political and regulatory framework, primarily the macroeconomic and sectoral development (structural change), demographic factors, energy prices, and temperature fluctuations. The individual fundamental factors which played a specific role in the increase in primary energy consumption during the years 2021/2022 will be outlined briefly below.

Temperature and Weather Influence

The temperature conditions play, to a large extent, a vital role in non-industrial energy consumption because most of the energy consumed in these sectors is designated for the heating of privately and commercially used rooms. The temperature influence is usually measured with degree day figures; in simple terms, this index reflects the cumulative number of the specific days on which the average temperature falls below a certain level (heating threshold temperature; here: 15 degrees Celsius).[2]

In 2022, the number of degree days was noticeably below the level of the long-term average (arithmetic average between 1990 and 2021 taken from 16 measurement stations). The low number of days with heating threshold temperatures of less than 15° C generally points towards a higher average temperature level in the reporting year and an associated reduction of the observed demand for energy (in particular, for the heating of residential premises) as a result of milder weather.[3]

When compared to the (relatively cool) previous year, the number of degree days decreased as well by 429 to 3,141 because it was noticeably warmer in 2022 than it had been in 2021. In 2022, the degree day figures were about 12 % below those of the previous year (higher temperatures) so that energy consumption in 2022, when compared to 2021, decreased just alone on the basis of the influence of the weather.

When considering the development of the degree day figures during the individual months, it becomes apparent that the year 2022, particularly between the months of January and May, was significantly milder than the previous year. In contrast, and as measured by the degree day figures, the temperatures in September 2022 were significantly lower than those of 2021. The months between October and December 2022 which are relevant for the heating period were once again, with the exception of December, milder than had been the case during the respective months of the previous year. When compared to the long-term average, the year 2022, except for the month of April, was consistently warmer during the first five months; and the second half of the heating period (between September and December), except for the month of September, was also milder than the weather recorded on the long-term average (please see Figure 1).

The impact of short-term temperature effects on the development of primary energy consumption is typically eliminated in that temperatures are assumed as indicated in the long-term average[4] and that inventory-adjusted data are taken into account for mineral oil consumption.[5] When taking these assumptions as a

2) Degree day figures (in accordance with DIN VDI 3807) are specifically defined as the sum of the differences between a fixed indoor temperature (here: 20° C) and the daily average of those days on which the air temperature falls below the heating threshold temperature (here: 15° C).

3) When compared to the long-term average (average number of degree day figures between 1990 and 2021), the year 2022 was warmer; consequently, the milder winter caused the heating period to be less pronounced. On an annual average (as measured by the degree days), the temperatures were 11 % higher than the values of the long-term average. If one were to shift one's considerations solely towards this long-term perspective, then primary energy consumption in 2022 would have been noticeably above the observed level provided that the weather conditions during this year had equaled those of the long-term average.

4) For assessing the long-term developments of energy consumption (as of 1990), the temperature adjustments in this report are generally conducted by taking the long-term average into account (please see Table 15, Diagrams 15 and 16). For short-term comparisons, the weather conditions prevailing during any other comparative period (for example, the previous year) could also be considered as an alternative. It is obvious that both the level of the temperature-adjusted absolute energy consumption and the rate of change compared to the previous year depend on the reference period chosen for the respective adjustment procedure.

Figure 1

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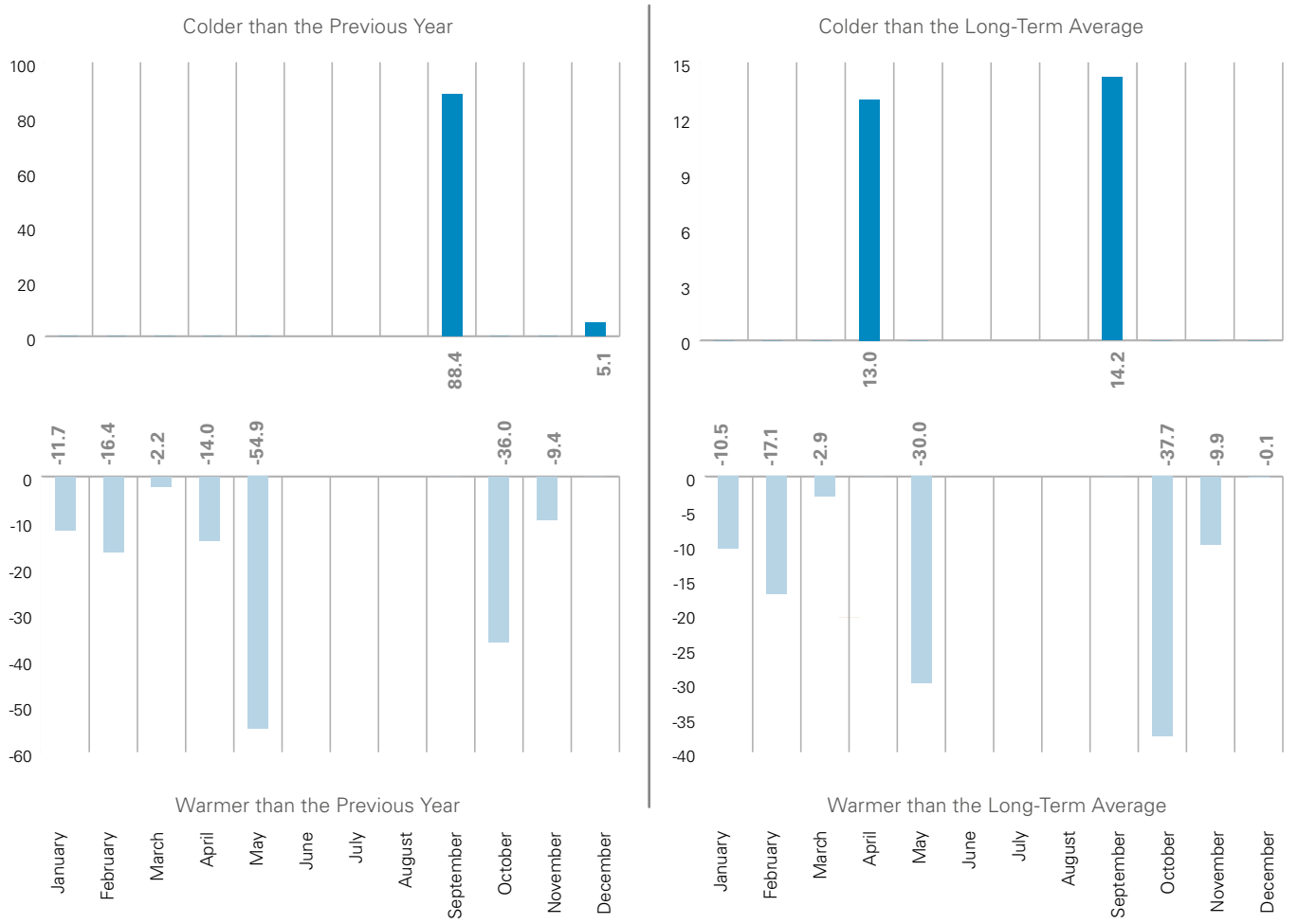
Monthly Degree Day Figures in Germany in 2022 (16 Measurement Stations)

Changes in 2022 compared to the previous year and to the long-term average (1990-2021) in %
Due to their limited informative value, the months of June and August are not included.



Source: Germany's National Meteorological Service (DWD)

basis, then primary energy consumption would not have decreased by 5.4 %; instead, the decrease would have merely been 4.0 % in 2022. The adjustment effect has a different impact on the individual energy carriers which is dependent upon their use for space heating purposes (please see Figure 2).

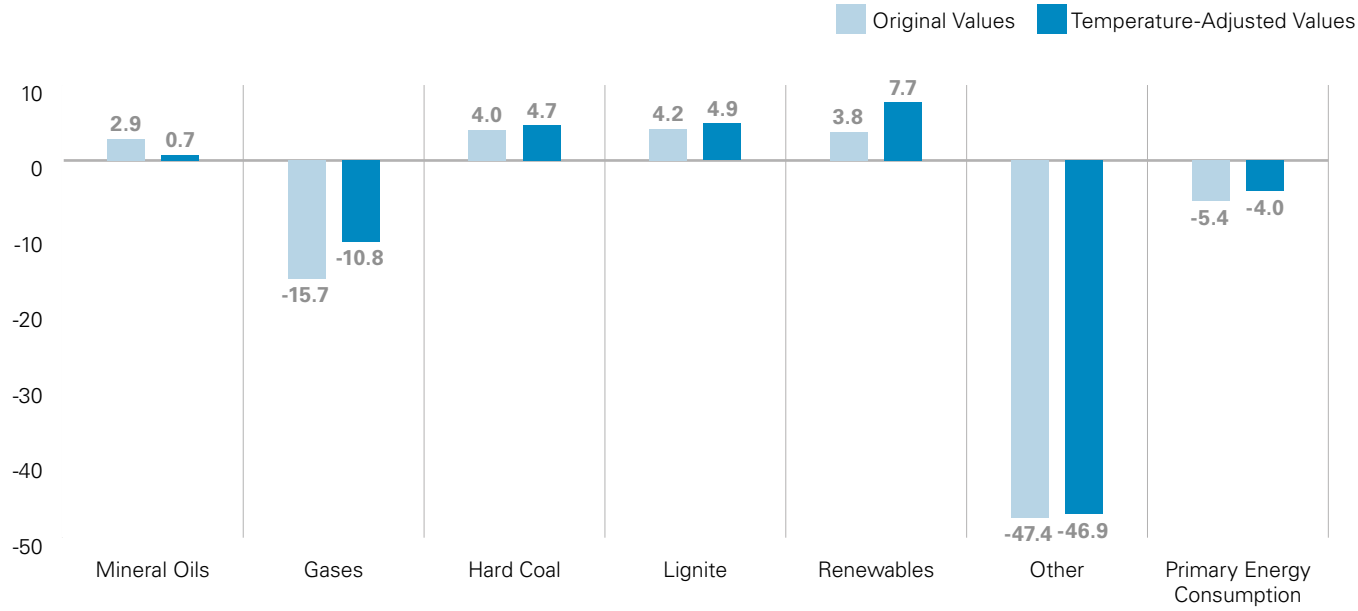
When it comes to the influence of the weather, it is generally accepted that temperature-adjusted changes in energy consumption in comparably warmer years are stronger than changes in the original values; accordingly, in colder years the increases in temperature-adjusted values are generally lower than those in the original values. This becomes also apparent from the different spreads of the energy carriers depicted in Figure 2.

5) *The information on mineral oil consumption provided in the energy balance (particularly on light fuel oil) includes, in part, only sales figures. Hence, the actual consumption of this energy carrier may deviate from the indicated sales volumes by the respective changes in stockpiling. Yet official statistics actually record these inventory changes only for the energy sector and the manufacturing industry which means that the requisite figures can only be incorporated into the consumption calculations of these two sectors. No original statistical data are available on the changes in fuel oil stocks for private households and for the trade, commerce, and service sector. In order to close the described gap, the Arbeitsgemeinschaft Energiebilanzen (AG Energiebilanzen) – Working Group on Energy Balances (Energy Balances Group) has been using for quite some time now an econometrically based method which is designed to empirically determine the inventory changes for these sectors, and which permits complete and comprehensive consumption calculations also for mineral oils. For more details on this procedure, please see Umsetzung eines Verfahrens zur regelmäßigen und aktuellen Ermittlung des Energieverbrauchs in nicht von der amtlichen Statistik erfassten Bereichen (2016), a survey conducted by the AG Energiebilanzen on behalf of the German Federal Ministry for Economic Affairs and Energy (BMWi), pp. 82ff. (Internet: https://www.bmwi.de/Redaktion/DE/Downloads/Studien/umsetzung-verfahren-ermittlung-energieverbrauch-nicht-amtliche-statistik-langfassung.pdf?__blob=publicationFile&v=7 (download date: 2023-02-21; currently only available in German)).*

Figure 2

Primary Energy Consumption in Germany According to Energy Sources

Changes between 2022 and 2021 in %



Sources: Working Group on Energy Balances (AGEB); Germany's National Meteorological Service (DWD)

When it comes to mineral oil, the (stock level adjusted) trend was additionally influenced by the fact that regardless of the increase in energy prices, many consumers stocked up on additional fuel oil and refilled their tanks for fear of supply disruptions. Thus, the available quantities of the fuel oil that was already stored in tanks were built up in 2022 (whereby this stockpiling was additionally benefited by the milder weather). Considering mineral oils as a whole, the opposing effects (stockpiling reduces the actual consumption of fuel oils whereas excluding the influence of the weather increases it) result in the fact that the primary energy consumption adjusted by inventory and temperature effects did not increase by 2.9 %, but only by 0.7 % (this means that the inventory effects actually overcompensated the impact of the weather adjustment, which increased consumption when taken in isolation, on the development of consumption in 2022).

When it comes to gases, however, it is solely the weather effect which plays a role within the scope of the adjustment. Against this backdrop and after having excluded the temperature influence, as expected natural gas consumption went down less significantly than it had initially been presumed by the observed trend (namely, by about 11 % instead of the observed decline of 15.7 %).

Compared to the previous year, the primary energy consumption resulting from the exclusion of the temperature influence and the movements in the inventory of light fuel oil (private households and the trade, commerce, and service sector) decreased, on a purely mathematical basis, by about 4 % (if and when the weather adjustment, as done here, is carried out on the basis of the long-term average of the degree day figures between 1990 and 2021).

Macroeconomic and Sectoral Factors

An export-oriented economy which imports a substantial share of its demand for energy carriers and raw materials as is characteristic for Germany depends, of course, to a large extent on global economic trends. According to estimates of the International Monetary Fund (IMF), the global economy ought to have increased only by a mere 3.5 % in 2022.[6]

6) Please see International Monetary Fund (2023), World Economic Outlook Update, January 2023.

For comparison: In 2021, the global economy had still increased by 6.2 %. The German economy is particularly affected by higher energy prices in the aftermath of the Russian war against Ukraine and by the outlined dampening of the global growth perspectives.

The price-adjusted gross domestic product (GDP) in Germany increased by about 1.9 % in 2022; this caused the economic downturn to be noticeably lower than had most recently been anticipated. In the preceding year, the gross domestic product had still increased by 2.9 %.

In 2022, growth impulses came primarily from consumption expenditure. Compared to the previous year, the overall consumption expenditure increased by 3.6 % (2021: +1.4 %), whereby positive growth impulses came primarily from private consumption expenditure (plus 4.6 %). Gross fixed capital formation[7] went up by only 0.2 % in 2022 (after it had still grown by 1.2 % in the previous year). All told, a contribution to growth amounting to 3.4 % emanated from the total domestic utilization (2020/2021: +1.9 %).

With a plus of 3.2 % (previous year: +9.7 %), the growth in the export of goods and services also slowed down substantially in 2022. At the same time and when compared to 2021, the value of imports went down by 6.7 % (previous year: +9.0 %) so that all told, a negative growth contribution (-1.3 %) came from the foreign trade balance (net visible and invisible exports). Owing to these developments, but above all due to the considerable increase in prices for energy imports, the German export surplus decreased significantly when compared to the previous year.

In line with the general macroeconomic conditions, the economic development in the individual economic branches was very heterogeneous. While some sectors, such as transportation or accommodation and food and beverage services, were able to benefit from the lifting of the Covid pandemic related protective measures and/or from the associated catching-up effects, the economic performance (as measured by the price-adjusted gross value creation) in such other branches as, for example, the construction industry decreased as a result of material shortages/supply bottlenecks, the lack of skilled professionals as well as high construction costs (interest, inflation).

In the producing industry as well, the diverging trends of the individual macroeconomic aggregates contributed to the fact that the sectors developed very differently also in 2022.

The production trend of those economic branches which either directly sell a significant proportion of their production abroad or act as prepaid suppliers for export-dependent sectors was decelerated by the slump in exports. Economic branches which depend on the overall situation in the construction sector recorded setbacks in growth and/or reduced their production because price-adjusted construction investments (residential and non-residential buildings) decreased by 1.6 % when compared to the previous year 2021. In addition, governmental consumption expenditure, which increased by 1.1 % when compared to the previous year, also had a stabilizing effect on the entire domestic demand in 2022.

All told, the output in the producing industry dwindled by about 0.8 % in 2022 (2021: +3.5 %); in the manufacturing industry, production (also measured by the production index) decreased by 0.5 % in 2022 which was primarily due to high energy prices and delivery problems with important precursors, primary products, and preliminary services (after it had still increased by 4.5 % in the year before). Naturally, energy-intensive economic branches were particularly affected by the increasing energy prices; compared to 2021, their production as a whole decreased by about 7 %.

Against this backdrop, Figure 3 provides an overview of the annual rates of change in the production indices for 11 key economic branches of the manufacturing industry (aggregated at the two-digit level of the economic branch classification WZ) between 2021 and 2022:

7) Investments into equipment, mechanical plants, and buildings (residential and non-residential buildings, including building construction and civil engineering) as well as changes in stocks.

Figure 3

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Production Index in Germany's Manufacturing Industry between 2021 and 2022

Changes Compared to the Previous Year in %

Source: Federal Statistical Office (Destatis)

- In 2022, 5 sectors of the 11 economic branches were able to attain increases in production when compared to the previous year whereas, in particular, such energy-intensive economic branches as "manufacture of chemical products" (-11.8 %), "production of paper, cardboard, and paper products" (-5.5 %), or "metal manufacture and metal machining" (-4.2 %), and others recorded declines in production after they had still been able to expand their production in the previous year.

- Compared to the manufacturing industry as a whole, an increase in production which was significantly above average was only observed in the economic branches "manufacture of computers, electronic and optical products" (+6.2 %) as well as "other vehicle construction" (+7.6 %).

- In 2022, below-average (albeit positive) growth rates (except for the significantly shrinking energy-intensive sectors already referred to hereinabove) when compared to the previous year could be observed in the sectors "manufacture of machinery and equipment" (+0.3 %), "manufacture of motor vehicles, trailers, and semi-trailers" (+2.5 %), and finally "production of electrical equipment" (+3.5 %).

As a result of the described decline in production in the manufacturing industry as a whole, a consumption-reducing impulse can generally be expected for the use of energy in the reporting year 2022. The described impulse tends to be strengthened by the disproportionally high production decrease in all energy-intensive sectors of the manufacturing industry.

It should also be remembered at this point that the substantial increase in energy prices as well as the concerns about a disruption of the energy supply ("gas shortage situation") ought to have triggered additional

incentives for saving hitherto unused efficiency potentials in all economic branches.

High energy costs in combination with the expectation that a rapid and/or full return to the old (low) price level is almost impossible ought to have enhanced the competitiveness of investments into energy-saving technologies (and methods designed to substitute energy, for example, with secondary raw materials, etc.). That is why despite the partly tense economic situation, improvements in energy productivity can be expected which go above and beyond the structural change in industry.

Demographic Factors

Between 2021 and 2022, the population (inhabitants) in Germany grew from 83.196 million people to around 83.839 million people; this equals an increase in population of 0.8 % (+643,000 people).[8] For comparison: In the previous year, the domestic population had only grown by 35,000 people (which equaled a stagnation in the demographic development). The increase in population is solely attributable to the high number of immigrants (predominantly war refugees from Ukraine). Without the net immigration, the population would have shrunk because more people died than were born.

Under these premises (updated statistical figures are not yet available), the number of households is likely to slightly increase further as well. In 2021, almost 41 million private households existed in Germany, of which around 41.7 % were single-person households (which translates into approximately 17.1 million).

The increase in the number of households is not only due to the demographic development, but at the same time also due to the existing trend of living in smaller households. Currently (2021), an average of approximately 2.03 persons lives in one household.

That is why the demographic development as such is likely to have had a noticeable consumption-enhancing effect on the development of energy consumption in 2022.

Energy Prices

In addition, the energy prices also play an important role when it comes to the consumption behavior, efficiency improvements, and substitutions (between energy and capital as well as materials and/or resources). Generally speaking, the higher the prices for individual energy carriers are, the sooner efficiency improvements and substitutions occur.

The Covid-19 pandemic and/or the associated effects on economic growth and the global demand for energy had exerted a substantial influence on the condition of the global energy markets in the years 2020/2021. On average, the import prices for crude oil, natural gas, and hard coal increased significantly between 58 % and 179 % in 2022 (whereby the prices for imports of hard coal and crude oil peaked during the first quarter of 2022 while the import price for natural gas peaked during the second quarter of 2022). Already in the previous year, the import prices for energy had once again increased considerably as a consequence of overcoming the pandemic-related global economic downturn in 2019/2020 (please see Table 2).

The development of the exchange rate actually reinforced, in part, the described increase of energy prices on the global market for consumers in Germany. The exchange rate of the Euro against the US Dollar (by using the indirect quotation) decreased by almost 11 % in 2022, i. e. the Euro devaluated against the US Dollar which, in turn, made imports of goods and services from the Dollar zone even more expensive.

Notwithstanding the above, the prices for domestic consumers deviate to some extent noticeably from the development of import prices because these prices, in addition to governmental taxes as well as statutory charges and levies,[9] also include such components as transport and distribution costs as well as other distribution expenses. In addition, due to the contractual ties that exist and depending on the specific energy carrier and customer group considered, the import prices and/or procurement costs normally have no

8) Average population based on the 2011 Census and on the results of the population projections as also applied within the scope of the National Accounts. According to the Federal Statistical Office, the population in Germany increased by about 1.1 million people to 84.3 million inhabitants until the end of 2022. For more details, please see: https://www.destatis.de/EN/Press/2023/01/PE23_026_124.html (download date: 2023-03-15).

9) For example, the introduction of the national CO_2 pricing (2021: € 25/t of CO_2) on the transportation and heating markets (national emissions trading) resulted in an increase in the consumer prices for fuels and fuel oils of approximately 10 ct/liter as per January 1, 2021.

direct impact on the final consumer prices. In 2022, consumer prices for light fuel oil increased by 87 %, for natural gas by 65 %, and for electric power by more than 20 % when compared to the previous year.

The consumer price trend for specific customer groups and/or end users will be highlighted in more detail in the respective sections referring to the individual energy carriers.

Table 2

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Prices of Selected Energy Sources

Changes 2022 to 2021 in %

	2021	2022				
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Average
	Import Prices					
Mineral Oil	66.6	73.3	81.2	58.7	26.8	57.8
Natural Gas	138.7	370.9	579.3	888.3	498.8	178.6
Hard Coal	76.0	221.2	307.3	187.6	51.1	161.9
	Consumer Prices					
Fuel Oil, Light	41.8	84.7	100.7	107.5	61.1	87.0
Natural Gas	4.7	36.6	54.4	84.7	82.1	64.8
Electricity	1.4	13.9	20.9	18.6	26.7	20.1

Source: Federal Statistical Office (Destatis)

Dependence on Energy Imports

When it comes to the German economy's vulnerability to energy crises, an outstanding role is assigned to the availability of energy resources and the associated possibility of their domestic production and utilization. Higher domestic production volumes generally reduce the dependence on imports and, thus, lower the risk of disturbances or disruptions in the overall supply as well as the commodity price risk for the domestic economy.

Against this backdrop, a glance at Germany's foreign trade balance for energy carriers is of particular interest. Germany is a considerable net importer of virtually all fossil fuels (i. e. hard coals, mineral oil, and natural gas). In 2021, domestic primary energy consumption had been covered by imports which amounted to about 97 % for mineral oil and about 95 % for natural gas. 100 % of the hard coals had been sourced from imports. In contrast, 100 % of the lignite had been made available from indigenous resources, and renewables had also come almost entirely from domestic production. All told, nearly 70 % of the German energy supply had been dependent on imports in 2021.

This situation did not fundamentally change in 2022 as well; Germany's dependence on imports remained at a level that was similarly high as in the previous year even though the procurement and supply structures of energy imports (natural gas, hard coal, petroleum) changed dramatically against the backdrop of the Russian invasion of Ukraine in February 2022.

What changed fundamentally (in addition to the supply regions for energy imports to Germany) – as already outlined above – were the import prices for fossil fuels (which was also a direct consequence of the Ukraine conflict). All told and notwithstanding the fact that the imported energy volumes[10] decreased by 4.7 %, the considerable increase in import prices caused the import calculation for coal, oil, and gas to almost double from about 69.6 billion euros in 2021 by 67.1 billion euros to 136.7 billion euros in 2022.

A glance at the individual energy carriers reveals the following picture: The value of oil imports increased by 66 %, the value of natural gas imports even by 123 %. The value-based import balance for coals increased by more than 172 %. When it comes to electric power, the (value-based) export surplus increased by about 127 %, whereby the physical surplus gained from electricity trading with foreign countries when compared to the previous year increased by only 9.5 TWh, which translates into about 51 %, in 2022 (please see Table 3).

Table 3

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Balance of Foreign Trade with Energy Carriers in Germany between 2017 and 2022

	2017	2018	2019	2020	2021	2022	Changes in 2022 Compared to 2021	
							Billion Euros	%
Coal, Coke, and Briquettes	5.2	5.0	4.1	2.3	4.7	12.6	8.0	171.6
Petroleum, Petroleum Products, and Related Goods	36.1	43.8	42.8	26.9	36.6	60.7	24.1	66.0
Gas [1]	15.0	18.0	15.9	12.3	28.4	63.3	34.9	123.0
Total Fossil Fuels	**56.3**	**66.8**	**62.9**	**41.4**	**69.6**	**136.7**	**67.1**	**96.3**
Electric Power	-1.8	-1.9	-1.6	-0.9	-2.3	-5.2	-2.9	127.4
Total	**54.5**	**64.9**	**61.3**	**40.6**	**67.4**	**131.5**	**64.2**	**95.3**

1) Including transit volumes

Source: Federal Statistical Office (Destatis)

10) Net imports: Sum of imports minus exports minus international marine bunkering.

Primary Energy Production in Germany

Except for petroleum, natural gas, and other energy carriers, domestic energy production increased for all other energy carriers in 2022 which resulted in an overall increase of approximately 2.2 % to 3,647 PJ or 124.4 Mtce (please see Table 4).

According to initial preliminary calculations made by the Arbeitsgemeinschaft Energiebilanzen (AG Energiebilanzen) – Working Group on Energy Balances (Energy Balances Group), the domestic production of fossil fuels (without renewables) attained a level of 1,620 PJ in 2022, which more or less corresponds to the previous year's value (1,617 PJ). This stagnation is the result of opposing trends. Compared to 2021, the production of natural gas and petroleum in 2022 declined by 6.6 % and 5.1 % respectively, which translates into a total decrease of approximately 15 PJ;[11] furthermore, the domestic production of other energy carriers decreased by 23 PJ (which equals a minus of approximately 10 % when compared to the previous year). The declines recorded for the above-mentioned energy carriers (in total, minus 38 PJ) were actually overcompensated by the increased production of lignite which was able to augment its share in domestic energy production by 3.5 % and, thus, by approximately 40 PJ.

A significant contribution towards increasing the total domestic energy production came (in addition to lignite) primarily from renewable energy sources; they were able to expand their production not only due to the construction of new plants, but also because of the increased supply of wind by 74 PJ, which translates into 3.8 %, in 2022.

The overall result shows that renewables represented the most important indigenous energy source with a proportion of almost 56 % in 2022. About one third of the domestic energy production was provided by lignite in 2022; thus, lignite was able to augment its share once again by 0.5 percentage points when compared to the previous year. Both energy carriers (renewables and lignite) continued to rank far ahead of natural gas and petroleum.

When taking primary energy consumption in 2022 into account, the overall proportion of domestic production increased; namely, from 28.7 % in 2021 to now about 31 % (please see Table 4).

Table 4

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Primary Energy Production in Germany in 2021 and 2022

	Production				Changes in 2022 Compared to 2021		Proportions	
	2021	2022	2021	2022			2021	2022
	Petajoules (PJ)		Million Tons of Coal Equivalents (Mtce)		PJ	%	%	
Mineral Oil	77	73	2.6	2.5	-4	-5.1	2.1	2.0
Natural Gas, Petroleum Gas	165	154	5.6	5.2	-11	-6.6	4.6	4.2
Hard Coal	0	0	0.0	0.0	0	0.0	0.0	0.0
Lignite	1,153	1,194	39.3	40.7	40	3.5	32.3	32.7
Renewable Energy	1,953	2,027	66.6	69.2	74	3.8	54.7	55.6
Other Energy Carriers	223	200	7.6	6.8	-23	-10.1	6.2	5.5
Total	**3,570**	**3,647**	**121.7**	**124.4**	**77**	**2.2**	**100.0**	**100.0**
For information purposes: Proportion of Primary Energy Consumption							28.7	31.0

Some figures are estimates; discrepancies in the totals are due to rounding off

Sources: German Association of Energy and Water Industries (BDEW); German Brown Coal Industry Association (DEBRIV); Federal Office for Economic Affairs and Export Control; en2x - Fuels & Energy Business Association; Working Group on Renewable Energy Statistics (AGEE-Stat)

11) Over the past few years, the domestic production of petroleum and natural gas dropped because of the increasing depletion of old fields and deposits. To that extent, this trend continued during the reporting year 2022. However, it also needs to be pointed out in this context that the production of natural gas and petroleum not only depends on geophysical-technical factors, but also on economic constraints. Increasing oil and gas prices usually generate a particular impulse to reinforce the exploration efforts. Also worth mentioning here is that in times of high energy prices, the recommissioning of old fields and the use of new production technologies can perhaps be economically viable as well.

Mineral Oil

According to preliminary calculations made by the AG Energiebilanzen, the primary energy consumption of mineral oil in Germany amounted to 4,156 PJ (141.8 Mtce) in 2022, which was 2.9 % above the previous year's level.

With an increase of approximately 3 %, the development of domestic sales of mineral oil products recorded a plus in 2022. Taken together, consumption of the most important mineral oil products developed very differently from one another (please see Table 5): Compared to the previous year, the consumption of diesel fuels decreased by 0.5 % to 34.8 million tons. Nonetheless, sales of diesel fuels continued to be more than twice as high as those of gasoline (17 million tons) whose demand increased by 3.8 % in 2022 when compared to the previous year. The consumption of aviation fuels increased considerably once again during the reporting year 2022; namely, by 43.8 %, after it had initially exhibited a decline of almost 54 % in the wake of the Covid-19 pandemic in 2020. Thus, sales in this segment in 2022 (about 8.8 million tons) still fell about 14 % (1.4 million tons) and, thus, below the "normal volumes" which had been observed before the outbreak of the Covid-19 crisis. All told, the demand for fuels (2022: About 60.6 million tons), which accounted for an approximate share of 63 % in Germany's total oil consumption, was almost 5.4 % (which equals 3.1 million tons) higher in 2022 than it had been in 2021.

With an increase of more than 9 % (which equals +1 million tons), sales of light fuel oil experienced a clear upward trend. In light of the weather, which was comparably milder in 2022 than in the previous year (for more details, please see Section *Temperature and Weather Influence* hereinabove), continuing savings in fuel oil due to the substitution of oil-fired heating systems with electric heat pumps or natural gas condensing systems), continuing efficiency improvements (for example, due to the use of modern oil condensing heating systems or investments into the improved thermal insulation of building envelopes) as well as attitude and behavior related savings on part of the consumers, against the backdrop of fuel oil prices which temporarily increased to record levels in 2022, this trend was most likely not due to a "real" increase in the energy consumption of oil-heated buildings. In fact, it can be assumed that both private and commercial consumers were concerned about a further worsening of the energy crisis in the aftermath of the war in Ukraine to such an extent that they replenished their fuel oil stocks as a precaution in the event of further crises.

According to our estimates, and despite the substantial increase in the fuel oil price,[12] the fuel stock volumes just in private households alone were likely to have been built up in the ballpark of 67 PJ (which equals approximately 1.5 million tons or 1.3 million liters) in 2022. In addition to the extraordinary effects and the crisis-related effects described hereinabove, increases in the stock volumes of extra light fuel oil (particularly on part of private consumers) were likely to have been additionally fostered by the comparably high outside temperatures during the heating period. If this were indeed the case, then the actual consumption would most likely be correspondingly lower than the volume of fuel oil which was statistically recorded and/or sold in 2022.

With a plus of 5.9 %, refinery production increased to a level of 103 million tons in 2022. Towards this end, refinery production from crude oil, which accounted for a share of about 89.8 %, went up by 8 % whereas the processing of products actually decreased by 7 %. In light of the increasing production, the refining capacity of 105.7 million tons, which (compared to the previous year) remained unchanged once again, was actually utilized at 85 % in 2022; in 2021, the degree of utilization had still amounted to about 79 %.

Foreign trade in mineral oil products changed significantly in 2022. On balance, imports predominated in 2022; with 35.7 million tons, they topped the exports of 27.4 million tons (albeit by now only about

12) Prices for light fuel oil increased at an annual average between 2021 and 2022 from about 71 c/liter to € 1.33/liter, which equals an increase of about 87 %. In October 2022, the price for light fuel oil peaked at € 1.56/liter. Under normal market premises, customers order fuel oil depending on the anticipated price trend. Well-filled fuel oil tanks in combination with the expectation that fuel oil prices will fall over the medium term would, therefore, actually cause consumers to postpone their decision to refuel their oil tanks and/or to reduce their fuel stock volumes in times of extremely high fuel oil prices (such as, for example, between June and October 2022).

8.3 million tons). Quantitative exports of mineral oil products increased by more than 7 % whereas imports decreased by over 3 % when compared to 2021.

Due to its very limited domestic petroleum resources, Germany is primarily dependent on crude oil imports; with 88.2 million tons, they exceeded the previous year's level by 8.5 %, which translates into 6.9 million tons, in 2022.

Compared to the previous years, the procurement regions for deliveries of crude oil to Germany shifted significantly in 2022. The main cause of these structural shifts were the resolutions adopted by the EU on the imposition of an embargo on Russian oil,

Table 5

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Consumption and Volume of Mineral Oil in Germany in 2021 and 2022

		2021	2022 [1]	Change
		in Million Tons		in %
Total Consumption		**94.1**	**97.1**	**3.2**
Self-Consumption and Losses [2]		5.5	5.8	5.6
Domestic Consumption		88.6	91.3	3.0
Proportion of:	Gasoline	16.4	17.0	3.8
	Diesel Fuel	35.0	34.8	-0.5
	Aviation Fuels	6.1	8.8	43.4
	Fuel Oil, Light	11.2	12.2	9.1
	Fuel Oil, Heavy [3]	1.3	0.9	-32.5
	Naphtha	13.7	13.1	-4.3
	Liquid Gas	3.7	3.4	-8.7
	Lubricants	0.9	0.8	-3.0
	Other Products	10.0	10.2	1.8
	Recycling (to be deducted)	-6.1	-6.4	4.6
	Biofuels [4] (to be deducted)	-3.7	-3.7	-0.3
Total Volume		**88.6**	**91.3**	**3.0**
Domestic Production		1.9	1.8	-4.5
Refinery Production		97.2	103.0	5.9
Generated from:	Input of Crude Oil	83.1	89.8	8.1
	Input of Products	14.1	13.1	-7.0
Foreign Trade Products (Balance)		11.2	8.3	
	Imports	36.8	35.7	-3.1
	Exports	25.6	27.4	7.1
Compensation [Balance (Bunker, Differences)]		-14.2	-14.1	
Refining Capacity		105.7	105.7	0.0
Utilization of Refining Capacity in %		78.6	85.0	
Primary Energy Consumption of Mineral Oil (Mtce)		**4,039**	**4,156**	**2.9**

1) Preliminary data; some figures are estimates
2) Including changes in stocks
3) Including other heavy residues
4) Only added biofuels

Discrepancies in the totals are due to rounding off

Sources: Working Group on Energy Balances (AGEB); Federal Office for Economic and Export Control (BAFA); en2x - Fuels & Energy Business Association

as a direct consequence of the outbreak of the war in Ukraine. The first step of the EU sanctions, which became effective as of December 5, 2022, stipulated a stop of crude oil imports via maritime transport (oil tankers).[13, 14]

Against this backdrop, imports of crude oil from the states of the Russian Federation had decreased noticeably in the growing German import market already before the first step of the gradual EU embargo came into force. In 2022, crude oil imports from Russia went down by more than 4 million tons to 22 million tons, which still equals a supply share of 28 % in the crude oil import market. For comparison: In 2021, Germany had still imported 27.7 million tons, which translates into a share of 34.4 %, of its total import volume from Russian sources.

The decline in Russian oil supplies (as well as the increase in the total import volume) was compensated, with the exception of the United Kingdom, by increased procurement volumes from other supplier countries; above all, the USA, Kazakhstan, and Norway.

In 2022, the most important supplier country for crude oil was Russia (nearly 28 %) whose share actually decreased for the first time ever. Kazakhstan (15.9 %) and the USA (15 %) followed on second and third place; they managed to substantially increase their market shares when compared to the previous year. Norway assumed fourth place among the major countries of importation in 2022 with a share of crude oil imports that increased by 0.2 % to 10 % when compared to the previous year (please see Table 6). Split into individual oil producing regions, the proportion of crude oil imports from the countries of the former Soviet Union (CIS states) decreased against the backdrop of a generally growing market; it went down from almost 41 % (2021) to 36.4 % in 2022. In contrast, the OPEC states (2022: 17.4 %) did not record any increases in their shares in the growing market (even

Table 6

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Germany's Crude Oil Imports in 2021 and 2022 According to Countries of Origin

Important Supplier Countries/Production Regions	2021	2022	Changes 2021/2022	2021	2022
	in Million Tons		in %	Proportions in %	
Russia	27.7	24.6	-11.2	34.1	27.9
United Kingdom	7.6	7.6	-0.4	9.3	8.6
USA	7.8	13.2	69.3	9.6	15.0
Norway	8.0	8.8	9.8	9.8	10.0
Kazakhstan	10.2	14.1	38.2	12.5	15.9
Nigeria	1.7	2.2	30.8	2.1	2.5
Other Countries	18.4	17.7	-3.8	22.6	20.0
Total	**81.4**	**88.2**	**8.3**	**100.0**	**100.0**
OPEC	14.2	15.3	8.3	17.4	17.4
North Sea [1] (excld. FRG)	21.4	25.4	18.7	26.3	28.9
Former CIS	33.2	32.1	-3.3	40.8	36.4
Other	12.6	15.3	21.2	15.5	17.3
Total	**81.4**	**88.2**	**8.3**	**100.0**	**100.0**

1) Including other EU countries

Discrepancies in the totals are due to rounding off. Data for 2022 preliminary, partially estimated.

Sources: Federal Office of Economics and Export Control (BAFA); Federal Statistical Office (Destatis)

13) At the same time, a price cap for crude oil amounting to 60 US dollars per barrel was agreed upon; this price cap is designed to force Russia into selling crude oil to clients in non-EU countries at prices that do not exceed this cap.

14) The second step of the embargo put a ban on imports of crude oil via the Druzhba pipeline as of January 1, 2023, and the third step finally prohibited imports of diesel and other mineral products (as of February 5, 2023).

Figure 4

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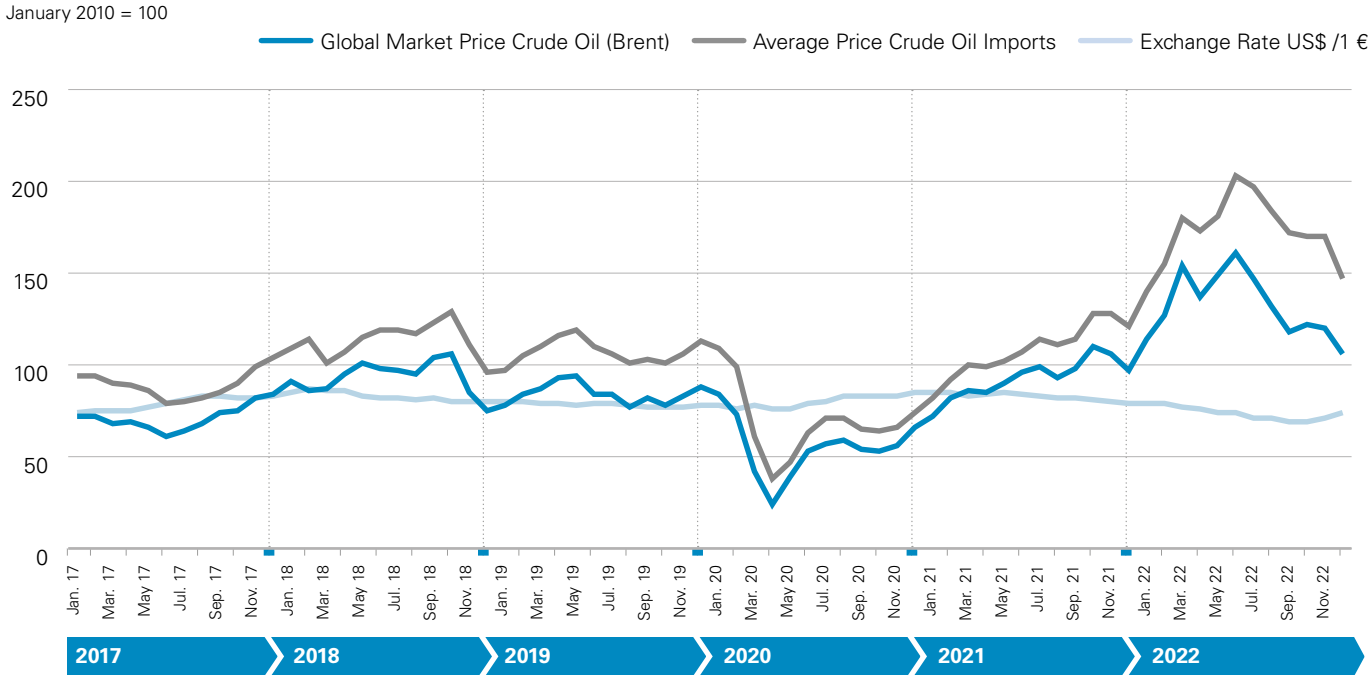
Global Market Prices for Crude Oil (Brent) [1], Border-Crossing Prices for German Crude Oil Imports [2], and Exchange Rates between 2017 and 2022



1) Original values in US dollars per barrel
2) Original values in euros per ton

Sources: Federal Ministry for Economic Affairs and Energy (BMWi); Deutsche Bundesbank (German Central Bank); en2x - Fuels & Energy Business Association

though deliveries from this region increased by more than one million tons) whereas the countries bordering the North Sea increased their supply share by about 2.6 percentage points to almost 29 % (2022).

In 2022 as well, international oil prices and the Euro/US Dollar exchange rate, which determine the price for German crude oil imports, exhibited a very volatile development not least as a consequence of the war in Ukraine; in other words, they experienced considerable short-term fluctuations (please see Figure 4).

While the prices for crude oil grade Brent UK, which is important for Europe, with an annual average of about 71 US dollars per barrel (US-$/bbl; 1 barrel = 159 liters) in 2021 had already been about 29 US dollars above the previous year's values, they continued to increase to more than 102 US dollars in 2022. The development during the course of 2022 clearly indicates the above-mentioned price increases in a more pronounced manner. Based on its value in January (with about US-$ 86/bbl), the crude oil price continued to go up and reached its annual peak of almost US-$ 123/bbl in June. It was, thus, only about US-$ 2.70/bbl below the previous record value that had been attained in March 2012. Subsequently, a continuous decline in the price to nearly US-$ 81/bbl was observed once again until December 2022.

Compared to the Covid-19 related low in May 2020 (about US-$ 18/bbl), the oil price based on dollars was five to seven times higher during all months of the year 2022.

German crude oil import prices developed to a large extent parallel to the global market prices. Differences are essentially influenced by fluctuations in the exchange rate of the Euro (to the US Dollar). Since January 2022, the exchange rate of US-$ 1.13/€ (indirect quotation) decreased to about US-$ 1.06/€ at the end of the year (December 2022). Compared to the previous months, a slight appreciation of the Euro could be observed once again during the last two months of 2022 (November and December).

A direct monthly comparison with the previous year shows corresponding trends: From January to December 2022, the exchange rate (indirect quotation)

ranged in the ballpark between more than 6 % and nearly 16 % below the level of the respective months of the previous year. On an annual average, the exchange rate in 2022 decreased by almost 11 % to US-$ 1.05/€ when compared to the year 2021 (depreciation of the Euro against the US Dollar).

Consequently, the depreciation of the Euro described above tended to intensify the increases and/or fluctuations in crude oil prices on the global market for German consumers during the course of the year. In November 2022, however, the appreciation of the Euro resulted in a slight weakening of the exchange rate related increase in prices for consumers in Germany.

All told, German crude oil import prices (on an annual basis and calculated in Euro/bbl) increased to a noticeably greater extent (+58.3 %) than the global market prices (in US-$/bbl) for crude oil (+41.0 %) between 2021 and 2022.

Converted into euros and tons, German crude oil import prices went up from an annual average of € 436/t in 2021 to about € 690/t in 2022. Due to the import volumes, which increased by nearly 8.5 % (6.9 million tons) in 2022 when compared to the previous year while the crude oil prices for German consumers increased by more than 58 % over the same period of time, the overall costs for crude oil imports went up considerably by almost 72 %; namely, from about 35.4 billion euros to 60.9 billion euros.

Prices for oil products in Germany followed primarily the changes in crude oil costs and in international product quotations; albeit at different rates (please see Figure 5). In 2021, the average annual prices for premium gasoline, diesel fuel, and light fuel oil had already increased noticeably in conjunction with the renewed demand for these products after having overcome most of the restrictions imposed by the Covid-19 crisis.

In 2022, the price increase gained momentum until March 2022. For example, prices for premium gasoline at gas stations increased by more than 25 % (+43 ct/liter) just between January and March 2022 alone, for diesel fuel by more than 36 % (+58 ct/liter), and for light fuel oil even by about 81 % (+78 ct/liter).

After having reached their peak level in March 2022, it was in particular the gas station prices for

Figure 5

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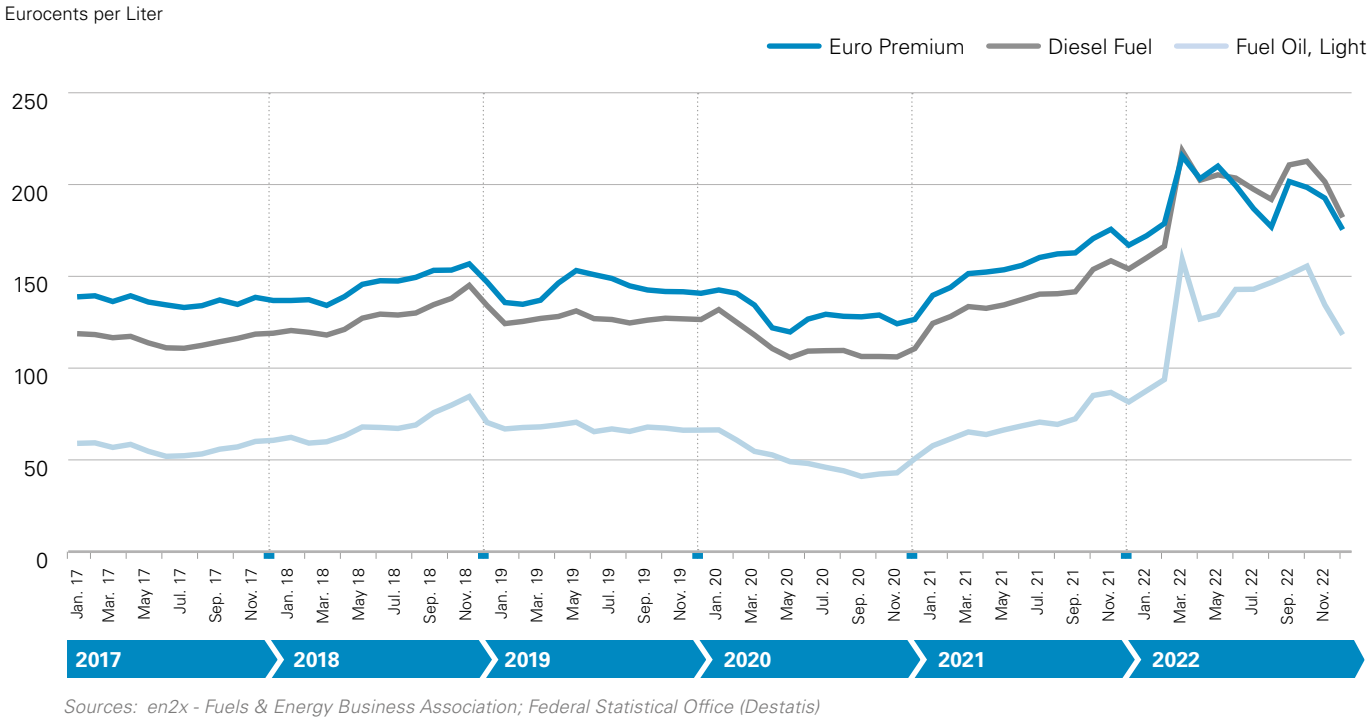
Prices for Fuels and Light Fuel Oil in Germany between 2017 and 2022



Sources: en2x - Fuels & Energy Business Association; Federal Statistical Office (Destatis)

gasoline and diesel fuel which declined once again until August. The development of fuel prices was additionally influenced by the temporary reduction of the energy tax on gasoline and diesel fuel ("fuel price brake," "fuel discount") which was in effect between June 1, 2022, and August 31, 2022. After the expiration of the fuel discount, fuel prices initially went up before they once again decreased significantly by the end of the year.

Despite this decline, the prices for all three products recorded in December 2022 were still noticeably above the level which had been observed at the beginning of the year (January 2022). For example, the price for light fuel oil in December 2022 was approximately 31 ct/liter higher than the price that had been recorded in January 2022 (which equals an increase in prices of almost 35 %). At the end of the year, prices for gasoline were 3.3 ct/liter higher and prices for diesel fuel were 22 ct/liter higher than the respective prices quoted in January of the same year (which equals a plus of 1.9 % for gasoline and a plus of 13.8 % for diesel fuel).

At an annual average and compared to 2021, the prices for gasoline went up by almost 22 %, for diesel fuel by more than 40 %, and for light fuel oil by approximately 87 %. As measured by the producer price index, mineral oil products in Germany were at an annual average and in total 40 % more expensive in 2022 than in 2021.

Natural Gas

According to preliminary data, natural gas consumption in Germany decreased by 15.7 % to about 773 billion kWh (H_i) in 2022.[15] Thus, natural gas consumption dropped more or less down to a consumption level which had last been recorded for the years 2014/2015.

Domestic production of natural gas went down in 2022; with an estimated volume of almost 42.7 billion kWh, it will, thus, fall about 6.6 % below the previous year's value (2021: 45.8 billion kWh). In 2022, domestic production of natural gas covered about 5.5 % of Germany's natural gas consumption. About 95 % of the natural gas used in Germany were imported.

Since the reporting year 2018, the data reflecting the development of natural gas imports and exports have also included all transit volumes which pass through the Federal Republic of Germany's territory to our neighboring countries. That is why only the foreign trade balance (net imports) will be examined closer here. In 2022, the import volume of natural gas remaining in Germany (imports minus exports) amounted to about 822 billion kWh. Thus, the net import volume increased slightly when compared to the previous year; namely, by 0.7 %.

The consequences of the war in Ukraine are reflected by distinctly changed import structures. Whereas about 55 % of the natural gas consumed in Germany had still come from Russia in 2021, only about 20 % were sourced from there in 2022. Since September 2022, no more pipeline gas has flowed from Russia into Germany. The discontinuation of these supplies was offset by additional imports from the Netherlands as well as via pipelines from Belgium and France (please see Figure 6).

For the first time ever on December 21, 2022, gas was fed into Germany's natural gas grid via the LNG terminal in Wilhelmshaven; a few days earlier, the "Höegh Esperanza" had been the first tankship to

Figure 6

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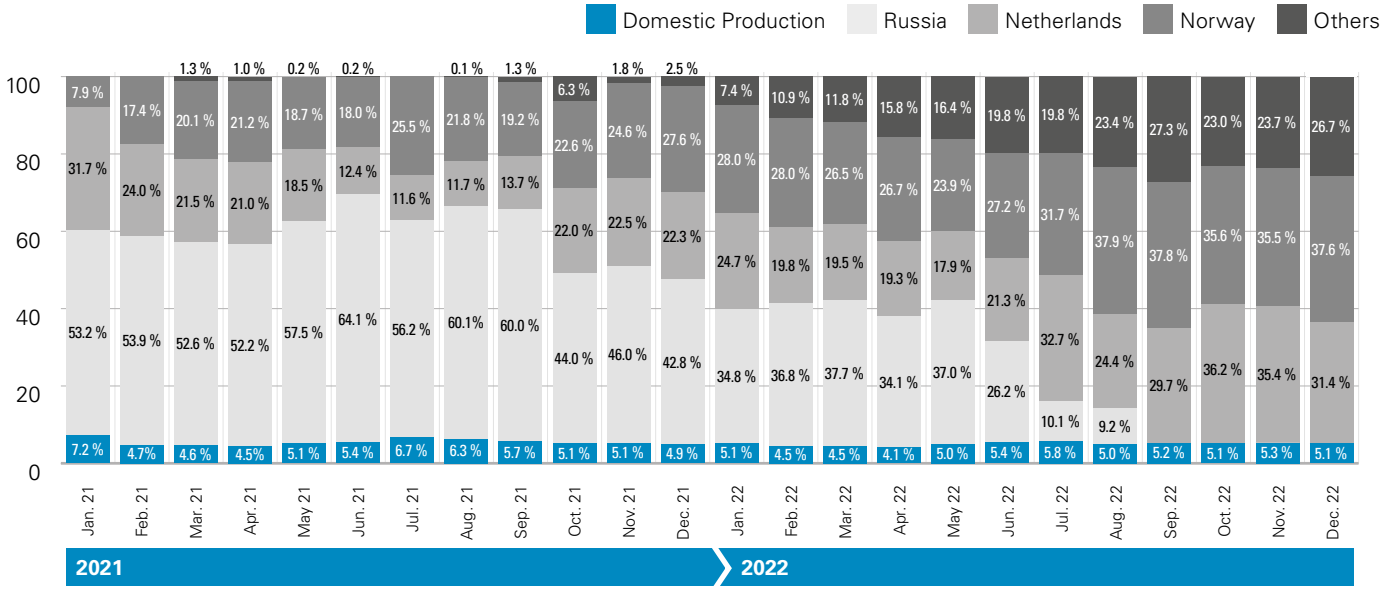
Origin of the Gas Consumed in Germany

January 2021 to December 2022; Shares in Total Consumption in %



Sources: ENTSOG; FNB; BDEW; own calculations

15) The AG Energiebilanzen calculates natural gas consumption both in the energy balance for Germany and in all other publications based thereon according to the heating value (previously referred to as lower calorific value, H_i, i = inferior, Latin for "below"). The calorific value (previously referred to as upper calorific value, H_s, s = superior, Latin for "higher") of natural gas is approximately 10 % above the heating value.

moor alongside the dock of the new terminal for the regasification of natural gas delivered in liquid form.[16] By December 31, 2022, about 0.9 billion kWh (H_s) were fed into the German gas grid; as measured by the net imports amounting to 911 billion kWh (H_s), this equaled a share of 0.1 %. According to the current state of planning, additional LNG terminals (8 floating FSRUs and 3 fixed LNG terminals on shore, with a projected total capacity of 73 billion cubic meters, which equals 846 billion kWh, H_s) are to be put into operation so that the contribution of LNG to the natural gas supply ought to increase quite rapidly. When interpreting these figures, it should be kept in mind that part of the FSRUs will be removed and/or dismantled again as soon as the onshore terminals have commenced with their operations.

At the beginning of 2022, the underground storage facilities connected to Germany's natural gas grid were filled up to an average volume of 50 %. With almost 25 %, the lowest filling level was attained in mid-March 2022. Thereafter, the storage facilities were refilled continuously. With the statutory requirement of filling levels for gas storage facilities, operators of such storage facilities in Germany are obligated to safeguard and guarantee minimum filling levels of 75 %, 85 %, and 95 % at the beginning of the months of September, October, and November respectively. These requirements were all met at the respective points in time. In mid-November, the storage facilities attained a filling level of 100 %. Due to partially very low temperatures, the phase of withdrawal began during the first half of December; the stock level dropped to a filling level of 90.1 % by December 31, 2022.

On balance, about 92 billion kWh of natural gas were stored in 2022. For comparison: On balance, more than 55 billion kWh of natural gas had still been withdrawn from storage facilities in 2021.

In 2022, the utilization of natural gas in the individual consumption sectors was characterized by the consequences of the Russian invasion of Ukraine which resulted, for example, in substantially increased prices for energy and/or natural gas and, related thereto, declining consumption. All told, the following trends become apparent for 2022 (please see Table 7):

- Industry's demand, which had still experienced a considerable increase in 2021 in the wake of the economic recovery after having overcome the pandemic year 2020, dwindled by 17.1 % to 274.2 billion kWh in 2022. The outlined decline in industrial natural gas consumption was due, on the one hand, to price-induced substitutions and savings measures but, on the other hand, also due to production cutbacks as a consequence of the high energy prices which particularly affected the energy-intensive economic branches. In some branches, problems with the delivery of urgently required intermediate goods from prepaid suppliers also caused production to be continued at a reduced consumption of natural gas. When interpreting the differentiation of industry's use of natural gas which was selected here, it should be noted that this representation also includes consumption in natural gas fired power plants that generate electricity and heat and are operated by the industrial enterprises themselves as well as the non-energetic consumption of natural gas. Finally, it should be pointed out that by its nature, consumption in the industrial sector is less temperature-dependent, but rather dependent on economic trends (the space heating proportion of natural gas consumption in industry amounted to about 9 % which is why an interpretation of the weather influence is not considered within the scope of this report).

- Natural gas consumption of companies in the trade, commerce, and service sector decreased noticeably as well. In contrast to industry, more than nine tenths (approximately 90.6 %) of the natural gas in this consumption segment are used for space heating purposes. Hence, the milder weather conditions prevailing in 2022 caused the demand for natural gas of the businesses and enterprises in the trade, commerce, and service sector to decrease. Investment as well as attitude, behavior, and price related savings measures reinforced this effect. The overall result shows that the weather, attitude and behavior as well as price induced savings actually overcompensated the increased consumption by the comparably favorable economic trend in this segment (the price-adjusted gross value creation went up by 2.5 % in 2022 when compared to the previous year). All told, a consumption minus of almost

16) Such LNG storage and regasification vessels as the "Höegh Esperanza" are also referred to as "Floating Storage and Regasification Units," abbreviated FSRUs.

Table 7

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Volume and Use of Natural Gas in Germany in 2021 and 2022

	Unit	2021	2022 [1]	Change in %
Domestic Production	Billion kWh	45.8	42.7	-6.6
Imports [2]	Billion kWh	1,510.0	1,306.4	-13.5
Total Volume of Natural Gas	Billion kWh	1,555.8	1,349.1	-13.3
Exports [2]	Billion kWh	693.8	484.1	-30.2
Storage Balance [3]	Billion kWh	55.4	-92.0	-
Domestic Sales of Natural Gas	**Billion kWh**	**917.4**	**773.0**	**-15.7**
Primary Energy Consumption	**Billion kWh**	**917.4**	**773.0**	**-15.7**
	Petajoules (H_i)	**3,303.0**	**2,783.0**	**-15.7**
	Mtce (H_i)	**112.7**	**95.0**	**-15.7**
Structure of Natural Gas Generation by Origin				
Domestic Production [4]	%	5.0	5.5	
Import Quota	%	97.1	96.8	
Structure of Natural Gas Consumption According to Consumer Groups				
Industry (Including Industrial Power Plants)	Billion kWh	331.5	274.2	-17.3
Power Supply (Including CHP Plants)	Billion kWh	111.6	92.9	-16.7
Provision of District Heating and Cooling (Including CHP Plants)	Billion kWh	57.8	47.8	-17.3
Private Households	Billion kWh	288.0	249.2	-13.5
Trade, Commerce, Services	Billion kWh	111.1	102.8	-7.4
Transportation	Billion kWh	1.8	1.9	4.3
Total Sales of Natural Gas	**Billion kWh**	**901.8**	**768.9**	**-14.7**
Self-Consumption	Billion kWh	9.5	14.2	50.0
Statistical Differences	Billion kWh	-6.0	10.2	
Primary Energy Consumption	**Billion kWh**	**917.3**	**772.9**	**-15.7**

1) Preliminary data; some figures are estimates
2) Import and export volumes including all transit volumes
3) Minus = storage; plus = withdrawal
4) Share of domestic natural gas supply

Discrepancies in the totals are due to rounding off

Sources: Federal Statistical Office (Destatis); Federal Association for Natural Gas, Crude Oil, and Geoenergy (BVEG); German Association of Energy and Water Industries (BDEW)

7.4 % can be anticipated in the trade, commerce, and service sector for 2022.

- When it comes to private households (including the housing companies supplying them with space heating and hot water), a significant decline in consumption is to be anticipated as well due to the milder outside temperatures in 2022. Current data indicate a 13.5 % reduction of the natural gas consumption to 249.2 billion kWh for 2022. The decrease in consumption was additionally reinforced, above all, by the considerable increase

in natural gas prices, but without a doubt also by fierce public discussions about necessary savings in the use of natural gas to avert a supply crisis in the aftermath of the war in Ukraine.

- The use of natural gas as a fuel in power plants and heating stations supplying electricity declined, above all, because of the prices (furthermore, the political desire to substitute natural gas in electricity and heat production through hard coal and lignite at short notice in order to be freed from the dependence on Russian gas imports ought to have played an additional role here, too). When it comes to electricity supplied to the general public, a decline in natural gas consumption is to be anticipated in the ballpark of 16.7 %. All told, about 79.8 billion kWh of electricity, which is about 12 % less than during the previous year, were consumed in the gas-fired power plants of electricity suppliers and industrial enterprises and in combined heat and power plants of other electricity producers in 2022.

- Higher temperatures caused the demand for district heat and/or heat extraction to decrease as well. The use of natural gas for the coupled and uncoupled provision of district heat went down by 17.3 % to 47.8 billion kWh in 2022.

- Sales of natural gas (either in compressed form, CNG, or in liquefied form, LNG) to the transportation sector are also likely to have increased by 4.3 % in 2022 so that a consumption level of 1.9 billion kWh will be attained here.

In light of these developments, the proportion of natural gas of the total primary energy consumption decreased by 2.4 percentage points to 24.2 % in 2022 when compared to 2021.

According to initial figures, about 10.4 billion kWh (H_s) of biogas processed to natural gas quality (biomethane) were fed into the German natural gas grid in 2022 – in 2021 as well, it had already been 10.4 billion kWh. Around 8.4 billion kWh of biomethane went into combined power generation, about 1.3 billion kWh were used as a fuel, and another approximately 0.7 billion kWh were sold on the heating market (space heating, hot water). In accordance with the balancing scheme of the AG Energiebilanzen, these quantities are recorded both on the volume side and the consumption side under renewable energy and not under natural gas.

The number of companies active in the gas industry increases continuously. A closer look reveals that in 2022, seven enterprises were active as natural gas producers, 31 as storage operators, 16 as transmission grid operators, 715 as gas distribution grid operators, and 1,038 as distribution companies in the end customer business. In addition, there were 15 gas wholesalers who were also active as balancing group managers.[17]

About 41,400 people and, thus, approximately as many persons as in the year before were employed in companies of the gas industry at the end of 2022.

Since the liberalization of the energy markets, spot and futures markets for natural gas have developed rapidly. All told, gas trading at the European hubs exhibits significant growth. At these virtual trading points, essential supply and demand based price signals are created for the European and, thus, also the German market today. With short-term action gaining increased relevance on spot markets and in other trading centers, a price spread has been in place between the border-crossing prices for crude oil and natural gas since 2010. The price trend for oil no longer plays any role in the development of the procurement costs for gas today.

During the reporting year 2022, the import price for natural gas was significantly influenced by the consequences of the war in Ukraine. Over the course of the year 2022, the import prices for natural gas (in euros per gigajoule) to some extent shot up dramatically after having increased considerably already during the second half of the year 2021. Between 2021 and 2022, the border-crossing price (on an annual basis) increased from € 7.07/GJ (which equals 2.54 ct/kWh) to about € 21/GJ (7.56 ct/kWh); thus, it tripled (+197 %) when compared to the previous year. The annual

17) It is not possible to add up the company figures because many of the companies are active at multiple stages of the value creation chain and are, thus, recorded several times.

average for 2022 was, thus, even significantly above the old peak level which had been attained in 2012 (€ 8.08/GJ or 2.90 ct/kWh).

A glance at the monthly development reveals an even more pronounced picture: Just between January and August 2022 alone, the average price for natural gas imports increased from € 14.09/GJ (5.07 ct/kWh) to € 41.26/GJ (14.85 ct/kWh). This equals a price increase of 193 % (please see Figure 7). At the same time, the import price for August 2022 marked a new all-time high. Until October 2022, the import price dropped once again to a value of € 18.74/GJ (6.75 ct/kWh); however, this was still significantly above the average price level attained in the previous year or above that of April 2022. Based on this high price level, an increase in prices for natural gas imports became apparent once again by the end of 2022. In December 2022, the border-crossing price for natural gas imports attained once again a level of about € 26.10/GJ (9.38 ct/kWh) which equals a price increase of about 85 % when compared to January 2022.

In addition, Figure 11 indicates that the import price for natural gas to some extent decoupled itself significantly from the development of the border-crossing price for crude oil imports during the crisis year 2022, a phenomenon which had been observed to a less pronounced degree in the periods before the start of the war in Ukraine.

Parallel to the import prices for natural gas, the price level for natural gas at the energy exchange (spot market) increased significantly; namely, from € 47.09/MWh to € 126.60/MWh (+169 %).[18]

The development of import and wholesale prices, i. e. costs for the procurement of natural gas, has different effects on domestic sales prices. Varying procurement periods for diverse customer groups typically result in diverging price trends on the end consumer market. In addition, the relative price changes for bulk consumers are higher because of the lower overall price level.

Against the backdrop of the drastic increase in import and wholesale prices for natural gas over the course of the year 2022 (with price peaks in the spring and

Figure 7

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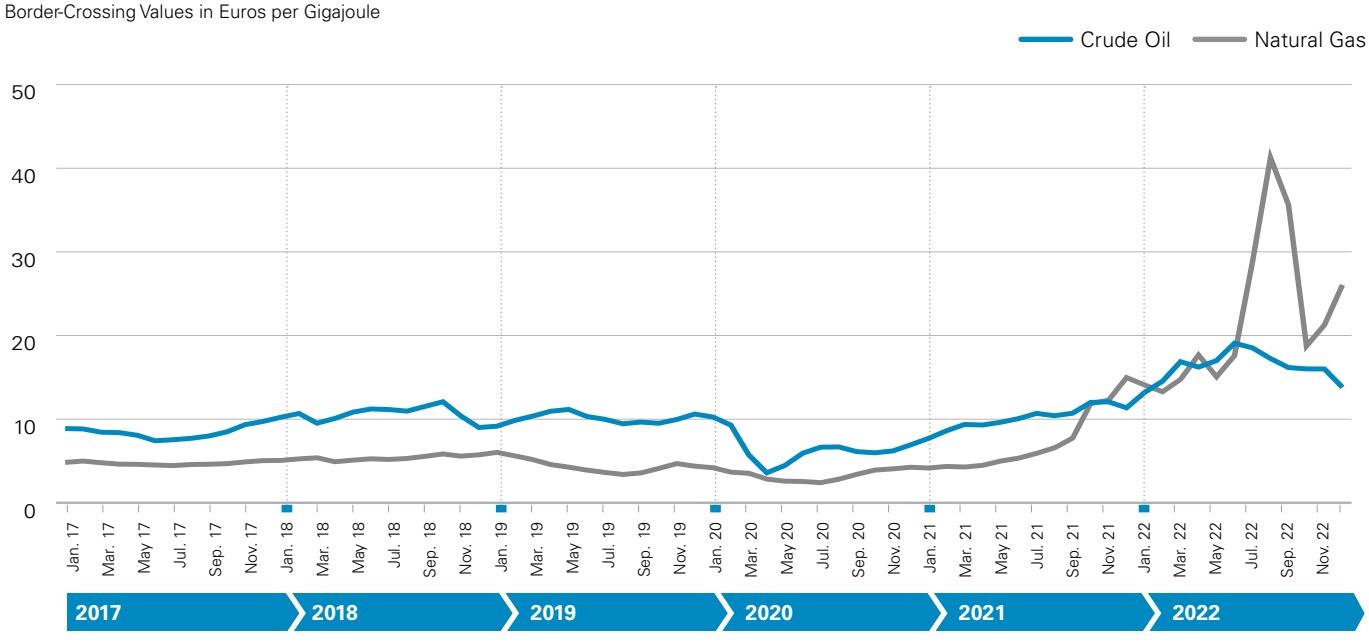
Monthly Border-Crossing Values for Crude Oil and Natural Gas between 2017 and 2022



Source: Federal Office of Economics and Export Control (BAFA)

18) Average value taken from the daily reference prices of the market areas Gaspool, NCG, and TTF; for more details, please see the BDEW Gaspreisanalyse [Gas Price Analysis] (last update: December 2022) (currently only available in German).

late summer), the end customer prices and/or sales prices to consumers also increased substantially over the course of the year; albeit to a different extent. For example, it was above all the sales prices to power plants and industrial clients which reached new record highs until September 2022. While the price observed for power plant gas doubled between January and September 2022 (+113 %), prices for industrial clients increased by about 88 % over the same period of time.[19] Similar to the import price for natural gas, price peaks for such bulk purchasers as power plants and industry over the course of the year 2022 actually occurred in September.

When interpreting the price trend for industrial clients, it should be noted that the purchase prices for large industrial clients (annual supply of more than 500 GWh) increased by about 176 % compared to the previous year because natural gas had to be procured at shorter notice; for small industrial gas consumers (supply of 11.63 GWh/a), the prices actually doubled (price increase 2021/2022: +106 %).

Due to early procurement, the gas prices for the trade, commerce, and service sector increased underproportionately compared to the bulk purchasers (industry, power plants) considered so far; namely, by almost 85 %. For private households, an average increase in prices of approximately 78 % was observed in 2022 when compared to the previous year (please see Figure 8).

Figure 8

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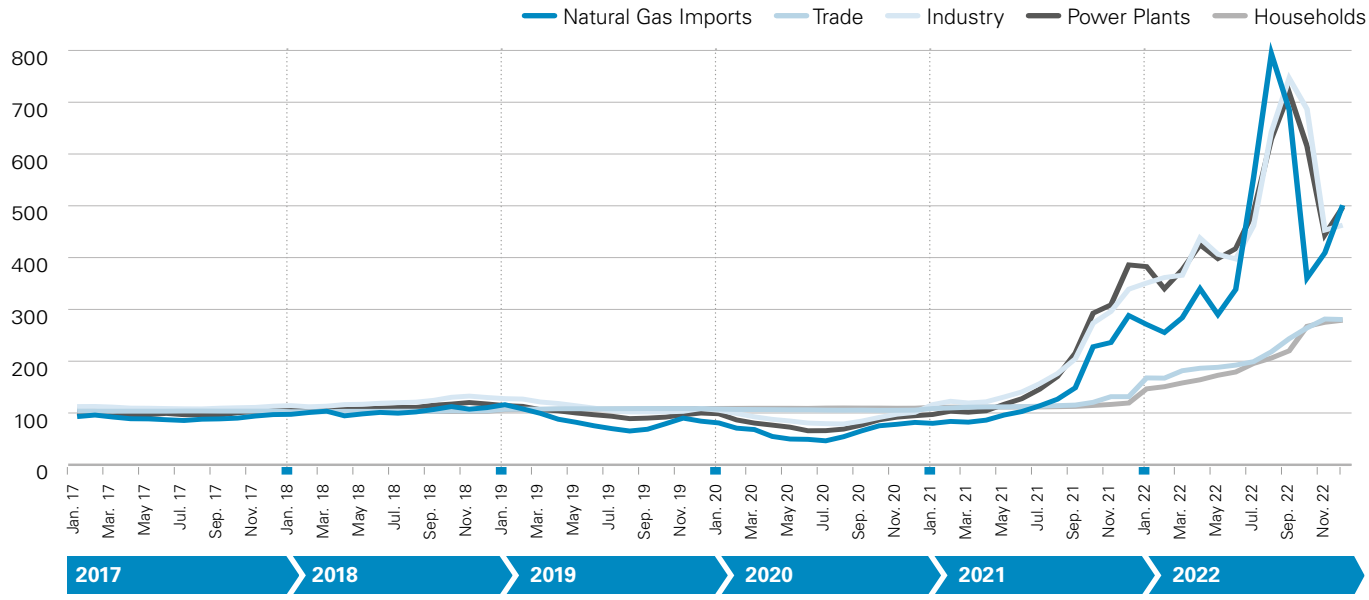
Prices for Natural Gas Imports and Natural Gas Sales in Germany between 2017 and 2022

January 2010 = 100 (Basis of Producer Price Indices 2015 = 100)



Sources: Federal Office of Economics and Export Control (BAFA); Federal Statistical Office (Destatis)

19) Also based on the annual average, sales prices for natural gas to power plants as well as to industrial clients went up dramatically between 2021 and 2022. For industrial clients, this resulted in a price increase of 163 %; for power plants, the increase amounted to about 164 %.

Hard Coal

According to preliminary estimates and compared to the previous year, Germany's primary energy consumption based on hard coal increased once again in 2022 – by 4.0 % to 1,156 PJ (39.4 Mtce) (please see Table 8). Thus, the continuous downward trend, which had previously persisted for many years, had been interrupted by an increase in 2021 which was continued also in 2022. In contrast to 2021 (due to increases in prices for other energy carriers and due to the weather, less electricity coming from regenerative energy carriers had been fed into the grid), though, last year's increase was caused, above all, by the direct consequences of the war in Ukraine and, in part, also by the strengthening economic recovery after the pandemic. Towards this end, hard coal benefited particularly in the power industry from a declining power supply based on natural gas. An additional factor was the structure-related decline in electricity production from nuclear energy which particularly promoted the generation of electricity in hard coal fired power plants.

Correspondingly, the use of hard coal in power plants supplying the general public and in industrial power plants generating electricity and heat increased by more than 16 % to 595 PJ (which translates into 20.3 Mtce).

According to data released by the German Association of the Energy and Water Industries (BDEW) in its quick statistics and in comparison to the respective months of the previous year (based on normal working days), hard coal gained additional shares in power generation almost over the entire course of the year 2022, in part with high two-digit growth rates, in August even three-digit increases (+102.0 %). Only the months of October (-19.9 %) and November (-16.9 %) were characterized by declining growth rates. It is particularly worth mentioning in this context that in order to avert a gas emergency and to prevent an electricity supply crisis, hard coal fired power plants were taken from the reserve as of the summer of 2022 which had already been decommissioned and/or which had been earmarked for decommissioning before.

In contrast, the use of hard coal in the steel industry declined slightly by 2.2 % in 2022 and fell back to

Table 8

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Volume and Use of Hard Coal in Germany in 2021 and 2022

	2021		2022 [1]		Change
	PJ	Mtce	PJ	Mtce	in %
Primary Energy Consumption	**1,112**	**37.9**	**1,156**	**39.4**	**4.0**
Power Plants and Thermal Power Stations	512	17.5	595	20.3	16.2
Steel Industry [2]	545	18.6	534	18.2	-2.2
Other Sectors [3]	52	1.8	47	1.6	-10.5
Stat. Differences	-2	-0.1	20	0.7	-
Hard Coal Production	**0**	**0.0**	**0**	**0.0**	**0.0**

1) Preliminary data
2) Coke converted to coal, including coking plant
3) Other industrial sectors including non-energy consumption and other heating market (private households; trade, commerce, and service sector; district heating plants); stat. differences

Discrepancies in the totals are due to rounding off

Sources: German Coal Importers Association (VDKi); The German Coal Industry's Statistical Office; bsn - Industry Association for Hard Coal and Post-Mining

Table 9

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German Hard Coal Imports[1] According to Supplier Countries in 2021 and 2022 (January to December)

	2021	2022 [2]	Change	2021	2022
	in Million Tons		in %	Proportions in %	
Poland	1.6	1.6	0.0	3.9	3.6
Czech Republic	0.3	0.2	-33.3	0.7	0.5
Russia	20.5	13	-36.6	49.9	29.3
South Africa	1	3.9	290.0	2.4	8.8
USA	7.1	9.4	32.4	17.3	21.2
Canada	1.3	0.9	-30.8	3.2	3.0
Columbia	2.3	7.2	213.0	5.6	16.2
Australia	5.5	6.3	14.5	13.4	14.2
Other EU Countries	1.5	1.9	28.6	3.6	4.1
Total Imports	**41.1**	**44.4**	**8.0**	**100.0**	**100.0**

1) Including coke imports; coke converted into coal
2) Preliminary information

Sources: German Coal Importers Association (VDKi); The German Coal Industry's Statistical Office; Federal Statistical Office (Destatis)

534 PJ (18.2 Mtce). This was primarily attributable to the reduced production of oxygen steel which decreased by 8.2 % to almost 25.9 million tons. Crude iron production went down as well; namely, by 7.6 % to about 23.7 million tons. This information was derived from data released by the German Steel Federation (WV Stahl).

The use of hard coal in foundries, district heating plants, small businesses, and private households is summarized under the label "heating market" in this report; in terms of volume, it rather played a subordinate role. Compared to the previous year, hard coal consumption in the heating market dropped by 10.5 % to 47 PJ (1.6 Mtce). This reduction was partially due to supply bottlenecks caused by the discontinuation of Russian supplies that could not be covered otherwise.

After the termination of domestic hard coal mining at the end of 2018, the volume side of Germany's hard coal market has been sourced merely from imports and existing stocks. According to preliminary data derived from the foreign trade statistics of the Federal Statistical Office and compared to the previous year, Germany's hard coal imports increased by 8 % to 44.4 million tons in 2022. Converted into a lump sum (without considering the actual heating values), this value equals imports amounting to more than 38 Mtce. Of this figure, 67.0 % accounted for power plant coals, 25.9 % for coking coals, 1.9 % for anthracite coals and briquettes as well as 5.2 % for hard coal coke.

The hard coal embargo issued by the EU against Russian exports scheduled a transitional period of 120 days as of April 2022. Accordingly, imports of Russian hard coal to the EU were initially permitted if and to the extent that the underlying supply contracts for coal were concluded before April 9, 2022. As of August 11, 2022, the EU embargo against Russian hard coal entered into full force and effect. Additional hard coal imports from Russia to the EU were now strictly forbidden. But even thereafter, i. e. during the period between September and December 2022, the Federal Statistical Office still recorded imports in its monthly reports that were declared with "country of origin: Russia." These volumes were imported to Germany from neighboring EU countries (above all, the Netherlands and Belgium) and came, in particular, from storage sites of the Northwest European coal terminals (in Amsterdam, Rotterdam, and Antwerp =

ARA ports). This Russian coal had already been stored there within the EU before August 11, 2022, which is why it did not fall under the embargo.

With the EU embargo in mind, coal importers imported quantities of Russian hard coal (and hard coal coke) to the extent that was permitted by virtue of the respective contracts and coal logistics. Thus, a total of about 13 million tons of coal (11.7 million tons of power plant coal, 0.8 million tons of coking coal, 0.5 million tons of anthracite coal and briquettes as well as almost 68,000 tons of hard coal coke) made their way from Russian production sites to Germany. This equaled an approximate share of 29 % in Germany's total hard coal imports (including hard coal coke). As had already been the case in the previous years, Russia thus continued to be the most important country of origin for German hard coal imports also in 2022. Compared to the previous year, hard coal imports from Russia decreased by 36.6 % (please see Table 9).

In contrast, considerable increases were recorded for imports from the United States, Columbia, Australia, and South Africa. That is why these countries, when it comes to German hard coal imports, ought to have benefited most from the shortfalls in the delivery of Russian coal. In a sectoral breakdown according to the individual coal types, Russia was the dominating supplier country with a share of 70 % for power plant coals, 62 % for anthracite coals, and 56 % for hard coal briquettes. About half of the German coking coal imports came from Australia and only almost 7 % (about 0.8 million tons) from Russia. With a share of 63 %, most of the hard coal coke was imported from Poland. Here, Russia accounted for a share of only 3 %. On the markets for power plant coals, coking coals, and hard coal coke, it was possible to successfully cushion the Russian delivery failures by additional supplies from other countries of origin. For anthracite coals and briquettes, though, substantial bottlenecks and undersupplies of the market became apparent which caused the respective price levels to multiply.

In 2022, the development of the global hard coal industry was also influenced by the high Asian demand and massive shifts in the global flow of supplies. According to initial estimates of the German Coal Importers Association (VDKi), global hard coal production ought to have increased by 7.2 % to almost 7.9 billion tons when compared to the previous year; this would be the highest volume of hard coal ever produced to date on the entire globe.

The People's Republic of China continued to assume the top position in global production also last year; its production volume increased by 463 million tons to nearly 4.5 billion tons. Thus, China alone accounted for a share of 57 % in the global production. In 2021, China had been temporarily struggling with supply bottlenecks on local domestic coal markets. The Central Government had responded with comprehensive programs designed to increase production which already began to bear fruit in 2022. India was also able to significantly increase its coal production (+84 million tons); with a production volume of 850 million tons, it reached second place in the international ranking. Other production countries that are worth mentioning in this context included Indonesia (539 million tons), the United States (482 million tons), Russia (431 million tons), and Australia (375 million tons).

About 14 % of the global production was distributed through maritime trade; the majority was used in the producer countries. In addition, a smaller portion accounted for domestic trade particularly with neighboring countries and included cross-border transports via inland navigation vessels and/or via rail transports. Compared to the previous year, maritime trade increased by 1.8 % to about 1.1 billion tons. Of this amount, 892 million tons (80 %) accounted for power plant coal and 227 million tons (20 %) for coking coal. The most important exporting countries in maritime trade were Indonesia with 362 million tons, Australia with 329 million tons, and Russia with 165 million tons. Together, these countries attained a proportion of 76.5 % of the entire global seaward hard coal trade. In the maritime trade of 2022, the highest increases in exports when compared to the previous year were attributable to Indonesia (+18 million tons) and South Africa (+7 million tons). The highest declines in exports, however, had to be suffered by Australia (-37 million tons) and Russia (-11 million tons).

Over the course of the year 2022, the price quotations for power plant coal, coking coal, and hard coal coke attained record highs that had never been reached before. Based on an already relatively high level of almost US-$ 121/t free at Northwest European ports (cif ARA), the weekly rate quoted for power plant coal increased to an all-time high which significantly

exceeded US-$ 400/t cif ARA in late July. Already in mid-March, the weekly rate quoted for Australian coking coal from the port of loading (fob) had also increased to an all-time high amounting to more than US-$ 650/t fob. Over the further course of the year, the price for power plant coal decreased continuously and was quoted below US-$ 190/t at the end of the year. The price for Australian coking coal also dropped over the course of the year; in early August, it amounted to slightly over US-$ 200/t fob. But thereafter, the price for coking coal started to increase again and escalated to a level of almost US-$ 280/t fob at the end of the year. Hard coal coke free Northwest European ports was traded on a monthly basis at US-$ 709/t cif ARA in April 2022. This also represented an all-time high. In contrast, the monthly quotation for hard coal coke cif ARA dropped sharply by the end of the year and leveled out at US-$ 332/t cif ARA, which was still a relatively high level particularly when compared to the preceding years.

The seafreight rates also increased substantially in 2022, particularly during the second quarter of the year; albeit far removed from their all-time highs. In May 2022, for example, freight in the Panamax ship from the US Gulf Coast to the ARA ports cost almost US-$ 31/t and in the Capesizer from Richards Bay in South Africa to the ARA ports about US-$ 29/t. With almost US-$ 15/t, for instance, a Capesizer transport from Puerto Bolivar in Columbia into the ARA region reached the annual peak on a monthly basis in July 2022.

Figure 9 conveys an indication of the long-term price trend for power plant coals also in comparison to the changes experienced by crude oil. The import price for steam coals[20] went up from almost US-$ 140/tce (annual average 2021) to approximately US-$ 338/tce in 2022. The import price for steam coals amounted to US-$ 195/tce in January 2022 and increased to almost US-$ 453/tce in July 2022. After this all-time high, the price for steam coals dropped once again during the second half of the year and reached a level of US-$ 265/tce by the end of the year.

Figure 10 shows the import prices for hard coal coke and coal from third countries (power plants and steel producers). The overall picture reveals that the import prices for steam coals and power plant coals had experienced a significant increase already during the

Figure 9

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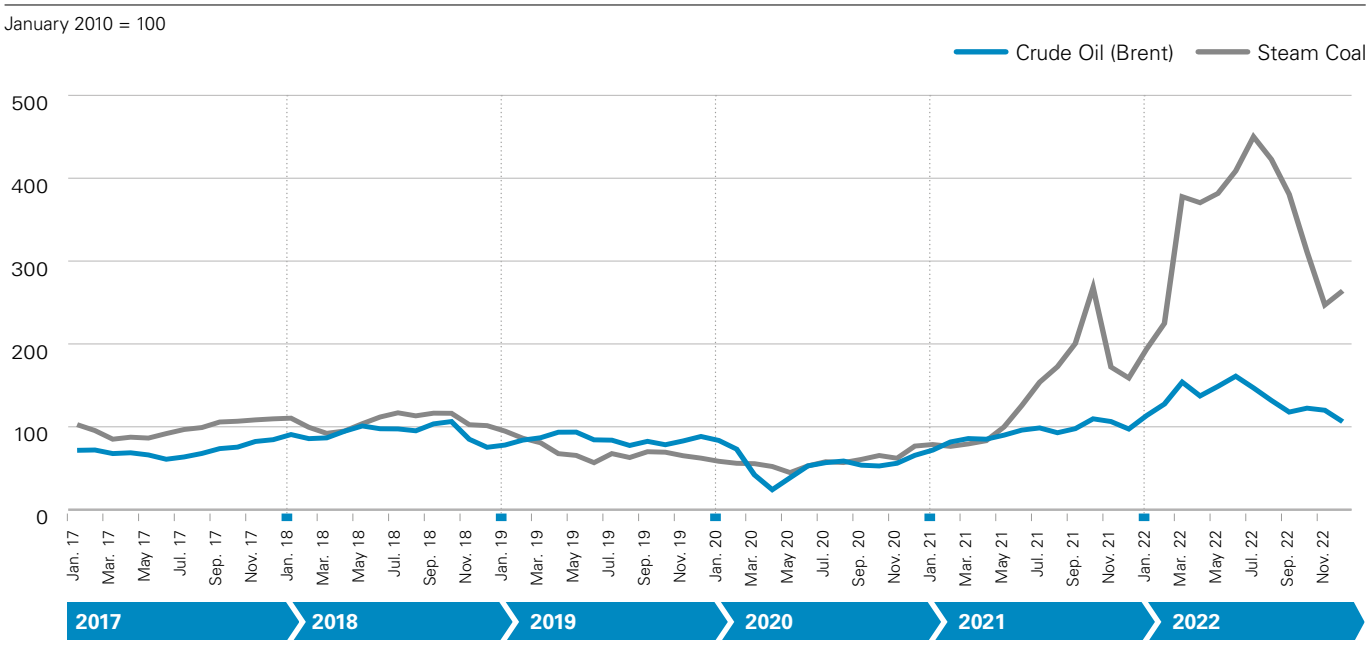
Global Market Prices for Crude Oil (Brent) and Steam Coal between 2017 and 2022

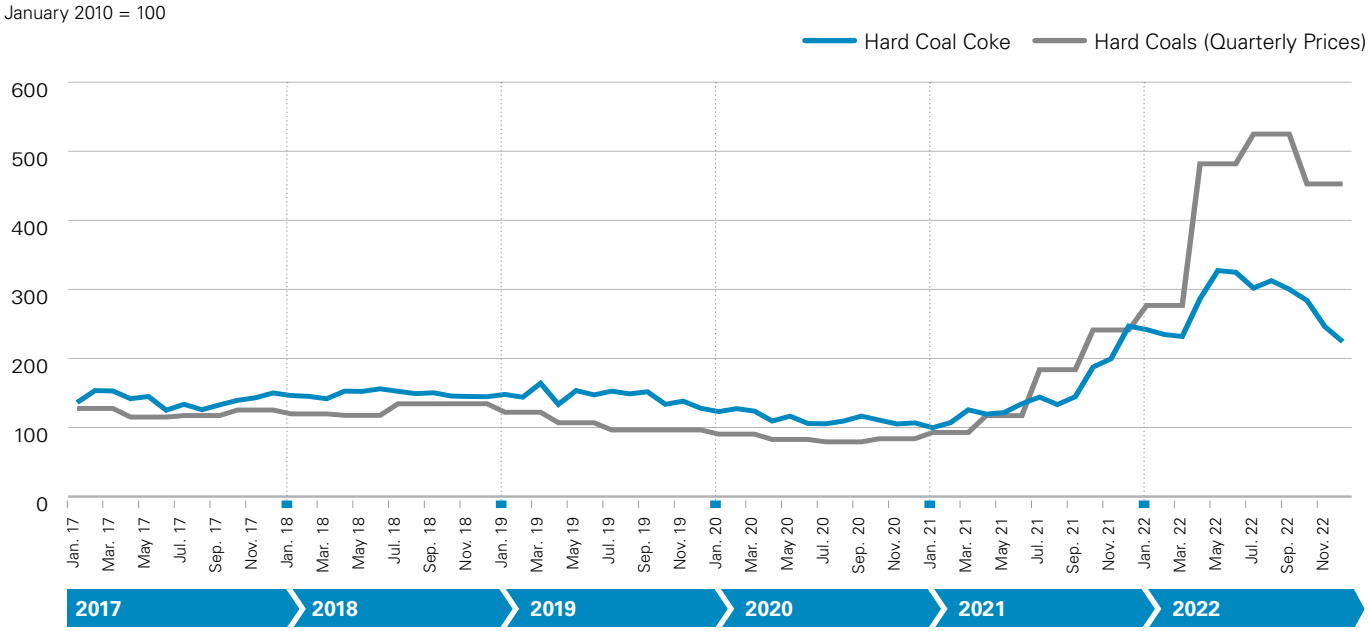


Sources: German Coal Importers Association (VDKi); en2x - Fuels & Energy Business Association

20) Spot price for power plant coals NWE; average over the weekly quotations according to the MCIS Steam Coal marker; expressed in US-$/tce; cif ARA.

Figure 10

Development of Selected Hard Coal Import Prices between 2017 and 2022



Sources: German Coal Importers Association (VDKi); Federal Office of Economics and Export Control (BAFA); Federal Statistical Office (Destatis)

second half of the year 2021. After the invasion of Ukraine by Russian troops on February 24, 2022, the import price for hard coal coke skyrocketed; in May/June 2022, it reached a level of almost € 600/t after it had still amounted to almost € 443/t in January 2022. With more than US-$ 394/tce during the third quarter of 2022, the import price for hard coal (steam coal) also attained a new record high. For comparison: During the third quarter of 2021, the import price for this energy carrier had still amounted to about US-$ 138/tce which was about 65 % below the record value reached during the third quarter of 2022.

Lignite

With about 130.8 million tons (40.7 Mtce) in 2022, lignite production as a whole was 3.5 % above the previous year's yield. When compared to the average over the past five years, however, a significant downward trend becomes apparent. Production developed quite differently in the individual mining districts: Whereas approximately 4 % more lignite was produced in the Rhineland area and in Lusatia, lignite production in Central Germany (+1 %) remained relatively constant. This change generally corresponds to the development of deliveries to power plants supplying the general public (a total of 116.9 million tons; +4.8 %) which receive around 90 % of the production. Power generation based on lignite in Germany increased from 110 TWh in the same period last year to approximately 116 TWh in 2022. Lignite's share in power generation amounted to about 20 % in 2022.[21]

Due to the decommissioning of the lignite-fired power plant units Neurath B, Niederaußem C, and Weisweiler E in the Rhineland area by December 31, 2021, pursuant to the German Coal-Fired Power Generation Termination Act (KVBG), a total of 900 MW less lignite-fired power plant capacity was available at the beginning of the year 2022. April 2022 marked the decommissioning of another power plant unit (Neurath A) with a capacity of 300 MW. Nevertheless, lignite-fired power plants were able to make an indispensable contribution towards a secure and reliable electricity supply in Germany in 2022. As a consequence of the Russian war of aggression against Ukraine, the wholesale prices for gas and, thus, also the electricity prices increased considerably. The German Act on the Provision of Substitute Power Plants to Reduce Gas Consumption in the Electricity Sector (Substitute Power Plants Maintenance Act, EKBG) paved the way towards the establishment of a replacement gas reserve. Since October 1, 2022, coal-fired power plants which had been in the standby mode for backup purposes have been part of the newly created supply reserve. These power plants have the opportunity of participating in the market for a limited period of time while the alert state or emergency state of the emergency plan for gas is in effect as well as on the basis of the German Ordinance on the Retrieval of Supply Reserves (VersResAbV) until June 30, 2023. Moreover, the electricity that was not produced by those nuclear power plants which had been shut down at the end of 2021 had to be compensated as well.

At the same time, the Ministry of Economic Affairs, Industry, Climate Action, and Energy of the State of North Rhine-Westphalia mutually agreed with Germany's Federal Ministry for Economic Affairs and Climate Action as well as the RWE AG corporation upon key points designed to implement the fossil fuel phase-out in North Rhine-Westphalia already in 2030, i. e. eight years ahead of the original time schedule. Furthermore, the agreement takes into account that a secure and reliable energy supply is to be safeguarded and assured also in times of crisis to the extent that the additional power plant capacity mentioned above initially remains in the market and that sufficient production volumes are safeguarded and assured in the upcoming months and years.

The manufacture of refined products based on lignite as a whole decreased by almost 4 % to more than 5 million tons. After the briquette factory in Frechen had been shut down in accordance with the German Coal-Fired Power Generation Termination Act (KVBG),[22] briquette production went down by 20 %.[23] The change in production amounted to +2 % for pulverized coals, +6 % for fluidized bed coals, and -8 % for coke.

With 40.7 Mtce (1,193 PJ), the contribution of lignite to domestic energy production amounted to about 33 %. Lignite, thus, continues to be an important domestic energy carrier.

21) Additional data on lignite can be found at: https://kohlenstatistik.de/ (currently only available in German).
22) KVBG – Act on the Reduction and Termination of Coal-Fired Power Generation and on the Amendment of Other Acts (Coal Phase-Out Act).
23) In the course of the fossil fuel phase-out, RWE Power stopped the production of briquettes according to plan: https://www.rwe.com/presse/rwe-power/2022-12-22-rwe-power-stellt-brikettherstellung-ein/ (download date: 2023-03-10; currently only available in German).

Table 10

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Volume and Use of Lignite in Germany in 2021 and 2022

	Unit	2021	2022 [1]	Change in %
1. Domestic Raw Lignite				
Total Lignite Production	**Million Tons**	**126.3**	**130.8**	**3.5**
	Mtce	**39.3**	**40.7**	**3.5**
	PJ	**1,153.2**	**1,192.8**	**3.4**
2. Foreign Trade				
Total Imports	1,000 tce	25.5	30.5	19.8
Total Exports	1,000 tce	896.8	898.5	0.2
Foreign Trade Balance	1,000 tce	-871.4	-868.0	-
3. Primary Energy Consumption				
	Mtce	38.5	39.8	3.4
	PJ	1,130	1,168	3.4
4. Sales				
Total Sales	**Million Tons**	**112.2**	**117.7**	**4.9**
to Power Plants Supplying the General Public	Million Tons	111.5	116.9	4.8
to Other Customers	Million Tons	0.7	0.8	13.2
Use for Refinement	Million Tons	11.9	11.5	-3.9
Use in Lignite-Fired Power Plants	Million Tons	2.0	1.7	-14.9
Change in Stocks	Million Tons	0.1	-0.1	-
5. Electricity Production from Lignite				
Power Plants Supplying the General Public	Billion kWh	106.8	113.4	6.2
Industrial Power Plants	Billion kWh	3.3	2.8	-14.0
Total Electricity Production from Lignite	**Billion kWh**	**110.1**	**116.2**	**5.6**

1) Preliminary data; some figures are estimates

Discrepancies in the totals are due to rounding off

Source: The German Coal Industry's Statistical Office

With 39.8 Mtce (1,168 PJ), lignite-based primary energy consumption was more than 3 % higher than the previous year's result. Lignite, thus, met approximately 10 % of the entire domestic demand for energy (please see Table 10).[24]

With a total consumption of about 2.5 Mtce in 2022, the final energy sectors used approximately 1 % more lignite and lignite products than in the previous year (please see Table 11). When it comes to industry, the use of lignite increased by more than 4 % while sales to private households (not least also because of the weather) declined by about 16 % (please see Table 11).

At the end of 2022, the number of employees working in the German lignite industry amounted to 17,216 people. This figure includes 1,046 apprentices and 3,822 employees who worked in the lignite companies' power plants supplying the general public. Employment statistics listed 7,676 employees in the Rhineland District, 7,675 in Lusatia, and 1,827 in Central Germany. After the end of coal mining and after the end of the power plant Buschhaus's standby mode for backup purposes, only 38 employees still worked on behalf of the lignite industry in the Helmstedt District.

Table 11

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Lignite Balance for Germany in 2021 and 2022
in 1,000 tce

		2021	2022 [1]	Change
				in %
	Domestic Production	39,349	40,701	3.4
+	Imports	25	31	19.8
=	**Volume**	**39,374**	**40,731**	**3.4**
+/–	Change in Stocks (Reduction: +, Replenishment: -)	-18	8	-
–	Exports	897	898	0.1
=	**Primary Energy Consumption**	**38,459**	**39,841**	**3.6**
–	Use in Power Plants	35,265	36,812	4.4
–	Other Conversion Input	4,180	3,948	-5.6
+	Conversion Output	3,979	3,919	-1.5
–	Consumption during Production and Conversion as well as Non-Energetic Consumption	496	480	-3.3
=	**Final Energy Consumption**	**2,496**	**2,521**	**1.0**
	Industry	2,071	2,163	4.4
	Households, Trade, Commerce, Services, Concessionary Coal	425	358	-15.8

1) Preliminary data; some figures are estimates

Source: The German Coal Industry's Statistical Office

24) Deviations from Table 1 due to minor variations in data statuses and rounding-off differences.

The Electric Power Industry

In 2022, the electric power industry was characterized by the overall weakening economy and the milder weather, but primarily also by the consequences of the war in Ukraine which became apparent through drastic increases in energy prices on wholesale markets and for final consumers. The consumption of electric power (gross domestic electricity consumption) decreased by 3.4 % to 549.2 billion kWh. Correspondingly, power generation (gross electricity production) also recorded a minus of 1.7 % and Germany's surplus obtained from electricity exchanges increased by 9.5 billion kWh to 28.1 billion kWh.

The electric power generation mix in 2022 was, above all, influenced by the weather and by price effects. Favorable weather conditions helped generate large amounts of wind power primarily during the first two months of the year. All told, this resulted in an increase of 9.3 % to 125.3 billion kWh. Electricity production from photovoltaics was able to grow by almost one fifth to 60.8 billion kWh when compared to the previous year. Electricity production from renewables as a whole increased by 8.6 % to 254.0 billion kWh. Their share in gross electricity production, thus, amounted to 44.5 % in 2022. The proportion of renewables in relation to gross electricity consumption – the decisive ratio for renewables to achieve their targets[25] – amounted to 46.2 %. With a total electricity production of more than 125 billion kWh, wind energy continued to be the most important energy carrier in the German electricity mix, ahead of lignite with 116 billion kWh (please see Table 12).

In 2022, lignite-fired power plants generated a total of 116.2 billion kWh of electricity. This equals a production plus of 5.5 % when compared to the previous year. A net power plant capacity of 18,502 MW was installed at the end of the year; however, 176 MW of which were decommissioned as per December 31, 2022, so that the installed capacity amounted to 18,326 MW at the beginning of the year 2023. This figure includes 1,886 MW of power plant capacity from the standby mode of lignite for backup purposes which return to the electricity market for a limited period of time.

With 64.4 billion kWh in 2022, hard coal fired power plants also delivered more electricity than in the previous year; their electricity production increased by 18.0 %. By the end of the year, the installed capacity of hard coal fired power plants amounted to 18,461 MW. With the Substitute Power Plants Maintenance Act (EKBG), which entered into force in July 2022, Germany's Federal Government created the possibility for coal-fired power plants to return to the electricity market and/or remain in the electricity market. That is why more than one third of the installed capacity are provided by power plants which are in the grid reserve or which return to the electricity market from the grid reserve for a limited period of time and/or whose decommissioning, which had initially been agreed upon within the scope of the fossil fuel phase-out, was suspended on a temporary basis in 2022.

In 2022, an expected total of 79.8 billion kWh of electricity were generated from natural gas in the power plants of electricity suppliers and in the power plants of industrial enterprises as well as in the combined heat and power plants of other electricity producers. Thus, electricity production from natural gas went down by a total of 11.6 %. It was, in particular, the considerable increase in spot market prices which had gas-fired power plants forfeit their competitive edge over coal-fired power plants despite the fact that the prices for CO_2 also went up significantly during the second half of the year, which caused gas-fired power plants to be increasingly forced out of the market. There is also the expectation that gas ought to be used in power plants only if and when electricity or decoupled heat cannot be provided by any other types of energy. The indicators which are typically used for measuring the contribution margin of power plants in a specific market environment (fuel prices, CO_2 price, EEX spot market price, degree of efficiency) are the so-called "clean spark spread" (gas-fired power plants) as well as the "clean brown

25) https://ag-energiebilanzen.de/wp-content/upload/2022/03/et_2022_04_Kramer_Maassen.pdf (currently only available in German).

Table 12

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Gross Electricity Production in Germany between 1990 bis 2022 According to Energy Carriers

	1990	2017	2018	2019	2020	2021	2022 [1]	2021/ 2022	1990/ 2022
	in Billion kWh							Average Annual Change in %	
Lignite	170.9	148.4	145.6	114.0	91.7	110.1	116.2	5.5	-1.2
Hard Coal	140.8	92.9	82.6	57.5	42.8	54.6	64.4	18.0	-2.4
Nuclear Energy	152.5	76.3	76.0	75.1	64.4	69.1	34.7	-49.8	-4.5
Natural Gas	35.9	86.0	81.6	89.9	94.7	90.3	79.8	-11.6	2.5
Mineral Oil	10.8	5.5	5.1	4.8	4.7	4.6	4.4	-3.4	-2.8
Renewables	19.7	215.7	223.3	241.6	251.5	233.9	254.0	8.6	8.3
Other	19.3	27.5	27.3	25.4	24.8	24.5	23.8	-2.8	0.7
Gross Electricity Production	**549.9**	**652.3**	**641.4**	**608.2**	**574.7**	**587.1**	**577.3**	**-1.7**	**0.2**
Electricity Flows from Foreign Countries	31.9	27.8	31.7	40.1	48.0	51.7	49.6	-4.2	1.4
Electricity Flows into Foreign Countries	31.1	80.3	80.5	72.8	66.9	70.3	77.7	10.5	2.9
Foreign Electricity Exchange Balance	0.8	-52.5	-48.7	-32.7	-18.9	-18.6	-28.1	-	-
Gross Electricity Consumption	**550.7**	**599.8**	**592.7**	**575.5**	**555.8**	**568.5**	**549.2**	**-3.4**	**0.0**
Change versus Previous Year in %	*X*	*0.2*	*-1.2*	*-2.9*	*-3.4*	*2.3*	*-3.4*		
	Structure of Gross Electricity Production in %								
Lignite	31.1	22.7	22.7	18.7	16.0	18.8	20.1		
Hard Coal	27.7	14.2	12.9	9.4	7.5	9.3	11.2		
Nuclear Energy	25.6	11.7	11.8	12.3	11.2	11.8	6.0		
Natural Gas	6.5	13.2	12.7	14.8	16.5	15.4	13.8		
Mineral Oil	2.0	0.8	0.8	0.8	0.8	0.8	0.8		
Renewables	3.6	33.1	34.8	39.7	43.8	39.8	44.0		
Other	3.5	4.2	4.2	4.2	4.3	4.2	4.1		
Gross Electricity Production	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**101.0**	**100.0**		

1) Some figures are preliminary and estimates

Discrepancies in the totals are due to rounding off

Sources: German Association of Energy and Water Industries (BDEW); The German Coal Industry's Statistical Office; Working Group on Energy Balances (AGEB); Federal Statistical Office (Destatis); Working Group on Renewable Energies-Statistics (AGEE-Stat) (for renewables)

Figure 11

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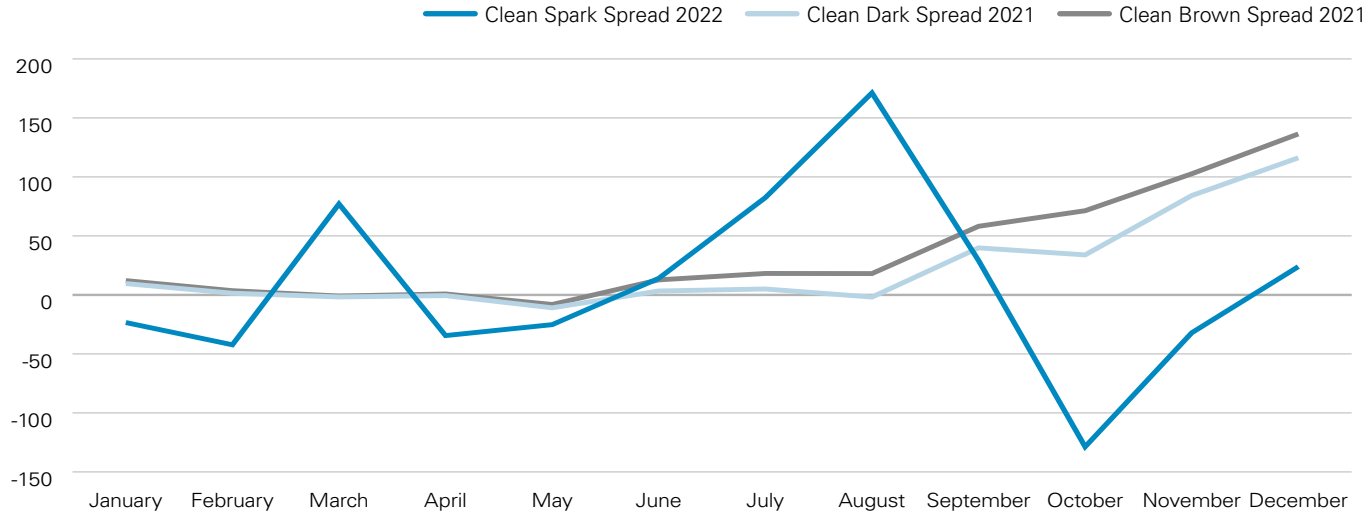
Profit Situation of Different Power Plant Types

2022, in EUR/MWh (Existing Power Plants)



Sources: Our own calculations in line with the Federal Statistical Office (Destatis), EEX, and The German Coal Industry's Statistical Office

spread" (lignite-fired power plants).[26] Figure 11 shows the changes in the profit situation of coal-fired power plants in relation to natural gas fired power plants over the course of the year 2022.

Compared to the previous year, the installed capacity of gas-fired power plants increased due to new installations by more than 1,000 MW to 31,187 MW in 2022; however, 1,382 MW of which are currently in the grid reserve. Another 1,056 MW are in the capacity reserve which is why they are not active in the electricity market.

During the reporting year, Germany's nuclear power plants generated 34.7 billion kWh of electricity which was about 50 % less than in the previous year. This reduction was due to the completed shutdowns of the nuclear power plant units Grohnde, Brokdorf, and Gundremmingen with a combined capacity of 4,058 MW. Thus, the installed capacity of nuclear energy went down from 8,113 MW to 4,055 MW at the beginning of the year. With the amendment of the Atomic Energy Act, the German Federal Government created the possibility of operating the remaining three nuclear power plant units Neckarwestheim 2, Isar 2, and Emsland three and a half months longer than had initially been planned so as to secure and assure a sufficient supply of electricity. That is why a small portion of the potentially remaining production volume will not be generated in 2022 but will instead be implemented by April 15, 2023.

Wind energy continued to be the most important renewable energy source in Germany. With 100.2 billion kWh, onshore wind turbines produced 11.0 % more electricity than in 2021. Offshore wind turbines with a total output of 25.1 billion kWh supplied slightly more electricity than had been the case in the previous year (+3.1 %). According to preliminary figures, the installed capacity of wind energy on shore increased by more than 1,800 MW to currently about 57,900 MW in 2022. At sea, a new offshore wind farm with a capacity of almost 342 MW was connected to the grid in 2022. The installed capacity, thus, amounted to 8,116 MW. The next expansion phase for wind energy off shore will follow between the years 2023 and 2025.

With 60.8 billion kWh, photovoltaic systems supplied significantly more electricity than in the previous year (+23.2 %). This amount of electricity includes not only the electric power fed into the grid supplying the general public, but also the plants' own in-house

26) The calculation of "clean spreads" represents an approximation of the costs incurred from the conversion of fuels into electric power while also taking the CO_2 costs into account. Consequently, this indicator helps assess whether the production in the individual type of power plant under review will be profitable with regard to the specific market situation or whether the production should be limited and/or suspended. The "clean spreads" shown herein were ascertained with the help of average degrees of efficiency in the existing power plant pool, which means that they do not refer to the competitive situation of any single plants or new plants.

consumption on site. According to preliminary calculations, an additional photovoltaic capacity of almost 7,100 MWp was newly installed in 2022; thus, the total capacity installed at the end of the year amounted to approximately 65,800 MWp. Hence, the installation of new photovoltaic capacities reached the highest level since 2012 when a photovoltaic capacity of nearly 8,200 MWp had been newly installed.

According to preliminary data, 44.6 billion kWh of electricity were produced from solid, liquid, and gaseous biomass (including landfill gas, sewage gas as well as sewage sludge) in 2022; this equals a slight increase of 0.7 %. With the proportionate volume produced in waste-fired power plants (from biogenic waste), a total of 5.0 billion kWh of electricity were produced from biogenic energy sources in Germany in 2022.

Electricity production from hydropower decreased by 11.2 % to 17.5 billion kWh in 2022. The decline was due to the amount of precipitation which was significantly lower in the reporting year when compared to 2021. Electricity production in hydroelectric power plants was, thus, even below the level of the year 2018 which had also exhibited low precipitation.

In 2022, energy storage facilities connected to the German power grid (with a net nominal capacity of at least 1 MW and/or a storage capacity of at least 1 MWh) collected a total of 8.1 billion kWh of electric power and fed 6.0 billion kWh back into the grid again. Pumped storage plants assumed the largest proportion in this development: While the pumping capacity was 7.9 billion kWh, 5.9 billion kWh were withdrawn from the plants.[27]

The negative balance in Germany's electricity exchange, which had initially been halved after 2018, increased once again in 2022. According to the German Association of Energy and Water Industries (BDEW), whose data exhibit a slightly divergent differentiation when compared to the data published by the Federal Statistical Office,[28] the balance exceeded the previous year's value with an export surplus of 28.3 billion kWh in 2022 (2021: 20.8 billion kWh) (please see Figure 12). The structure of the load flows between Germany and foreign countries changed as well: The largest amounts of electricity flowed in the direction of Switzerland and Austria, followed by France and Poland (Switzerland: 18.2 billion kWh, Austria: 15.6 billion kWh, France: 9.2 billion kWh, and Poland: 8.4 billion kWh). Most of the electricity in 2022 came from Denmark to Germany, followed by the Netherlands, the Czech Republic, and Austria (Denmark: 9.7 billion kWh, Netherlands: 8.9 billion kWh, Czech Republic: 7.1 billion kWh, and Austria: 6.0 billion kWh).

All told, 78.9 billion kWh of electricity flowed from German power grids to foreign countries (2021: 73.2 billion kWh) while Germany sourced 50.6 billion kWh from abroad (2021: 52.3 billion kWh). The structure of the load flows between Germany and foreign countries changed in 2022: Exports increased primarily in the direction of Switzerland and France whereas more imports came from the Netherlands, Norway, and Denmark. The electricity exchange with the Czech Republic exhibited significant increases both for imports and exports. The electricity exchange with France recorded an electricity export surplus for the first time ever in 2022 which was above all due to the low availabilities of the French nuclear power plants. However, it must always be considered in this context that due to Germany's central location, a certain proportion of the cross-border electricity flows are transit volumes and loop flows.

According to initial estimates, electricity consumption in the mining and manufacturing industries (without considering those amounts of electricity which in the

27) *In addition, there is a large number of home energy storage systems. According to Germany's Federal Energy Storage System Association (BVES), sector coupling increasingly reaches private households: 30 % of the households which use a PV system and an energy storage system also have a heat pump and 10 % of which have an electric car. According to preliminary figures published by the BVES, 500,000 home energy storage systems with a total capacity of 4,400 MWh were installed in Germany at the end of April 2022. The storage size has also been increasing for several years now. For example, it went up from an average of 6.8 kWh/system in 2017 to 8.8 kWh/system in 2021. Data on the actual amounts of electricity fed into and withdrawn from the grid are unknown.*

28) *In official statistics, the regional breakdown of the foreign trade in electricity is subject to confidentiality. That is why the data published by the BDEW are referred to at this point. Germany's energy balance does not require any differentiation between supplier and sourcing countries and generally uses the data contained in official statistics. It should also be kept in mind that the estimated primary energy consumption (please see Table 1 of this report) is based on an early estimate of Germany's energy balance for 2022 (last update in early February 2023). At this point in time, official data on the development of foreign trade had not yet been fully available for the reporting year 2022 and/or had to be supplemented by estimates. Consequently, the BDEW's data on the development of foreign trade in electric power differ from one another not only because of the selected data source, but also because of the more recent status of the appropriate information (data from January to December 2022).*

Figure 12

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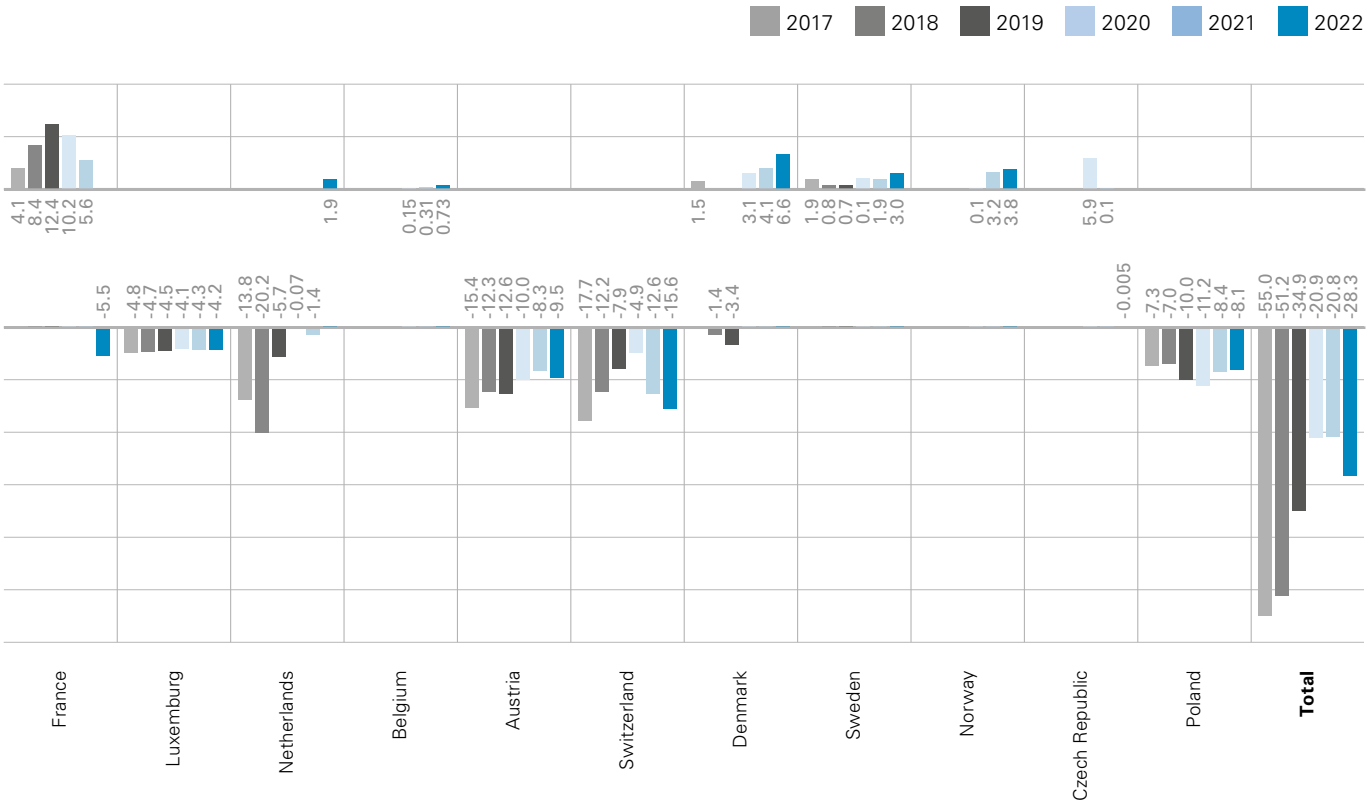
Germany's Electricity Exchange Balance with Neighboring Countries between 2017 and 2022

Electricity Flows in Billion kWh



Source: German Association of Energy and Water Industries (BDEW)

energy balance are attributed to the conversion sector such as, for example, refineries or coking plants) went down by 12 % in 2022. In the previous year, consumption had still increased by 3.7 % to 214.4 billion kWh in the aftermath of economic recovery processes.

The production decline in the manufacturing industry as a whole as well as the significant increase in electricity prices had different effects of varying intensity on the development of consumption in the individual sectors. With -25 %, consumption in the electricity-intensive basic chemicals industry, which also includes, for example, chlorine-alkali electrolysis, exhibited the highest drop. In addition, high consumption reductions are anticipated for the sectors manufacture of non-ferrous metals and casting of non-ferrous metals (-20 %), manufacture of machinery and equipment (-19.2 %), manufacture of rubber and plastic products (-17.8 %) as well as manufacture of motor vehicles (-16.4 %). Only the sector manufacture of glass, glassware, and ceramics is likely to exhibit a slight plus amounting to 1.3 %.

For the private households sector, estimates revealed a slight increase of 0.6 % in consumption when compared to the previous year to approximately 139.3 billion kWh (2022). For the trade, commerce, and service sector, the first preliminary estimates also indicated an increase in electricity consumption by about 3.4 % to 133.2 billion kWh. This consumption figure continued to be about 8 billion kWh (-5.8 %) below the electricity consumption which the companies and enterprises of the trade, commerce, and service sector had used for production purposes and/or the provision of services in 2019.

In 2021 (more recent data are not yet available), electric power in the trade, commerce, and service sector had primarily been used for such purposes as lighting (almost 31 %), drive and propulsion systems (20 %), information and communication technology (20 %), process heat and hot water (16 %) as well as process cooling and refrigeration (13 %).

In 2022, electricity consumption for mobility purposes (road and rail transport) most likely declined again

Table 13

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Electricity Balance of Germany's Power Supply between 2018 and 2022

	2018	2019	2020	2021	2022 [1]	Changes 2021/2022
	Billion kWh				Change in %	Change in %
Gross Electricity Production	**641.4**	**608.2**	**574.7**	**587.1**	**577.3**	**-1.7**
Self-Consumption in Power Plants	-34.8	-31.0	-27.7	-29.9	-30.7	2.8
Net Electricity Production	**606.6**	**577.2**	**547.0**	**557.2**	**546.5**	**-1.9**
Electricity Flows from Foreign Countries	31.7	40.1	48.0	51.7	49.6	-4.2
Electricity Flows into Foreign Countries	80.5	72.8	66.9	70.3	77.7	10.5
Net Domestic Electricity Volume	**557.9**	**544.5**	**528.1**	**538.6**	**518.4**	**-3.8**
Pump Current Consumption	8.3	8.1	8.8	7.2	8.1	12.5
Grid Losses and Unrecorded Factors	26.7	27.5	26.9	26.6	26.9	1.3
Net Electricity Consumption	**522.9**	**509.0**	**492.4**	**504.9**	**483.4**	**-4.2**
Proportion of:						
Mining and Manufacturing Industries	226.1	218.4	206.7	214.4	188.5	-12.1
Households	127.9	126.5	127.4	138.5	139.3	0.6
Commerce and Trade, Public Institutions	144.8	141.4	136.1	128.8	133.2	3.4
Transportation	11.7	11.6	11.5	12.9	12.3	-4.5
Energy Consumption in the Conversion Sector (without Power Plants' Own In-House Consumption)	12.4	11.0	10.6	10.4	10.2	-1.9
Gross Domestic Electricity Consumption	**592.7**	**575.5**	**555.8**	**568.5**	**549.2**	**-3.4**

1) Some figures are preliminary and estimates

Sources: Working Group on Energy Balances (AGEB); Federal Statistical Office (Destatis); German Association of Energy and Water Industries (BDEW)

when compared to the previous year and was now about 5.5 % below the previous year's level whereby the consumption volumes of electrical energy in this segment still hovered at a low level with about 12.3 TWh (2022).

All these figures resulted in a total net electricity consumption of 483.4 TWh in Germany for the reporting year 2022. In 2021, the net electricity consumption had still amounted to 504.9 TWh (this equals a minus of 4.2 %) (please see Table 13).

The number of companies which work in the electric power industry has been growing continuously since the start of the liberalization process in 1998. At the end of December 2022, 1,156 companies (+1.1 % when compared to the previous year) were active on the market as electricity producers, 4 as transmission grid operators (unchanged), 899 as power distribution grid operators (+0.3 %), 137 as power storage facility operators (>1 MW_{el} or >1 MWh) (unchanged), and 1,359 as electricity suppliers (-0.4 %).[29]

The number of employees in the companies of the electric power industry, which amounted to 146,740 persons, increased slightly in 2022 when compared to the previous year (+2.4 %).

Electricity prices for industrial clients (supply at the medium voltage level, annual consumption between 160,000 kWh and 20 million kWh) increased by about 54 % during the first half of 2022 when compared to 2021 and by an additional 62 % during the second half of the year (which translates into 150 % when compared to 2021). The reasons for this price hike were the increased costs for procurement, grid usage, and distribution which went up by 116.1 % during the first half of 2022 when compared to 2021 and by even

29) It is not possible to add up and combine the indicated numbers because many of the companies are active at multiple stages of the value creation chain and are, thus, recorded several times.

Figure 13

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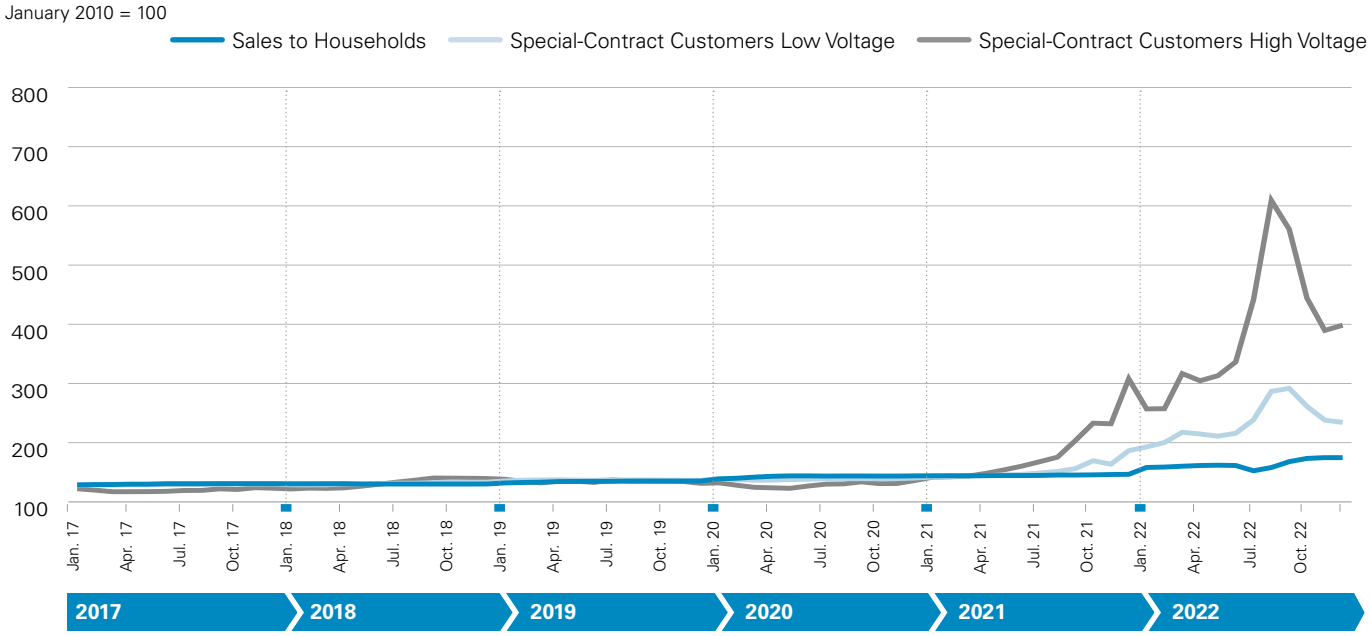
Electricity Producer Price Index for Special-Contract Customers and Sales to Households in Germany between 2017 and 2022



Source: Federal Statistical Office (Destatis)

312 % during the second half of 2022 when compared to 2021.

At the same time, the burdens imposed on industry in the form of taxes, duties, and levies increased by approximately 30 % during the first half of 2022 when compared to 2021. During the second half of 2022, the governmental burdens were even reduced by 70 % when compared to 2021 due to the abolition of the EEG levy.[30] As a result, the proportion of governmental charges included in the electricity price for industrial customers, which had still amounted to 42.5 % in 2021, decreased to about 20 % during the first half of 2022 and to only 5 % during the second half of the year (including the electricity tax).

Electricity prices for household customers increased significantly by almost 25 % to an average of 40.07 ct/kWh in 2022 when compared to the previous year. Thus, the price for household customers reached a new record high. This was due to the sharp increase in electricity prices on the wholesale market.

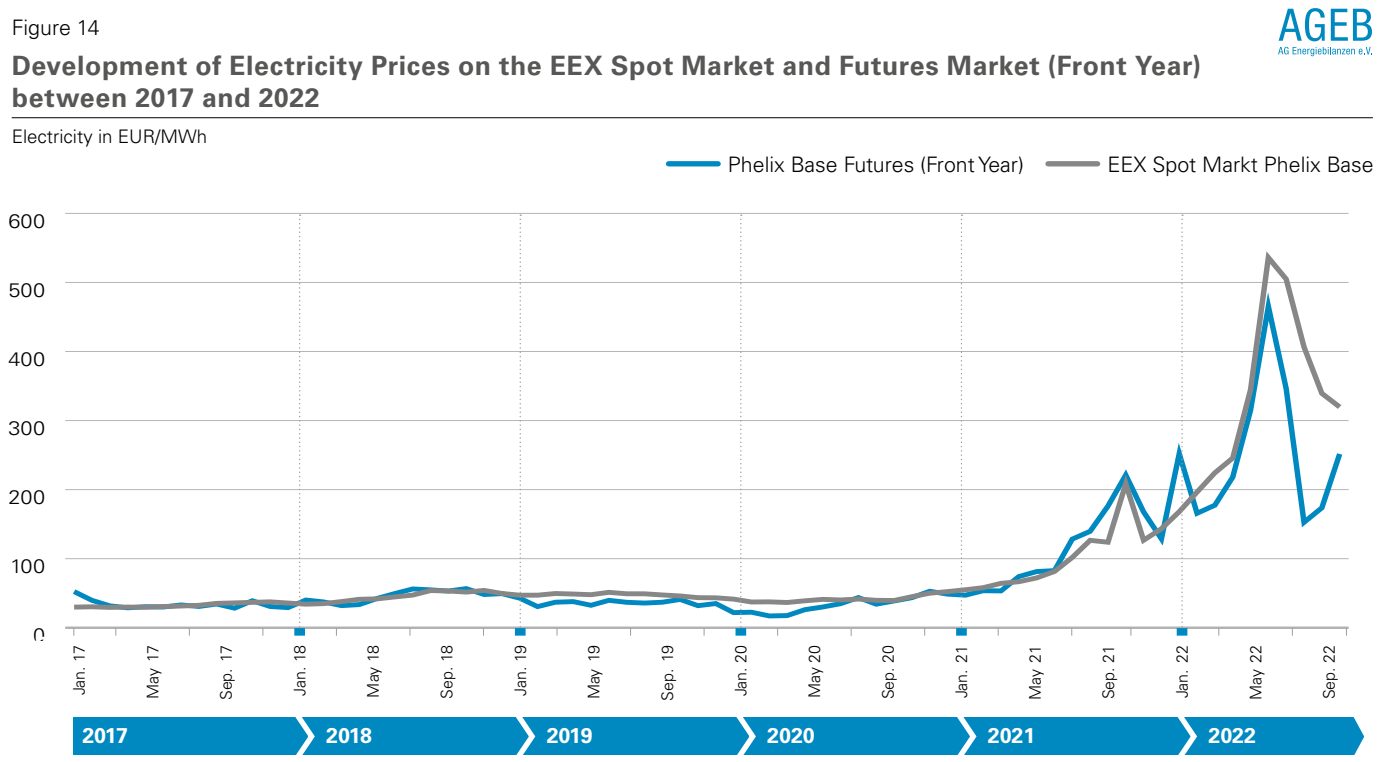
In 2022, the annual average market prices were three to four times as high as they had been in the previous year and more than double as high on the spot market for short-term procurement. This increase gradually affected the end customer prices. Even though the abolition of the EEG levy on July 1, 2022, led to a noticeable reduction of the end customer prices, it still could not compensate the increased costs of procurement. Taxes, duties, and levies, thus, only accounted for a share of 28 % in the electricity price while the share of the costs for the procurement and distribution increased to 52 %. The network charges had a share of 20 %. Taxes, duties, and levies will increase slightly in 2023, but above all the futures market prices which rose sharply in 2022 will initially continue to increase the electricity tariffs in 2023. The recently adopted electricity price brake, which caps the commodity price for 80 % of the forecast annual consumption at 40 ct/kWh, will, though, result in a noticeable relief of the electricity bill for household customers in the upcoming year (please see Figure 13).

If one were to take a look at the monthly development of the stock market prices for electricity since 2009,

30) On May 28, 2022, the Act to Reduce the Cost Burden of the EEG Levy and to Pass on This Reduction to End Consumers became effective. Its objective is to provide relief from the EEG levy for electricity customers as of July 1, 2022. Electricity suppliers are required to pass on this reduction (the EEG levy amounted to 3.72 ct/kWh so far) in full to end consumers. The EEG levy will then be permanently abolished as of January 2023. The subsidies for expanding renewable energies will be financed, thus, no longer via the electricity price but instead by the special Energy and Climate Fund (EKF) of the German Federal Government.

Figure 14

Development of Electricity Prices on the EEX Spot Market and Futures Market (Front Year) between 2017 and 2022



Source: Federal Ministry for Economic Affairs and Energy (BMWi)

then this curve initially exhibited fluctuations in the procurement costs which had always ranged between € 22/MWh and € 57/MWh from January 2009 to December 2019. As of 2020, this picture changed dramatically: After the wholesale prices had dropped significantly over the course of the year 2020 and reached a low level with about € 17/MWh in April 2020, the stock market price once again experienced a considerable increase already by the end of 2020 when it peaked at a level of € 44/MWh (December 2020). This price continued to increase nearly unabatedly over the course of 2021 and into 2022. The electricity price at the EEX rose in an exponential curve from € 52.80/MWh in January 2021 to € 221.06/MWh in December 2021. In 2022, the stock market price underwent strong fluctuations and reached a new all-time high with € 465.18/MWh in August 2022. During the fourth quarter of the year, the situation on the market calmed down, the wholesale price dropped significantly again, and ended at a level of € 251.62/MWh in December 2022. Thus, the price level of December 2022 was still about half as much above the wholesale price that had been observed at the EEX in January 2022.

Consequently, the prices at the electricity exchange developed parallel to the fuel prices (power plant gas and power plant coal) and to the costs for CO_2 certificates (please see Figure 14).

For the electric power industry, which after all represents the by far largest group of emitters in Germany, the development of certificate prices for CO_2, which are determined within the scope of European emissions trading, plays a significant role. High CO_2 prices in and by themselves improve the competitiveness of modern, low-emission gas and steam power plants and, at the same time, force carbon-intensive and/or less efficient power plants out of production.

The fourth trading period of the EU emissions trading system commenced in early January 2021. Important changes in the ten years' trading period, which will last until the end of 2031, include, for example:

- Emission rights will be allocated in two phases (from 2021 to 2025 and from 2026 to 2030) whereby the actual amounts of the rights to be allocated will be determined at the beginning of the respective phases.

- The linear reduction factor (defining the annual decrease of allocated amounts across all branches)

which had still amounted to 1.74 % p.a. during the third trading period will increase to 2.2 % p.a. during the current trading period.

- The allocation of emissions certificates free of charge for industry will be further reduced; namely, from 30 % (2021) to zero percent in 2030 whereby exceptions will continue to exist, for example, for economic branches which are affected by "carbon leakage."

- The major portion of emission allowances (57 % of the total amount) is to be allocated via auctions.[31]

All told, the new regulations entail that the emissions budget will decrease more rapidly in the future than had been the case in the past. The associated shortage in the amounts of certificates ought to result in a permanent "stabilization" of the CO_2 price at a higher level than had been observed during the second or third trading period.

On average, a CO_2 price of nearly 81 euros per ton was observed at the EEX (spot market) in 2022. The spot market price for CO_2 emission credits, thus, increased by 51.9 % when compared to the previous year. Already in 2021, the CO_2 price had more than doubled when compared to the previous year. Hence in 2022, a certificate for one ton of CO_2 cost about € 56.00 more than it did in 2020. This equals a price increase of 227 %.

The development of the CO_2 price during the course of the year 2022 was also very volatile at a very high price level. The price for CO_2 certificates fluctuated within the course of a lateral movement between a minimum of about € 70.00 per ton (September and October 2022) and a maximum of nearly € 91.00 per ton (in February 2022) (please see Figure 15).

Figure 15

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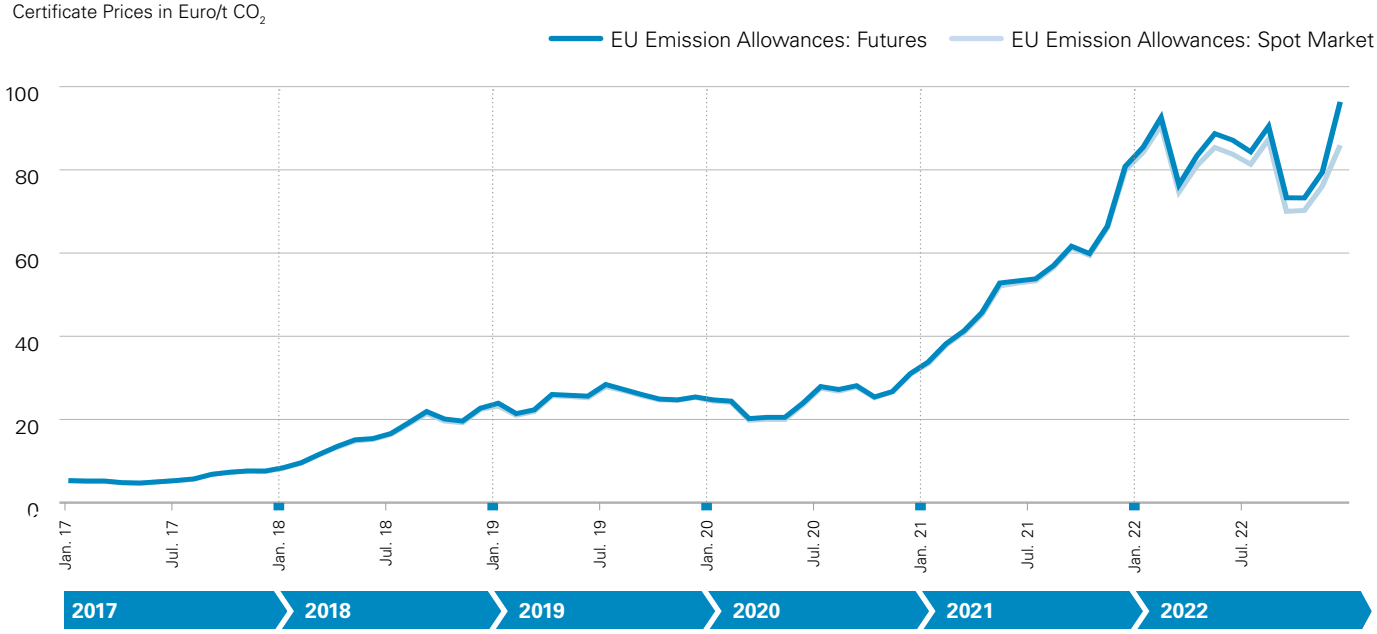
European Emission Allowances on the EEX Spot Market between 2017 and 2022



Source: Federal Ministry for Economic Affairs and Energy (BMWi)

31) For more details on the fourth trading period, please see, for example, DEHST at: https://www.dehst.de/DE/Europaeischer-Emissionshandel/Anlagenbetreiber/2021-2030/2021-2030_node.html (download date: 2022-02-24; currently only available in German).

Renewable Energy [32)]

In 2022, the primary energy consumption of renewable energy sources amounted to a total of 2,023 PJ (please see Table 14). When compared to the previous year (1,949 PJ), this equals an increase of 3.8 %. The decisive factors that influenced this development were, on the one hand, more favorable weather conditions for electricity production from wind energy than in the previous year and, on the other hand, a historic all-time high level of solar radiation which together with the addition of new solar panels resulted in a sharp increase of photovoltatic electricity production and solar thermal heat generation.

Compared to the previous year 2021, which had been characterized by weak winds, electricity production from renewable energy increased by 8.5 % in 2022. While with a total of 254 billion kWh, considerably more renewable electricity was produced than in 2021 (234 billion kWh), it was, however, at the same time only slightly more than in the year 2020 (251 billion kWh).

In 2022 as well, wind energy was again the most important energy carrier in the German electricity mix ahead of lignite. Onshore and offshore wind turbines delivered about 23 % of the gross electricity consumption. With 125.3 billion kWh, they contributed nearly half of the renewable electric power. Even though an increase of almost 11 billion kWh (+9 %) was registered compared to the less windy previous year, the absolute wind-based electricity production of the year under review, 2022, was actually just below the levels that had been attained in 2019 and 2020. In addition to the fluctuating wind conditions, the only slowly increasing addition of new production capacities must be mentioned as an important influencing factor in this context: While 342 MW were newly put into operation off shore after a pause of two years, the net addition on shore amounted to about 2.1 GW (+0.5 GW net addition when compared to 2021). Thus, a total capacity of 58.1 GW onshore and 8.1 GW offshore wind energy was installed at the end of 2022.

In 2022, electricity production from photovoltaics covered for the first time more than 11 % of the domestic gross electricity consumption. With 60.8 billion kWh, almost a quarter of the electricity produced from renewable energy sources came from photovoltaics. The strong increase compared to the previous year (+11.5 billion kWh or +23 %) can be traced back to the unusually sunny weather conditions in 2022 as well as the accelerated dynamic expansion: With a newly installed PV production capacity of 7.3 GW, about 28 % more photovoltaic power were added in 2022 than had been the case in the previous year (5.7 GW). The photovoltaic capacity installed by the end of the year 2022 amounted to a total of 67.4 GW.

Electricity production from biomass including biogenic waste (50.2 billion kWh) remained nearly constant in 2022 when compared to the previous year while electricity production from hydropower decreased by 2.4 TWh to about 17.5 TWh due to the extremely dry weather conditions. When it comes to balancing the primary energy contribution of electricity production from renewable energy sources, it needs to be pointed out that a special international statistical feature, the so-called efficiency principle, is applied here: In the absence of a physically ascertainable calorific value, a fictitious efficiency of 100 % is assumed for the conversion of energy in the balance sheets for the energy carriers hydropower, wind power, and photovoltaics while the use of biogenic fuels in power stations and other production plants is entered with their actual calorific value in the balance sheets. The efficiency principle, thus, results in the fact that the primary energy contribution of electricity production from photovoltaics (conversion input of 219 PJ) shown in Table 14 is entered in the balance sheet as being 44 % lower than the fuel input for electricity production from biomass including biogenic waste (conversion input of 387 PJ) even though electricity production from photovoltaics exceeded electricity production from biogenic sources (including biogenic waste) by 21 %.

32) This text is based on the work conducted by the Working Group on Renewable Energies-Statistics (AGEE-Stat; last update: 2023-02-21). For further information on the development of renewables in 2022, please turn to the background paper published by the Federal Environment Agency (UBA) under the title: Erneuerbare Energien in Deutschland - Daten zur Entwicklung im Jahr 2022 [Renewable Energy in Germany – Data on the Development in 2022]: https://www.umweltbundesamt.de/publikationen/erneuerbare-energien-in-deutschland-2022 (currently only available in German).

Table 14

Renewable Energy in Germany in 2021 and 2022 According to Its Use and Energy Sources

	Hydropower			Wind Energy (Onshore and Offshore)			Solar Energy			Geothermal Energy			Biomass			Waste			Total		
	2021	2022	Changes	2021	2022	Changes	2021	2022	Changes	2021	2022	Changes	2021	2022	Changes	2021	2022	Changes	2021	2022	Changes
	Petajoules		%	Petajoules		%	Petajoules		%	Petajoules		%	Petajoules		%	Petajoules		%	Petajoules		%
Domestic Production	71	63	-11	413	451	9	208	254	22	81	90	11	1,048	1,042	-1	132	127	-4	1,953	2,027	3.8
Foreign Trade Balance													-3	-4					-3	-4	
Primary Energy Consumption	**71**	**63**	**-11**	**413**	**451**	**9**	**208**	**254**	**22**	**81**	**90**	**11**	**1,044**	**1,039**	**-1**	**132**	**127**	**-4**	**1,949**	**2,023**	**3.8**
Use in Power Plants (Electricity)	71	63	-11	413	451	9	178	219	23	9	9	0	328	329	1	59	58	-2	1,057	1,129	6.8
Use in Power and Heating Plants (Heat)							0	0	18	4	4	-6	51	50	-2	50	47	-7	105	100	-4.6
Consumption during Conversion, Losses													24	24	1	0	0	0	24	24	0.7
Final Energy Consumption							**31**	**35**	**14**	**68**	**77**	**13**	**642**	**635**	**-1**	**23**	**23**	**0**	**763**	**770**	**0.9**
Industry							0	0	33	0	0	0	95	89	-6	23	23	0	118	112	-5.0
Transportation													124	123	-1				124	123	-0.5
Households, Trade, Commerce, Services							31	35	14	68	77	13	422	422	0				521	534	2.6

All values are preliminary (last update: February 2023)

Source: Working Group on Renewable Energies-Statistics (AGEE-Stat)

The entire primary energy consumption of biomass and biogenic waste amounted to 1,166 PJ in 2022 and was, thus, slightly below the value of the previous year (1,176 PJ). About 44 % of which were used in the conversion sector, i. e. essentially for the use as a fuel for the generation of electricity and district heat including the amount needed to cover the in-house consumption of the production plants. The majority (56 %) of the energetic use of biomass accounted for final energy consumption as had been the case in the previous years even though it decreased slightly to 658 PJ in 2022. Almost two thirds of the bioenergy sources were consumed by private households as well as in the trade, commerce, and service sector (422 PJ) while the share of the transportation sector (123 PJ) amounted to approximately 19 % due to the admixture of biofuels and the share of the industrial sector (112 PJ) to about 17 %. Due to the milder weather conditions in 2022 when compared to the previous year, a steeper decline could have been expected for bioenergy sources used for the heating of indoor spaces and for the generation of hot water in private households and in the trade, commerce, and service sector. However, since the prices of fossil energy carriers increased very rapidly as a result of the war in Ukraine and since the public was very concerned for quite some time about a gas shortage, it is assumed that wood fuels and biogenic gases replaced to a considerable degree such fossil sources of heating energy as natural gas and fuel oil. These substitution effects which are currently associated with considerable uncertainties essentially compensated the impact of the weather.

The other renewable energy carriers of environmental heat, including near-surface geothermal energy, deep geothermal energy, and solar thermal energy, accounted for a share of 6 % in the total primary energy consumption of renewables in 2022 (2021: 5 %).
In particular, electric heat pumps exhibited strong growth: According to the German Federal Heat Pump Association (BWP), about 236,000 heat pumps for heating purposes (+53 % when compared to 2021) and 45,500 hot water heat pumps (+93 %) were newly installed and put into operation in 2022. Consequently, approximately 1.7 million heat pumps were

Figure 16

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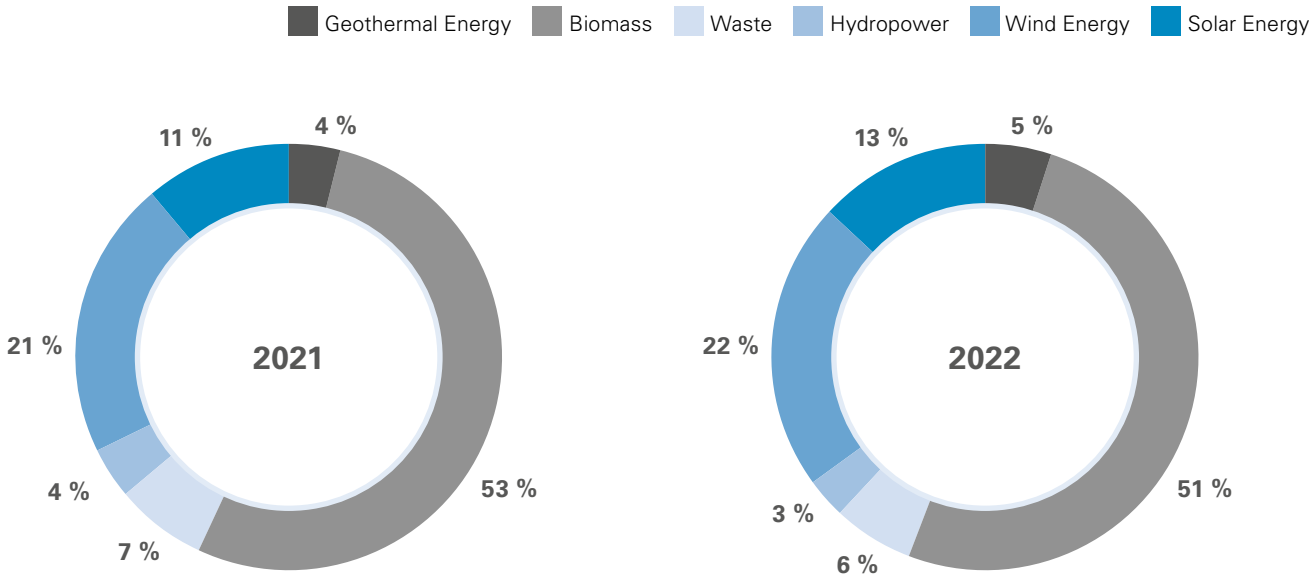
Structure of Renewable Energy Sources in Germany between 2021 and 2022

Shares in Total Renewable Energy in %



All values are preliminary (last update: February 2023)

Source: Working Group on Renewable Energies-Statistics (AGEE-Stat)

installed in Germany at the end of 2022. As a result, the renewable environmental heat generated through these heat pumps increased by 13 % to 73 PJ. And about 17 PJ of deep geothermal primary energy were used to produce electricity and heat.

Due to the high solar radiation in 2022, solar thermal heat generation also increased by about 14 % to 35 PJ. In addition, the fossil energy (price) crisis as a result of the war in Ukraine caused the demand for solar thermal systems which are used for hot water generation and complementary heating to rise again: According to the German Solar Industry Association (BSW-Solar), the newly installed collector surface amounted to approximately 709,000 square meters and was, thus, about 12 % above the previous year's level. Thus, the total collector surface installed in Germany increased slightly to 22.4 million square meters in 2022.

An analysis of the individual technologies designed to utilize renewables clearly illustrates that the energy carrier specific primary energy consumption shows different tendencies (please see Figure 16). When compared to 2021, solar energy was able to gain additional shares (+1.9 percentage points) due to the higher yielding solar radiation (and the addition of new systems). The same applies to wind energy which was able to increase its market share in the entire primary energy consumption of renewables by 1.1 percentage points due to the increased supply of wind (and the addition of new systems) when compared to 2021. In contrast, biomass (-2.2 percentage points) as well as hydropower and biogenic waste (each -0.5 percentage points) lost shares in the expanding market of renewables.

In 2022, biomass (including renewable waste) continued to be by far the most significant energy carrier amongst the renewable energies with a share of about 57.6 %, followed by wind energy with 22.3 % and solar energy with 12.5 %.

Energy Efficiency in Germany

Already within the scope of Germany's national sustainability strategy, the Federal Government had established the objective of doubling the macroeconomic energy productivity by 2020 when compared to the respective figures ascertained for 1990. The Energy Concept 2050 also continues to see improvements in increasing the energy efficiency as a key strategy for the success of the targeted energy turnaround.

It should be kept in mind, though, that empirically determining energy efficiency is by no means clear and simple, and not every technically feasible increase in energy productivity is, at the same time, also economically viable. Because efficiency improvements actually require not only time, but usually also the application of innovative technologies and, thus, the increased use of physical capital.

A typical indicator for the measurement of energy efficiency is considered to be the energy intensity; namely, the consumption of primary or final energy in relation to such guiding economic parameters as, for example, the gross domestic product or the population. Every reduction of the energy intensity defined that way is synonymous with an increase in energy productivity and/or energy efficiency.

In 2022, the macroeconomic energy productivity in Germany improved by about 7.7 % when compared to the previous year (based on the original values ascertained for primary energy consumption). By using a unit of primary energy (GJ), it was possible to generate a gross domestic product of more than € 277 in 2022. In 2021, this value had still amounted to € 257. The growth of the macroeconomic energy productivity has many overlapping causes. The drastic increase in the energy price as a result of the conflict in Ukraine created substantial incentives among commercial, industrial, and private consumers for substitutions and energy savings. In addition, the dramatic increases in energy (unit) costs hit some individual economic sectors harder than others. As a consequence, above

Table 15

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Macroeconomic Energy Productivity in Germany between 1990 and 2022

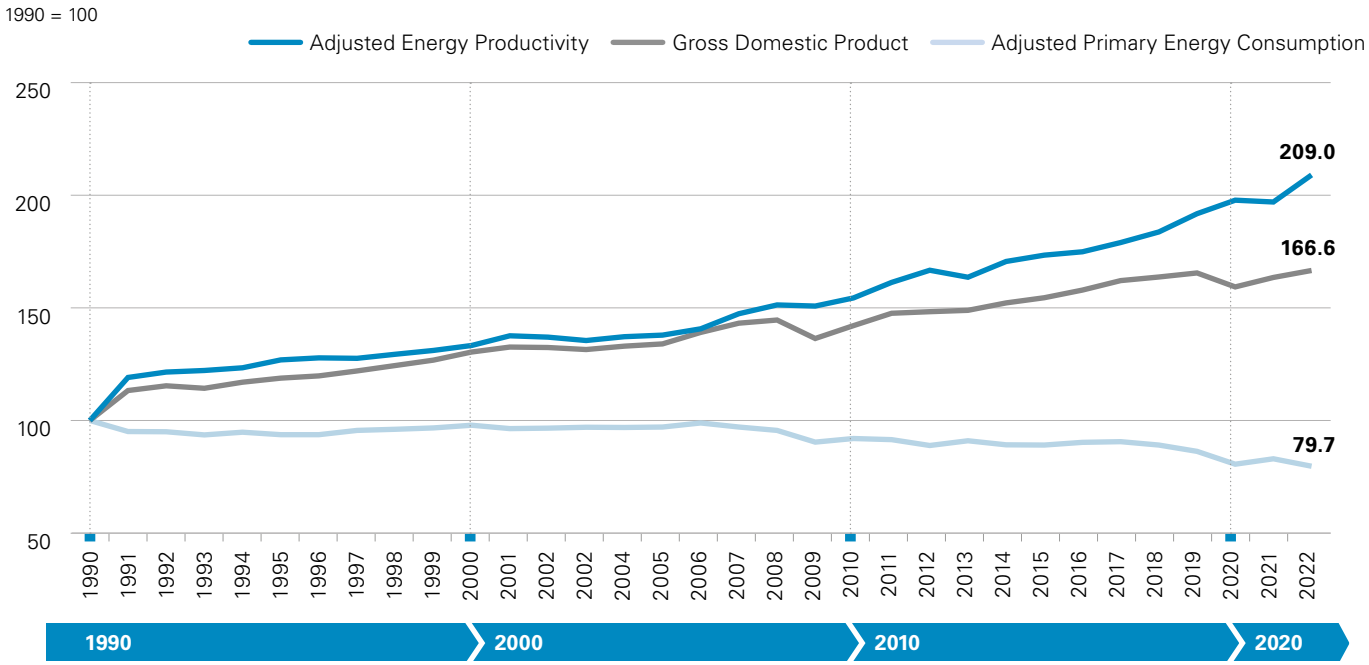
	Unit	1990 [1]	2018	2019	2020	2021	2022 [2]	Average Annual Change in %	
								2021 to 2022	1990 to 2022
Gross Domestic Product (Price-Adjusted; Reference Year 2015)	Concatenated Volume Figures in Billion Euros	1,959.1	3,207.8	3,241.6	3,121.8	3,203.8	3,264.3	1.9	1.6
Population [3]	1,000	79.8	82.9	83.1	83.2	83.2	83.8	0.8	0.2
Primary Energy Consumption (Unadjusted)	Petajoules	14,905	13,129	12,805	11,895	12,440	11,769	-5.4	-0.7
Primary Energy Consumption (Adjusted) [5]	Petajoules	15,038	13,405	12,975	12,117	12,482	11,986	-4.0	-0.7
Total Electricity Consumption [4]	Billion kWh	550.7	592.7	575.5	555.8	568.5	549.2	-3.4	0.0
Energy Productivity (Unadjusted)	Euros/GJ	131.4	244.3	253.2	262.4	257.6	277.4	7.7	2.4
Energy Productivity (Adjusted) [5]	Euros/GJ	130.3	239.3	249.8	257.6	256.7	272.3	6.1	2.3
Electricity Productivity	Euros/kWh	3.6	5.4	5.6	5.6	5.6	5.9	5.5	1.6

1) Some figures are estimates
2) Preliminary information
3) Average population based on the 2011 census (result as per the closing date May 9, 2011: 80,219,695 inhabitants)
4) Including pump current generation
5) Values adjusted for temperature, mineral oil adjusted for inventory

Sources: Federal Statistical Office (Destatis); Germany's National Meteorological Service (DWD); German Association of Energy and Water Industries (BDEW)

Figure 17

Gross Domestic Product, Primary Energy Consumption, and Energy Productivity in Germany between 1990 and 2022



All values for 2022 provisional

Sources: Federal Statistical Office (Destatis); Federal Ministry for Economic Affairs and Energy (BMWi); Federal Ministry of Finance (BMF); Working Group on Energy Balances (AGEB)

all energy-intensive branches had to accept noticeable declines in growth in 2022 when compared to the previous year. The economic structure has become "more energy-extensive" as a result of the price-induced consequences of the conflict in Ukraine and the associated unwelcome differentiation of the growth rates (energy-intensive branches have lost "market shares" when compared to other economic sectors).

A substantial impact on the macroeconomic energy consumption and/or energy productivity also emanated from the comparably mild weather conditions in 2022. Temperature and stock level adjusted, the macroeconomic energy productivity improved only with a plus of 6.1 % when compared to the previous year.

In the current reporting year 2022, this improvement of the (adjusted) macroeconomic energy productivity was significantly above the level of the long-term trend (1990 to 2022: About 2.3 % p.a.).

All told, the decoupling process between the overall economic development and energy consumption (related to the adjusted values) continued even further in 2022; albeit at an accelerated rate due to the special crisis-related developments of the year (please see Table 15 and Figure 17).

However, such a review of the macroeconomic energy productivity, which is based on primary energy consumption, also reflects statistical effects. These effects are associated with the assessment of hydropower, wind energy, photovoltaics as well as nuclear energy from a primary energy perspective (which are all used for electricity production and) for which no uniform conversion standard exists such as the calorific value (for fossil fuels). Within the scope of preparing its energy balances, the AG Energiebilanzen evaluates and assesses these energy carriers according to the so-called efficiency method (which is also applied internationally for calculating the primary energy consumption and for preparing energy balances). In the past, the substitution method used to be the common evaluation standard in Germany.

Depending on the respective substitution processes in the mix of energy carriers, any decision made in favor of the one or the other method actually influences not only the level, but also the development

of primary energy consumption and the associated macroeconomic energy productivity. Details of the effects both assessment methods have on primary energy consumption can be found, for example, in the AGEB publication *Energy Consumption in Germany in 2019*, p. 38, which can be downloaded from the AG Energiebilanzen's website at: https://ag-energiebilanzen.de/wp-content/uploads/2020/05/ageb_jahresbericht2019_20200505_engl_web.pdf.

In addition, the highly aggregated focus on macroeconomic energy efficiency prevents a clear view of many other factors which characterize energy consumption. With the component decomposition method, it is possible to illustrate the key factors which influence the changes in the (adjusted) primary energy consumption (please see Figure 18). Towards this end, the long-term changes between 2022 and 1990 aptly demonstrate the considerable influence of the decreased energy intensity (in other words, the improvement of the energy efficiency) on the reduction of the (temperature-adjusted) primary energy consumption (-10,418 PJ). This way, it was possible to significantly overcompensate the consumption-enhancing effects of macroeconomic growth (+6,650 PJ) and the increase in population (+716 PJ). All told, the adjusted primary energy consumption decreased by 3,052 PJ between 1990 and 2022.

The correlations outlined above apply in a similar way to the short-term consideration of the changes between 2021 and 2022: The gains in efficiency associated with the utilization of energy led to a slight decline in primary energy consumption (-724 PJ) when compared to the long-term perspective. This value is, though, considerably higher than the contributions of the efficiency component found in the short-term observation of the previous years. The economic growth increased the adjusted primary energy consumption by 135 PJ in 2022 when compared to the previous year. The consumption-enhancing effect of the population component (+94 PJ) had the least impact on primary energy consumption, as it also does in the long-term observation, when viewed

Figure 18

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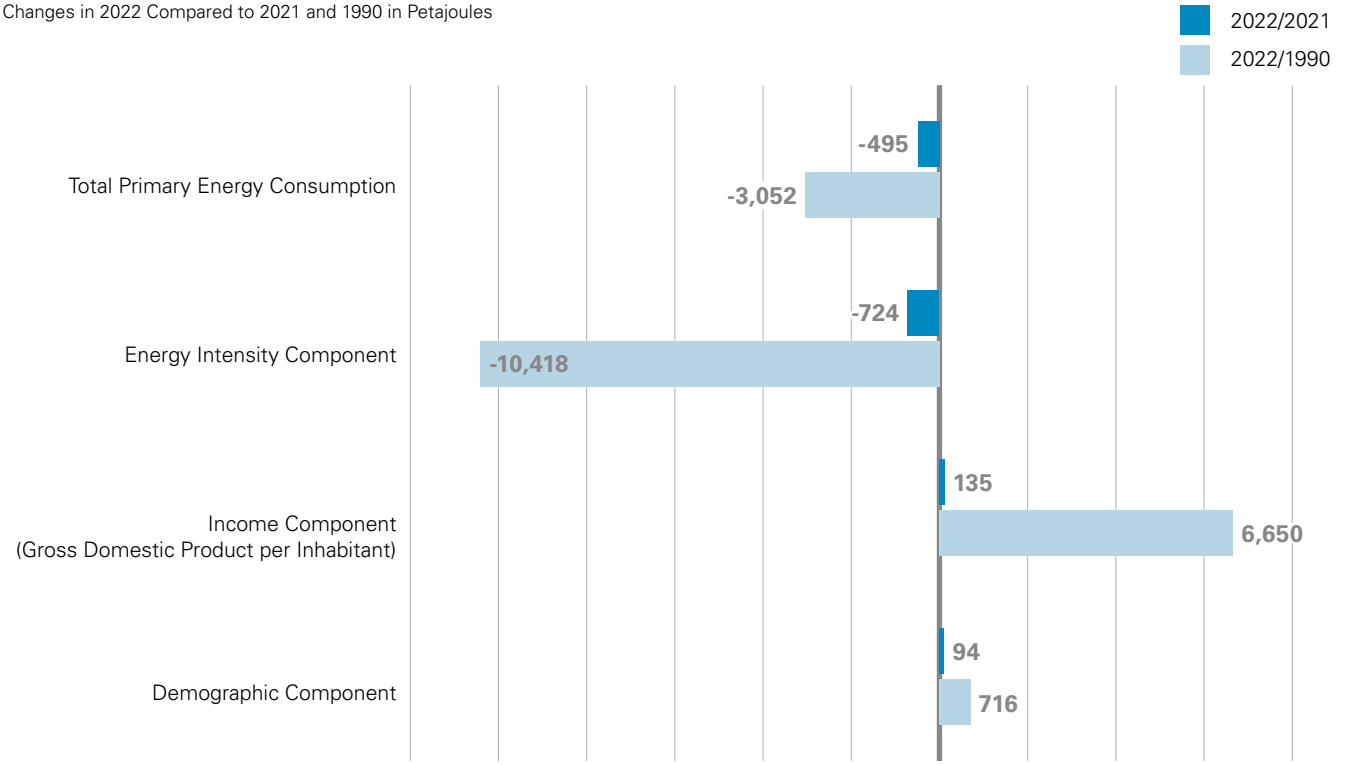
Contributions of Diverse Influencing Factors to the Changes in the Adjusted Primary Energy Consumption in Germany

Changes in 2022 Compared to 2021 and 1990 in Petajoules



Sources: Federal Statistical Office (Destatis); Germany's National Meteorological Service (DWD); Working Group on Energy Balances (AGEB)

absolutely. This resulted in a decline of the (adjusted) primary energy consumption by 465 PJ (when compared to 2021).

However, when it comes to the assessment of the results of such a component decomposition, it should be noted that the changes in primary energy consumption are, of course, not only influenced by the factors which are taken into account here (economic growth, population trend, and macroeconomic energy efficiency). In fact, the development of energy consumption can neither be sufficiently explained from a monocausal perspective nor in an extremely simplified form; it is rather the result of a very complex interaction between numerous (partially interdependent) determinants which, in addition to the influencing factors considered within this component decomposition, also have an impact on the consumption trend.

These factors and/or determinants include, above all, the impact of the structural change. Typically, a distinction is made between two types of structural change: The intersectoral structural change, which refers to the shift of economic activities between different industrial branches, as well as the intrasectoral, branch-internal structural change (in other words, the demand and/or sales induced shift of product portfolios within a single industrial branch). The structural change may result in energy savings (declining relevance of energy-intensive branches and/or products) or increases in the consumption of energy (growing relevance of energy-intensive processes). In Germany, the sectoral structural change tended to cause energy consumption to decrease in the past. Notwithstanding the above, such structural effects are not included in this component decomposition which is assumed here in a simplified manner.

When assessing the macroeconomic energy productivity, it must also be kept in mind that above average gains in efficiency in the use of fuels and heat are often contrasted by comparably moderate savings in the specific consumption of electricity. This is due to the fact that an improvement of the energy productivity in numerous economic branches can often only be attained through the increased use of state-of-the-art plant engineering, and that many of the applied process technologies which are designed to save fuels actually increase the specific electricity consumption. Yet there were also the increased requirements with regard to matters revolving around environmental protection as well as the persistent trend towards automation and the electronic control of processes which, for example, resulted in the fact that the electricity savings potentials, which are to be rated lower anyway, were partially compensated for by the increased use of this energy carrier in new fields of application.

Against this backdrop, the macroeconomic electricity productivity (expressed as the ratio of the price-adjusted gross domestic product to gross electricity consumption) improved disproportionally in 2022; namely, by 5.5 % (when compared to 2021), which was due to the sharp decline in electricity consumption (by 3.4 % to 549.9 TWh) and due to a simultaneous increase of 1.9 % in the price-adjusted gross domestic product. All told, a kilowatt hour of utilized electric energy generated about € 5.90 for the gross domestic product in 2022; in 2021, it had still been € 5.60.

When taking the long-term period between 1990 and 2022 into account, the electricity productivity increased by an annual average of 1.6 %. Please note: The total energy productivity (adjusted) increased by 2.4 % p.a. over the same period of time (for more details on this topic, please see Table 15 as well as Figures 19 and 20).

The impact of select components (economic growth, population trend, and electricity productivity) on the changes in electricity consumption in Germany between 1990 and 2022 and/or 2021/2022 is illustrated in Figure 21, which concludes this section. The diagram shows that the reduction of the gross electricity consumption by 19.5 billion kWh in 2022 when compared to 2021 was primarily caused by the higher electricity productivity (electricity intensity component) which resulted in a decline in the consumption of electric energy amounting to 29.8 billion kWh. The efficiency component of electricity consumption during the reporting year was influenced to a large extent by the mild weather conditions (unlike the component decomposition of the total primary energy consumption, the representation of electricity consumption is based on the observed, but not temperature-adjusted values) and by the dramatic increase in electricity prices on the wholesale market which were transferred

Figure 19

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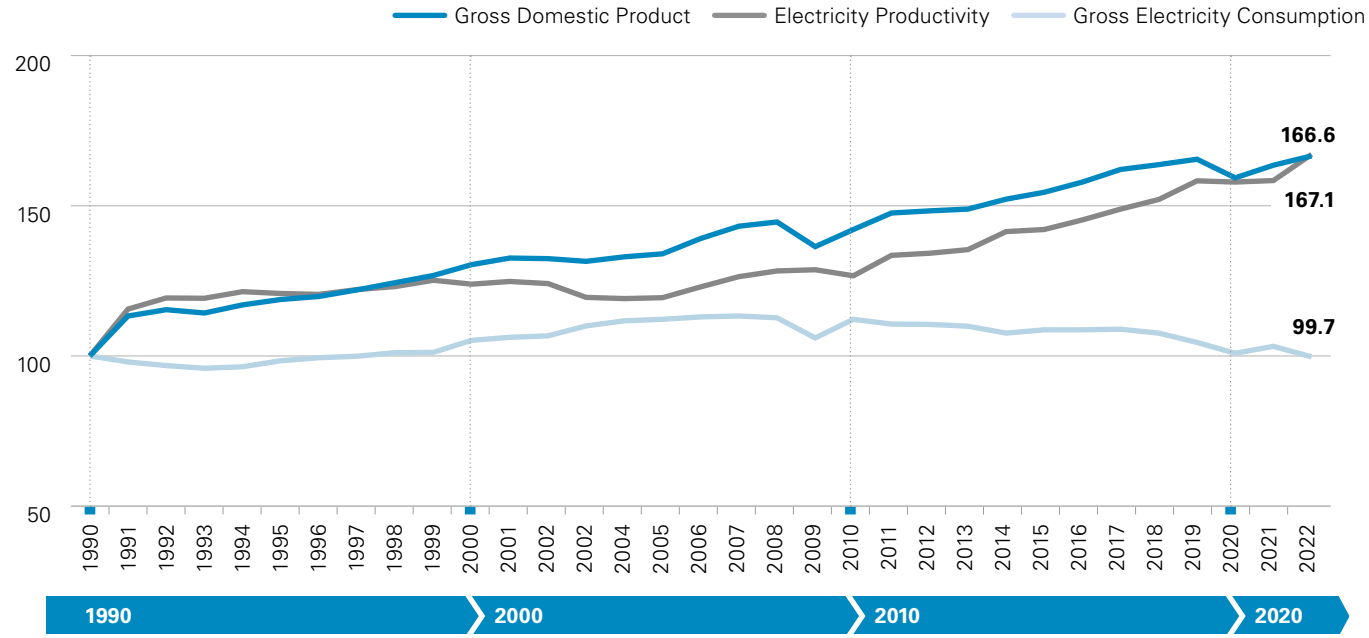
Gross Domestic Product[1], Gross Electricity Consumption, and Macroeconomic Electricity Productivity[2] in Germany between 1990 and 2022

1990 = 100



All values for 2022 provisional
1) Price-adjusted
2) Gross domestic product per unit of gross electricity consumption

Sources: Federal Statistical Office (Destatis); Federal Ministry for Economic Affairs and Energy (BMWi); Federal Ministry of Finance (BMF); German Association of Energy and Water Industries (BDEW)

Figure 20

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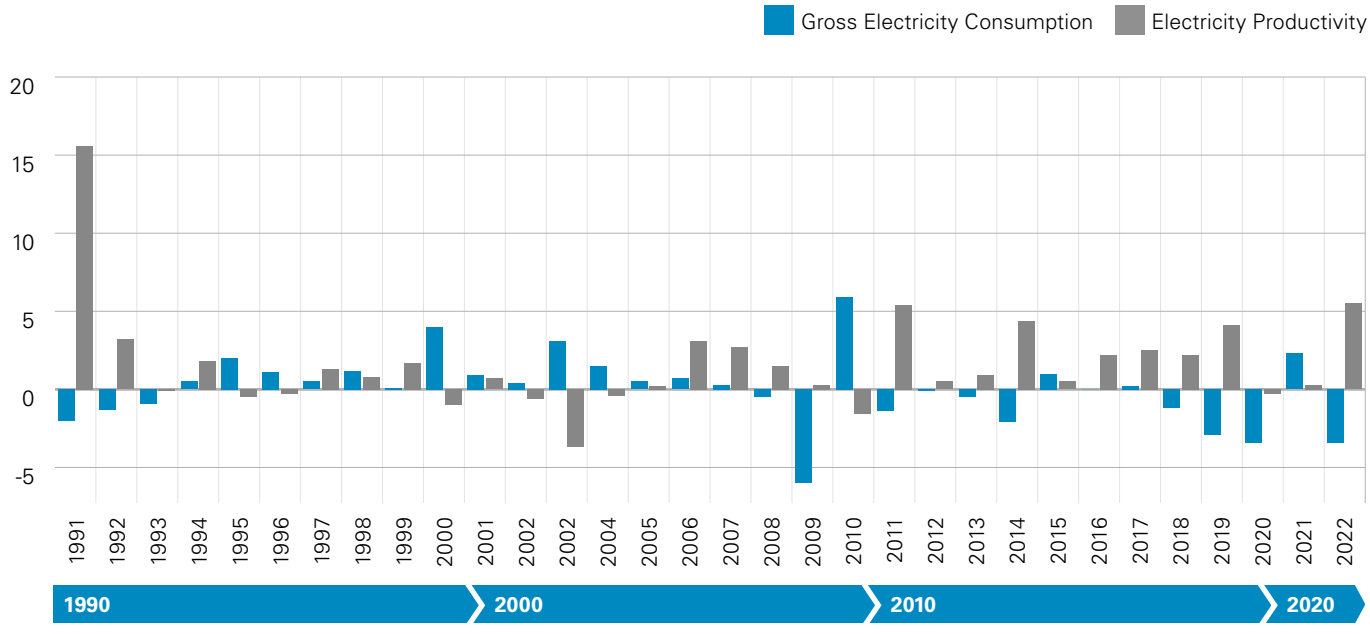
Changes in Gross Electricity Consumption and Electricity Productivity between 1991 and 2022

Changes Compared to the Previous Year in %



All values for 2022 provisional

Sources: Federal Statistical Office (Destatis); German Association of Energy and Water Industries (BDEW); Working Group on Energy Balances (AGEB)

(with delays, depending on the actual consumer category and/or tariff) to the final consumers among whom they created short-term attitudinal and behavioral as well as medium-term incentives for savings.

The economic growth led to a consumption-enhancing effect in 2022 when compared to the previous year despite a weakening economy. Electricity consumption increased by 6.2 billion kWh just on the basis of the growth component alone. The demographic component (population growth) also led to an increase in the macroeconomic demand for electricity by 4.3 billion kWh in 2022 due to the high population growth in that year.

Also when considering the entire period between 1990 and 2022, i. e. over the long-term perspective, the continuous increase in electricity productivity led in "purely mathematical terms" to an absolute decrease in electricity consumption; namely, by about 294 billion kWh. When it comes to electric energy, however, the achieved gains in efficiency were to a large extent offset again by the increased consumption of electricity on part of the expanding economy (+264 billion kWh) as well as the demographic component and/or the growing population (+29 billion kWh).

Hence, electricity consumption as a whole dropped by only 1.5 billion kWh (which equals 0.01 %) when compared to 1990; it was, thus, even about 6.6 billion kWh below the low point in 2020 (555.8 billion kWh) which had been due to the Covid pandemic.

Figure 21

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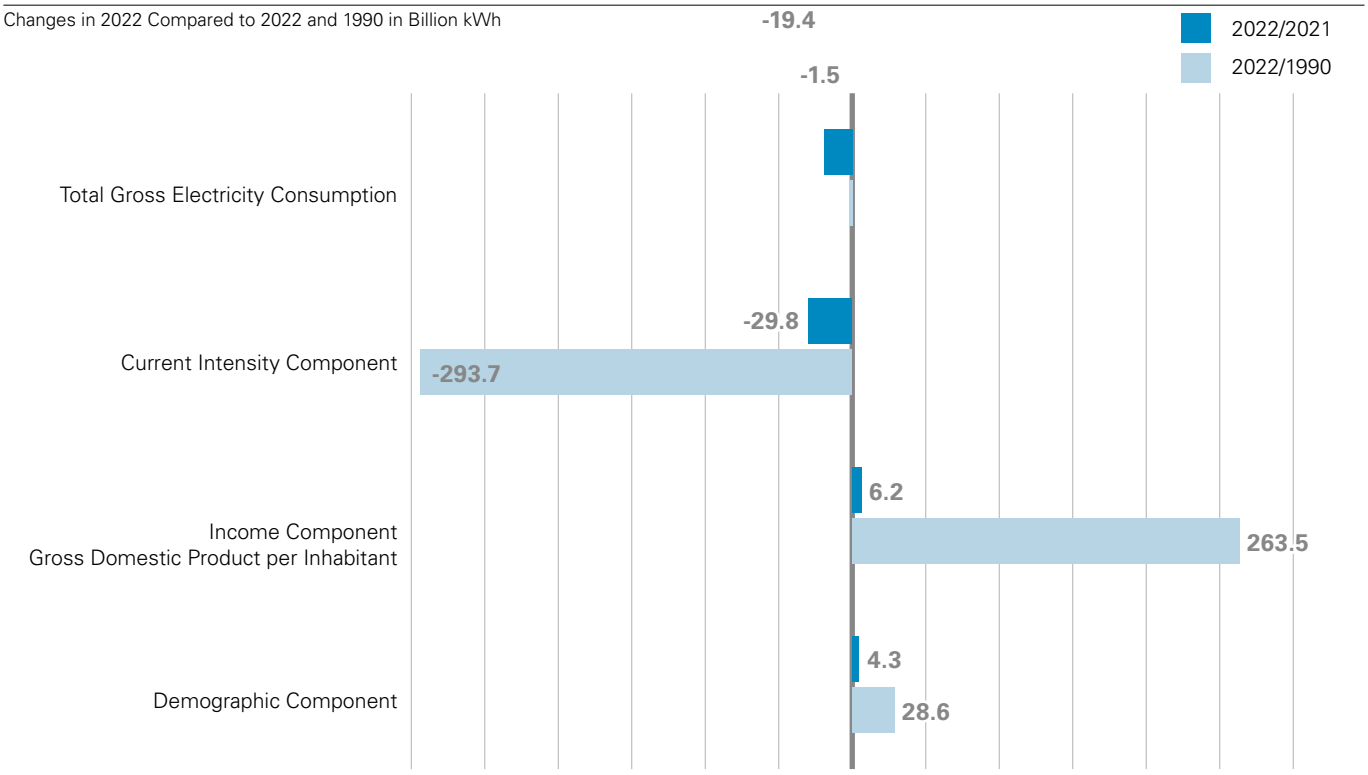
Contributions of Diverse Influencing Factors to the Changes in Gross Electricity Consumption in Germany



Sources: Federal Statistical Office (Destatis); Federal Ministry for Economic Affairs and Energy (BMWi); Federal Ministry of Finance (BMF); Working Group on Energy Balances (AGEB); German Association of Energy and Water Industries (BDEW)

CO_2 Emissions

According to initial calculations, power generation and heat generation plants supplying the general public emitted about 199 million tons of CO_2 in 2022. Compared to 2021, this equals an increase in CO_2 emissions of around 4.8 % or 9 million tons of CO_2.

The increase in CO_2 emissions in this sector was solely due to the electricity production in the plants supplying the general public (electric power generated in pure condensation units and cogeneration plants) which increased their carbon dioxide emissions by about 11 million tons. The reason for this was that the production mix which secured and assured the supply of electricity was noticeably more CO_2-intensive due to the reduction of nuclear power (-35 TWh), the electricity generated with natural gas (-10 TWh), and the increased reliance on hard coal and lignite (+10 TWh and +6 TWh respectively). The increased provision of electric power from renewable sources by 20 TWh in 2022 (as well as the 10 TWh reduction of the overall production) could not compensate this effect.

The production of district heat and the associated amounts of CO_2 emissions decreased (namely, by about 2.3 million tons of CO_2 or 11 %) primarily due to the noticeably milder exterior temperatures in 2022.

When it comes to power generation in the plants of mining facilities and the manufacturing industry, despite continuous efficiency improvements and substitutions of energy carriers, the production of electricity (and heat) exhibited a reduction between 2021 and 2022 which was primarily due to the overall economic situation. As already mentioned hereinabove, energy price induced declines in production were primarily found in such energy-intensive branches as, for example, the chemical or the paper industry and, thus, in those economic sectors in which the combined in-house generation of electricity and heat assumes a prominent role. According to first estimates, the CO_2 emissions just in this segment alone ought to have dropped in 2022 (compared to the previous year) by about 2.9 million tons (about 12 %).

From the preliminary data and estimates compiled in this report on the energy consumption trend in 2022, the following general assumptions can also be made for the development of energy-related carbon dioxide emissions in other sectors, primarily those related to final energy consumption:

- According to first estimates, the consumption (and/or sale) of fuel and energy in the transportation sector ought to have increased further in 2022. This development is also reflected in the CO_2 emissions which increased by more than 11 million tons or 7.7 % in 2022 when compared to the previous year. The outlined increase in the traffic-related carbon dioxide emissions is the result of various, partially contrasting developments: An increase amounting to about 1.8 % or 2.5 million tons appears to have occurred in road traffic despite a sharp rise in prices for diesel fuels, gasoline, and other fuel types (electricity, LNG). While road freight transport recorded a slight decline in 2022, the high fuel prices clearly did not stop people from undertaking trips with their own private cars. Although the price shock at the fuel pumps ought to have had an impact on the individual driving behavior, for example, in the form of reduced speed, anticipatory driving, etc. in order to cut fuel costs, this effect was overcompensated by the increased distance travelled.[33, 34]

A slight decrease in fuel consumption and the, thus, associated emissions is to be expected for rail traffic and inland water transportation. In contrast, CO_2 emissions from air traffic rose by about 48 % or about 9 million tons when compared to the previous year due to the continued recovery of the aviation sector. Thus, CO_2 emissions due to air traffic

33) *This conclusion is also supported by current studies; please see IW Report 54 (2022). Hohe Spritpreise: Autofahrer gehen vom Gas [High Fuel Prices: Car Drivers Are Slowing Down]. Retrieved from: https://www.iwkoeln.de/studien/thomas-puls-jan-marten-wendt-autofahrer-gehen-vom-gas.html (download date: 2022-02-23; currently only available in German).*

34) *It must be noted in this context that the impact of "fuel tourism" which takes advantage of the difference in fuel prices in regions close to national borders is not adequately represented in the sales volumes of diesel fuels and gasoline (fuel volumes with which foreigners refuel their tanks in Germany and which are, if applicable, used abroad are recorded therein whereas the sales volumes do not include those fuel volumes which are refueled abroad and used in Germany); consequently, the requisite calculations of CO_2 emissions in the transportation sector may also be distorted.*

reached a level close to 28 million tons in 2022 (for comparison: In 2019, emissions in this sector had amounted to nearly 32 million tons; during the Covid-19 crisis year 2020, less than 15 million tons).

- In the manufacturing industry (without electricity production in industrial power plants and without the energy used in refineries, blast furnaces, and coking plants), the AG Energiebilanzen expects, on the basis of the currently available estimates, that the (directly) energy-related CO_2 emissions are likely to have decreased by about 10 million tons in 2022 when compared to the previous year due to the decline in industrial production, price-induced cutbacks and substitutions as well as the short-term impact of the energy price shock on the economic structure (a decline in growth in energy-intensive branches). In the order of their relevance, the greatest absolute CO_2 reductions were recorded in the chemical industry (-3.2 million tons), metal production (-3 million tons), mining and quarrying (-0.8 million tons), and the paper industry (-0.7 million tons). In the steel industry, for example, the decline in the production of crude iron and oxygen steel, which decreased each by about 2 million tons or 7.5 % in 2022 when compared to 2021, made a major contribution to the outlined reduction in the emissions balance. Despite an increased reliance on hard coal (including coke) within the scope of substitutions in the energy carrier mix, the CO_2 emissions associated with the production of crude iron and crude steel decreased by more than 4.2 million tons or 6.8 % (including the use of coke for the combined production of furnace and converter gas in blast furnaces which are included in the energy balance of the conversion sector). The other, less energy-intensive sectors also achieved short-term energy savings along with the resulting savings in CO_2 in 2022 when compared to the previous year; these range somewhere between 0.1 million tons and 0.6 million tons.

- Due to the milder weather conditions when compared to the previous year, private households seem to have consumed less energy for heating private homes in 2022 which is probably also associated with a development in emissions heading in the same direction. This effect was reinforced by the drastic increase in energy prices for, among others, natural gas and light fuel oil. In fact, the entire energy consumption (including electricity and district heating) of private households declined by more than 5 % (125 PJ) in 2022 when compared to the previous year based on the calculations of the early estimates of the energy balance for 2022. Against this backdrop and according to first estimates, the CO_2 emissions of private households could have declined by about 4.5 million tons or 5.3 % in 2022. When interpreting these findings, however, it must be noted that the energy balance, for example, in the private households sector, only records the sold quantities (and not the actual consumption) of storable energy carriers. In 2022, it can be assumed that households probably increased their stocks despite the, in part, sharp price hikes and/or fluctuations for light fuel oil. Based on these assumptions, this means that particularly those fuel oil quantities were sold which are included in the energy balance but were not actually consumed. According to our estimates, restocking by private consumers amounted to approximately 67 PJ (that is, about 4.9 million tons of CO_2) in 2022. If one were to adjust the sales volumes shown in the energy balance for light fuel oil (in the years 2021 and 2022) by the estimated change in stocks (-57 PJ had been withdrawn from the stocks in 2021 and +67 PJ were restocked in 2022), then the CO_2 emissions (not adjusted to the weather conditions) would have actually decreased even by 15 % and not just by 5.3 % as the original balance sheet data seem to suggest at first glance.[35]

- Finally, a reduction of CO_2 emissions amounting to about 3.8 million tons (or -8.7 %) is also expected for the trade, commerce, and service sector (adjusted by the fuel stock effects for light fuel oil) when compared to the previous year.

By differentiating between the individual sectors according to the German Federal Climate Protection Act (KSG), the previous year's forecast published by the Federal Environment Agency (UBA) estimated

35) For other storable energy carriers (such as liquid gas, wood, or coal), which are also used by private households, a similar estimate of changes in stocks is currently impossible due to data and/or information gaps.

the CO_2 emissions for 2021 at about 679 million tons, of which approximately 631 million tons are directly attributable to the use of fuels and, thus, combustion processes which is how they are also recorded in the energy balance for Germany.[36] Thus, according to calculations made by the Federal Environment Agency (UBA), energy-related CO_2 emissions increased by about 4.8 % (29 million tons) in 2021 when compared to the previous year 2020 (primarily as a consequence of the economic recovery after having overcome the effects of the Covid-19 pandemic).

If one were to summarize the developments outlined in this section for an initial overall assessment, then according to rough calculations made by the AG Energiebilanzen another decrease in energy-related CO_2 emissions can be anticipated once again for the year 2022. By taking the early estimate of the energy balance for Germany for the reporting year 2022 as a basis, it is likely to be expected that the (observed) energy-related CO_2 emissions actually decreased by 1.3 % (related to the figure estimated by the Federal Environment Agency (UBA) for the previous year 2021, this would equal an absolute reduction in CO_2 emissions amounting to about 8.2 million tons). If one were to use for the calculation of energy-related carbon dioxide emissions – as already mentioned above – weather and stock level adjusted figures (expunging the impact of fluctuations in the weather and changes in the stocks on the consumption of energy) instead of the energy data observed, then this would produce a different result: According to this (adjusted) calculation, energy-related CO_2 emissions decreased by approximately 0.3 % and, correspondingly, by less than 2 million tons in 2022 (when compared to the previous year).

In this context, a continuing problem should once again be highlighted which from an emission perspective is associated with the fact that those emissions which originate from domestic electricity production and are accompanied by the high export surplus are to be allocated to Germany according to the territorial principle while conversely the emissions that would most likely be associated with the generation of electricity in those supplied countries are displaced which consequently results in lower emissions in those countries. But what the emissions balance sheet reveals from an international perspective depends essentially on the specific emissions of the export flow in relation to the specific emissions of the electricity displaced in the individual recipient country.

36) For more details, please see the Federal Environmental Agency (UBA); Daten der Treibhausgas-Emissionen für das Jahr 2022 nach KSG [Data of the Greenhouse Gas Emissions for the Year 2022 in Accordance with the German Federal Climate Protection ACT (KSG)]; last update: 2023-03-15 (Internet: https://www.umweltbundesamt.de/sites/default/files/medien/361/dokumente/2023_03_15_em_entwicklung_in_d_ksg-sektoren_pm.xlsx (download date: 2023-03-15; currently only available in German).

37) When considered in detail, the calculations on the development of energy-related CO_2 emissions conducted by the AG Energiebilanzen and the Federal Environment Agency (UBA) may differ from one another. Deviations may result, for example, from the divergent differentiation of sectors, the use of different emission factors, and different data statuses ascertained on the respective calculation dates.

Summary of the Trends

According to preliminary calculations made by the AG Energiebilanzen, energy consumption in Germany decreased by 5.4 % to 11,769 petajoules (PJ), which translates into 401.6 million tons of hard coal equivalents (Mtce), in 2022. It, thus, dropped to the lowest level since 1990. In 2022, it was even about 126 PJ or about 1 % below the level that had been recorded during the Covid crisis year 2020 (primary energy consumption 2020: 11,895 PJ). In 2022, the absolute primary energy consumption was, thus, more than 21 % (3,136 PJ) lower than in 1990.

Responsible for the outlined drop in energy consumption was primarily the Russian invasion of Ukraine on February 24, 2022, and/or the associated repercussions of the crisis on the energy markets and here, above all, the energy prices.

After the energy prices had already increased substantially during the second half of 2021, a price explosion erupted, initially for the import prices and on the spot markets (with pronounced price peaks in specific months), in 2022 which was then reflected with a certain delay in the prices paid by the end consumers for grid and non-grid bound energy products. Against this backdrop, there was already a considerable incentive to save energy just as a result of the development in energy prices in the year 2022 alone (via short-term attitudinal and behavioral based measures as well as investments in efficiency technologies which will to some extent only be recouped in full over the medium term). This incentive was additionally reinforced for domestic consumers through the devaluation of the Euro against the US Dollar.

Additional impulses to reduce energy consumption were without a doubt during the reporting year 2022 also generated by the intense public debate revolving around a looming energy crisis (gas shortage) as a result of the gradual reduction of gas supplies from Russia (on June 11, 2022, Russia reduced its supply via Nord Stream 1 to 40 % of the contractually agreed to quantity; on July 25, 2022, after the delivery had been suspended for several days due to maintenance work, it dropped to just a quarter). And finally on September 1, 2022, the Russian delivery of gas to Germany was stopped completely.

The weakened economic growth when compared to the previous year and sectoral structural change along with the exorbitantly high energy prices, which specifically in energy-intensive industries entailed reduced competitiveness as well as declines in growth and overall disproportionally low growth rates when compared to the manufacturing industry, all helped reduce consumption in 2022. For comparison: While production in the manufacturing industry as a whole shrank by 0.5 % in 2022 when compared to the previous year, energy-intensive industries reduced their production by about 7 % over the same period of time.

And finally, it must be pointed out that mild exterior temperatures also contributed towards dampening the development of the space-warming portion of the primary energy consumption. Based on the degree day figures, 2022 was about 12 % warmer than the previous year and about 11 % warmer than the long-term average (between 1990 and 2021).

Especially since the safe and secure delivery of gas and oil seemed in part uncertain for Germany in conjunction with the developments in Ukraine (and the, thus, associated disruptions of the deliveries from Russia), private and industrial consumers filled their fuel oil tanks (despite high oil prices). In addition, some industries reactivated decommissioned fuel oil tanks in order to compensate the risk of disruptions in the delivery of gas. Apart from that, the mild weather promoted the expansion of tank stocks. According to estimates of the AG Energiebilanzen, stocks of light fuel oil were replenished by an additional amount of about 80 PJ in both private households and companies of the trade, commerce, and service sector during the course of 2022 (the larger portion of which, about 67 PJ or 1.3 million liters, were stockpiled by private consumers).

Without the influence of the weather (and without considering the changes in the stockpiles of light fuel oil), primary energy consumption in 2022 would have been about 4 % below the level of 2021.

As measured by the original values, the macroeconomic energy productivity improved considerably in 2022 (according to preliminary calculations). It increased by about 7.7 % so that more than € 277 GDP_{2015} were

produced in 2022 while utilizing one gigajoule of primary energy (GJ); in 2021, this value had still amounted to almost € 258 GDP_{2015}/GJ. The average annual increase in the macroeconomic energy productivity between 1990 and 2022 is currently around 2.4 %. Based on the temperature and inventory adjusted primary energy consumption, the macroeconomic energy productivity increased, as was to be expected, at a lower rate in 2022 when compared to the previous year; namely, by more than 6 %.

A glance at the individual energy carriers reveals, also in light of the crisis-based developments already described above, the following picture in 2022: The consumption (and/or sale) of mineral oil (+2.9 %) and renewables (+3.8 %) as well as hard coal (+4 %) and lignite (+4.2 %) increased noticeably in 2022. In contrast, specifically the consumption of natural gas decreased by 15.7 % and the use of nuclear energy declined by about half when compared to the previous year.

In the shrinking energy market, primarily natural gas and nuclear energy lost market shares as a consequence. In 2022, natural gas covered 23.6 % (2021: 26.6 %) of the primary energy demand, nuclear power 3.2 % (2021: 6.1 %). Whereas in the order of their relevance, mineral oils (+2.8 %), renewables (+1.5 %) as well as hard coal and lignite (each +0.9 %) gained market shares. In 2022, mineral oils covered more than 35 % of the domestic demand for energy, renewable energy sources 17.2 %, lignite about 10 %, and hard coal approximately 9.8 %. The outlined structural changes in the composition of the primary energy consumption reveal that the energy mix in 2022 became more carbon-intensive than in 2021.

Similar to primary energy consumption, gross electricity consumption declined substantially in 2022 as a consequence of the price as well as the attitudinal and behavioral induced savings and production cutbacks in energy-intensive sectors. It dropped to 549.2 million kWh and was, thus, 3.4 % below the gross electricity consumption in 2021 and 0.1 % below the value of 1990. In contrast to primary energy consumption, though, gross electricity consumption did not exhibit any historic low levels in 2022 because in the years between 1991 and 1995, the macroeconomic electricity consumption had been even lower in this country.

Compared to the previous year, the macroeconomic electricity productivity improved by +5.5 % in 2022 and rose to a value of € 5.90/kWh after it had been around € 5.60/kWh in 2021. All told, the performance of the improved macroeconomic energy productivity surpassed this year (due to the special developments which evolved in the aftermath of the Russian invasion of Ukraine, and which have been referred to repeatedly above) the long-term development that can be seen in the average value for the years between 1990 and 2022. Between 1990 and 2022, it was possible to increase the electricity productivity on average by about 1.6 % p.a. Notwithstanding the previously mentioned special developments in the reporting year, the continuous improvement of power efficiency is increasingly reaching its technical limits because, for example, the growing reliance on electric power often represents a strategy that uses the modernization of processes to cut back on fossil energy carriers.

Gross electricity production decreased by about 1.7 % to approximately 577 billion kWh in 2022. The structure of electricity production according to the individual energy carriers continued to change as well: While electricity production based on the use of hard coal (+18 %), lignite (+5.5 %), and renewables (+8.6 %) rose, it dropped for nuclear energy by about 49.8 %. At the same time, electricity production based on natural gas decreased by 11.6 % in 2022 after having already declined by 4.6 % (4.4 TWh) between 2020 and 2021.

All told, renewable energies were able to maintain their top position with a total production volume of 254 billion kWh and a share of 44 % in the power generation mix. Lignite was in second place with a contribution of more than 20 % and natural gas was still in third place with a contribution of 13.8 % to the power generation mix. Hard coal contributed about 11.2 % to the total electricity production and nuclear energy still about 6 % in 2022.

When it comes to gross electricity consumption, renewable energies accounted for a share of 46.2 % in 2022; in the previous year, this share had still amounted to approximately 41.2 %.

The surpluses in the exchange of electricity with foreign countries[38] changed significantly in 2022 when compared to the previous year (2021: 18.6 billion kWh, 2022:

28.1 billion kWh). Particularly high export surpluses were recorded for the exchange with Switzerland (15.6 billion kWh), Poland (8.1 billion kWh), Austria (9.5 billion kWh), and France (5.5 billion kWh). The electricity exchange with France exhibited for the first time an electricity export surplus in 2022, primarily due to the reduced availability of French nuclear power plants. Surpluses in the flow of electric power from abroad focused in the order of their relevance on Denmark, Norway, and Sweden in 2022.

At the moment, it is not yet possible to precisely ascertain the energy-related CO_2 emissions for 2022 on the sole basis of final statistical data. However, a rough estimate of the development of energy-related CO_2 emissions can be made on the basis of current estimates and preliminary data on the changes in primary energy consumption according to the respective CO_2 content of the individual energy sources that are referred to and edited in this report. In total, the overall structure of energy consumption shifted again noticeably in favor of fossil fuels in 2022.

When considering the decrease in primary energy consumption, energy-related CO_2 emissions ought to have dropped by about 1.3 % in 2022 according to rough calculations based on the estimated data from the energy balances. On the basis of estimates made by the Federal Environment Agency (UBA) for the previous year 2021, this cutback would correspond to an absolute reduction of more than 8 million tons in energy-related CO_2 emissions. The decline in the reported energy-related CO_2 emissions as measured by the reduction of the primary energy consumption is more moderate because the energy mix became more carbon-intensive due to political decisions made to counter the energy crisis as well as due to price-induced substitutions resulting from the war in Ukraine.

If one were to use for the calculation of energy-related carbon dioxide emissions weather and stock level adjusted figures (expunging the impact of fluctuations in the weather and changes in the stocks on the consumption of energy) instead of the energy data observed, then this would produce a different result: According to this (adjusted) calculation, energy-related CO_2 emissions decreased by approximately 0.3 % and correspondingly by less than 2 million tons in 2022 (when compared to the previous year).

38) The data on international electricity trading which are used in this report generally relate to the physical exchange of electricity with foreign countries.