tel

HPT Annex 50

Heat Pumps in Multi-Family Buildings

Task 1: Market Overview

Country Report

GERMANY

Edited by Fraunhofer ISE

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Contents

Key Facts in Germany[JW1]

1. German Energy Demand

1.1 Global figures

1.1.1 Energy Demand in all sectors

Total primary energy consumption in Germany was of 3,736 TWh in 2016. 51 TWh, mainly electric energy, have been exported. Figure 1 shows the development of the primary energy consumption in Germany from 1990 to 2016 by energy carriers (BMWI, 2017).

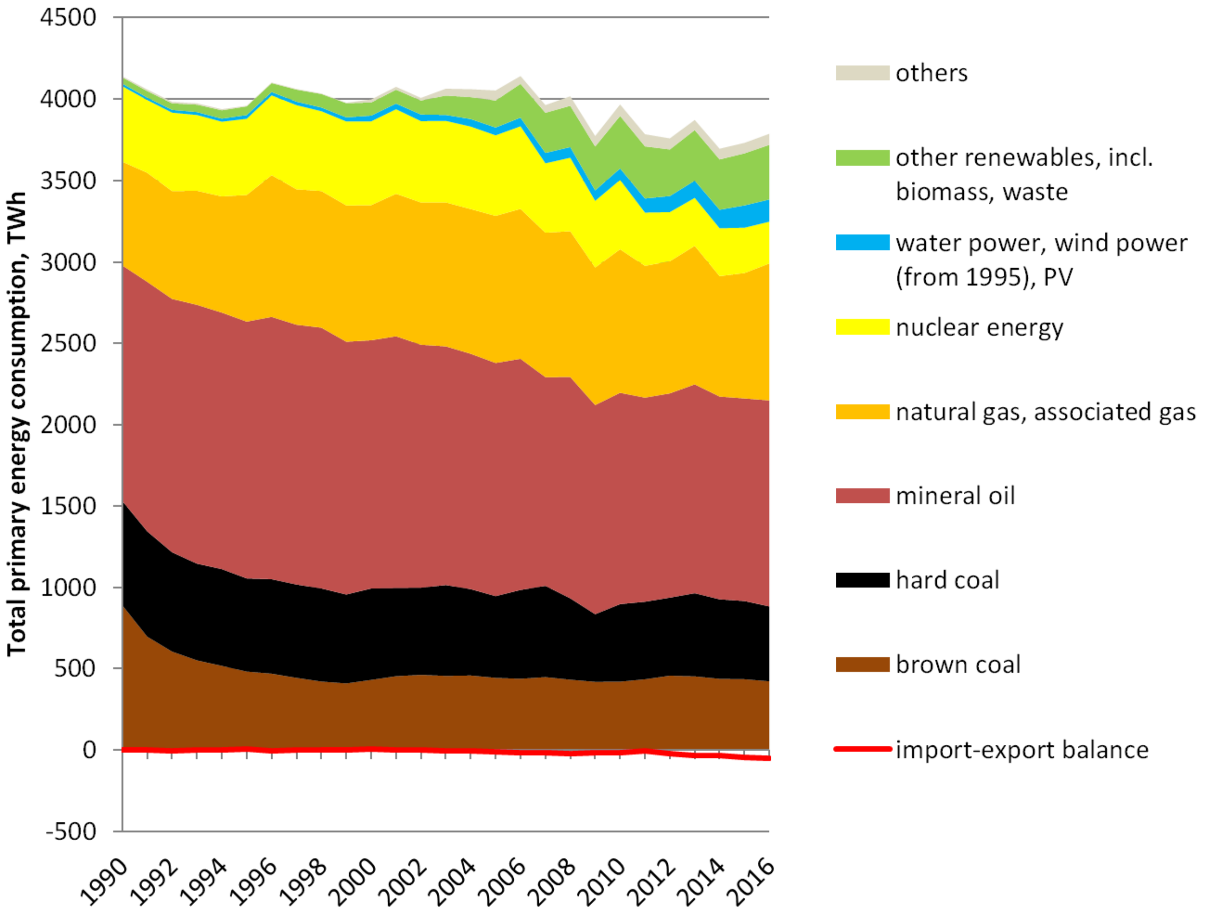

Figure 1: Development of the total primary energy consumption in Germany since 1990 by energy carriers in TWh. Source: [Zahlen und Fakten Energiedaten, Bundesministerium für Wirtschaft und Energie, 2017].

Total final energy consumption in Germany was of 2,542 TWh in 2016 and 2,472 TWh in 2015 (BMWI, 2017). Figure 2 shows the development of the final energy consumption by sectors in Germany since 1990. The diagram also shows non-energetic consumption as well as internal consumption and losses in the energy sector (including statistical differences).

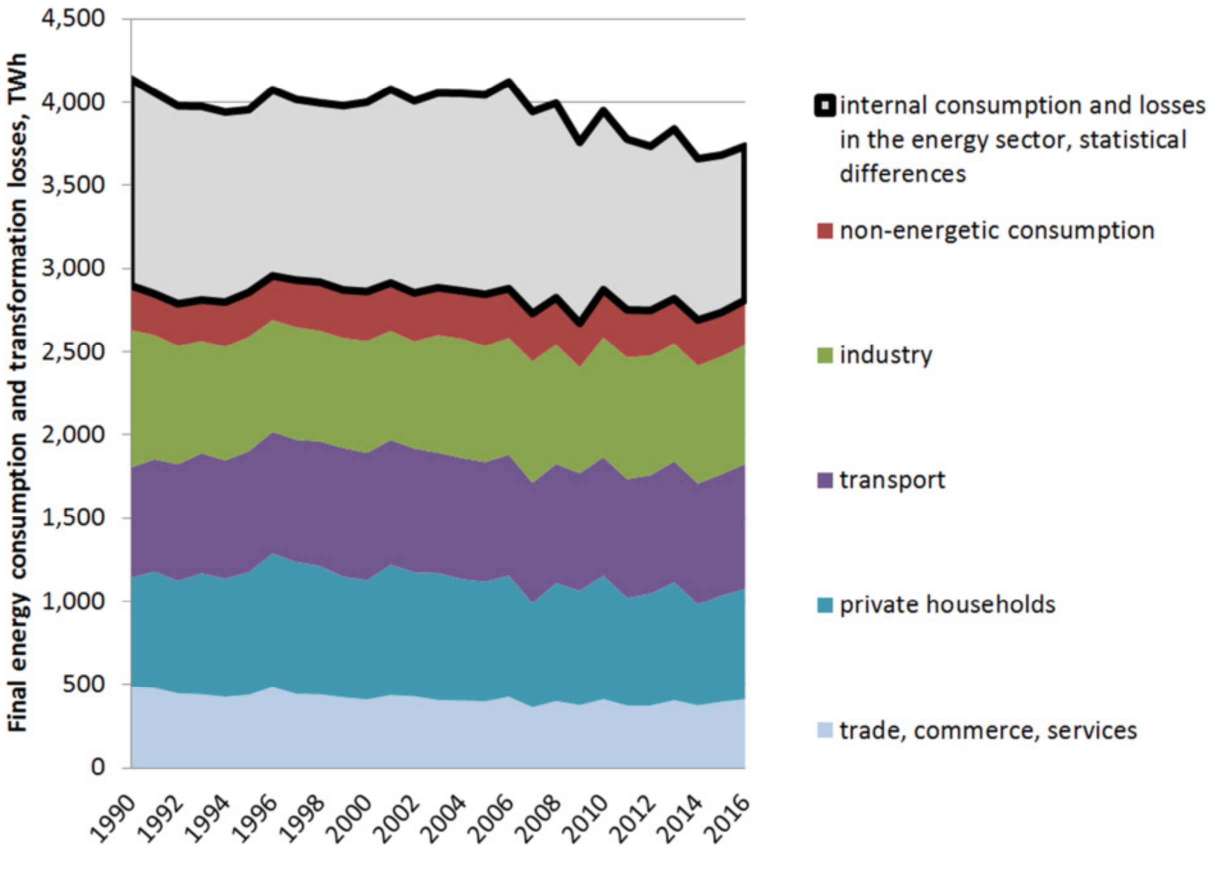

Figure 2: Development of the total final energy consumption by sectors in Germany since 1990. The diagram also shows internal consumption and losses in the energy sector (including statistical differences). Sources: [Zahlen und Fakten Energiedaten, Bundesministerium für Wirtschaft und Energie, 2017], [Arbeitsgemeinschaft Energiebilanzen e.V. , Auswertungstabellen zur Energiebilanz, Stand 07/2016].

Mainly due to the increasing usage of renewables the energy losses caused by internal consumption and energy transformations have been decreasing during the last decade. This is the main reason for the overall reduction of primary energy consumption in Germany since 2006. Nevertheless, in 2016, internal consumption and losses in the energy sector still counts for one quarter of the total primary energy consumption, as shown in Figure 3. Concerning the operation of electrically driven heat pumps, it has to be kept in mind, that the most part of these losses is due to the thermodynamic transformation from fossil energy carriers to electricity, and therefore still is part of the impact of this technology on the environment and climate change.

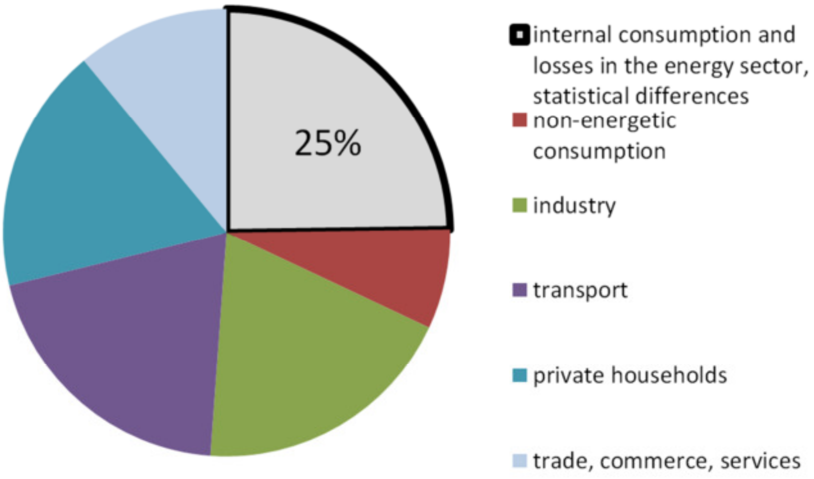

Figure 3: Fractions of the primary energy demand by final energy usage by sectors, including internal consumption and losses in the energy sector in Germany in 2016. Source: [Zahlen und Fakten Energiedaten, Bundesministerium für Wirtschaft und Energie, 2017], [Arbeitsgemeinschaft Energiebilanzen e.V. , Auswertungstabellen zur Energiebilanz, Stand 07/2016].

Figure 4 illustrates the fractions of the final energy demand by sectors in Germany in 2016 (BMWI, 2017) (Arbeitsgemeinschaft Energiebilanzen e. V., 2016). The industrial sector, transportation and private households count for roughly one quarter of the final energy consumption each. Trade, commerce and services count for 15% and the non-energetic usage of energy carriers' count for 10% of the final energy consumption.

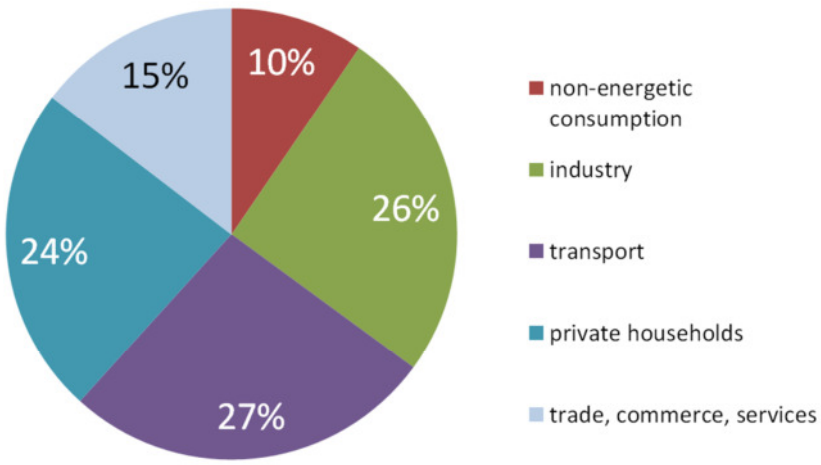

Figure 4: Fractions of the final energy demand in Germany in 2016. Source: [Zahlen und Fakten Energiedaten, Bundesministerium für Wirtschaft und Energie, 2017], [Arbeitsgemeinschaft Energiebilanzen e.V., Auswertungstabellen zur Energiebilanz, Stand 07/2016].

Figure 5 shows a detailed energy flow chart for Germany 2015 [BMWI, 2017].

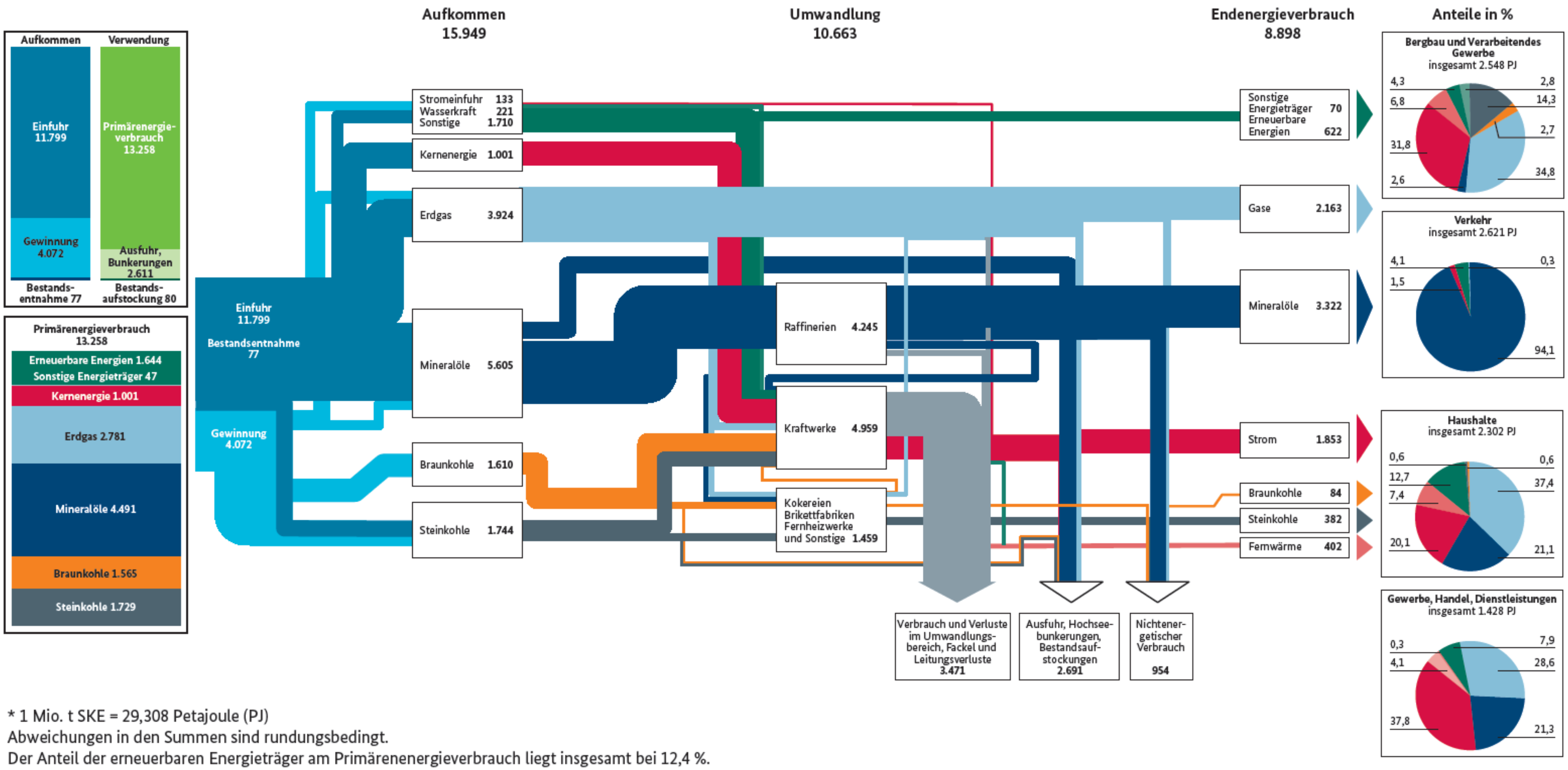

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Figure 5: Detailed energy flow diagram for Germany in PJ for 2015. Source: [Energiedaten: Gesamtausgabe, Bundesministerium für Wirtschaft und Energie, Oktober 2017], [Arbeitsgemeinschaft Energiebilanzen e.V., Auswertungstabellen zur Energiebilanz, Stand 07/2016].

1.1.2 German electricity generation

The German electricity supply is dominated by fossil fuels. Since 1991 the share of fossil fuel in the total electricty generation in Germany has continuously decreased from 94% in 1991 to 68% in 2016. Whereas the amount of electricity generation based on coal decreases, the amount of electricity generation based on gas increased until 2010. The share of nuclear power decreased in the last years from 29% in 2000 to 13% in 2016. By way of contrast the amount of renewable power (PV, biomass, wind, renewable part of hydro, geothermal) increased within the last years from less than 5% in 1998 to 32% in 2013. Within the renewable energy wind has the greatest share (37% of the renewables in 2016), followed by biomass[1] (23%), PV (18%) and the renewable share of hydrogeneration (10%).

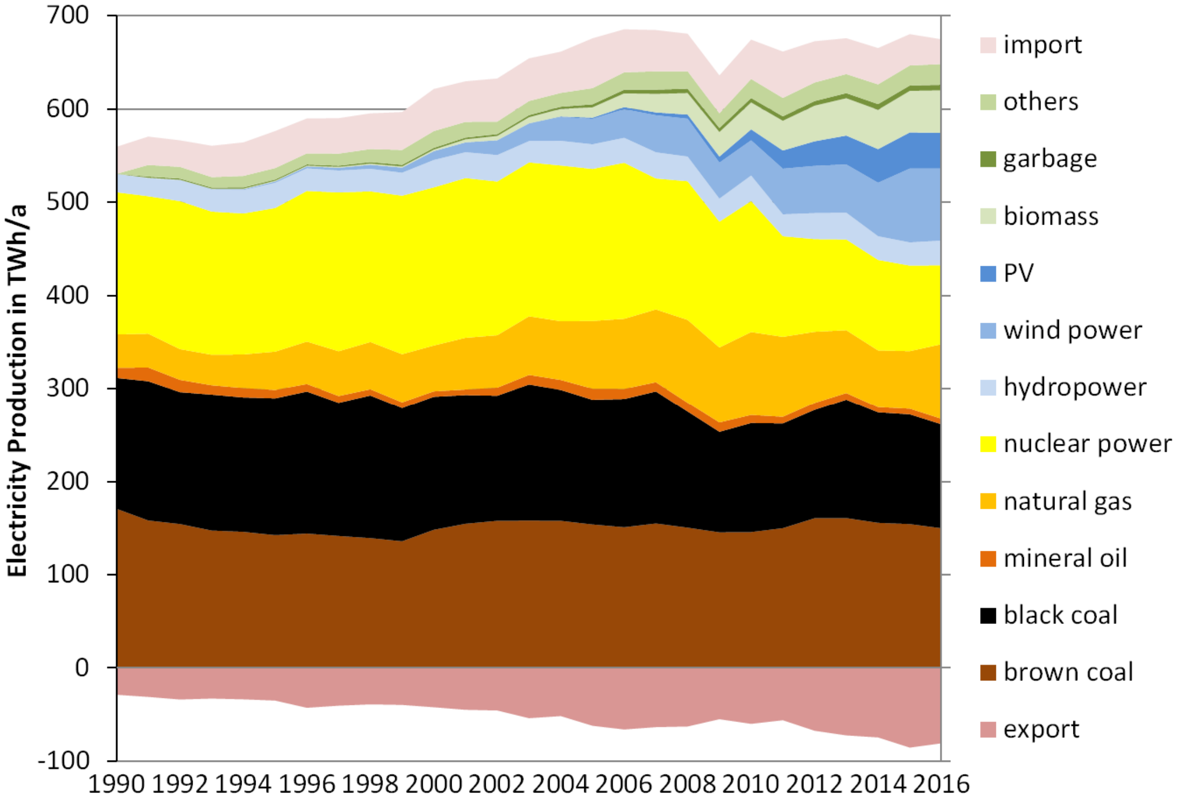


Figure 6 shows the development of electricity production as well as import an export since 1990 by fuel. Source: [BMWI, 2017]. As we can see, import and export play an increasing role.

[1] Considering 50% of energy generated based on waste to be biomass

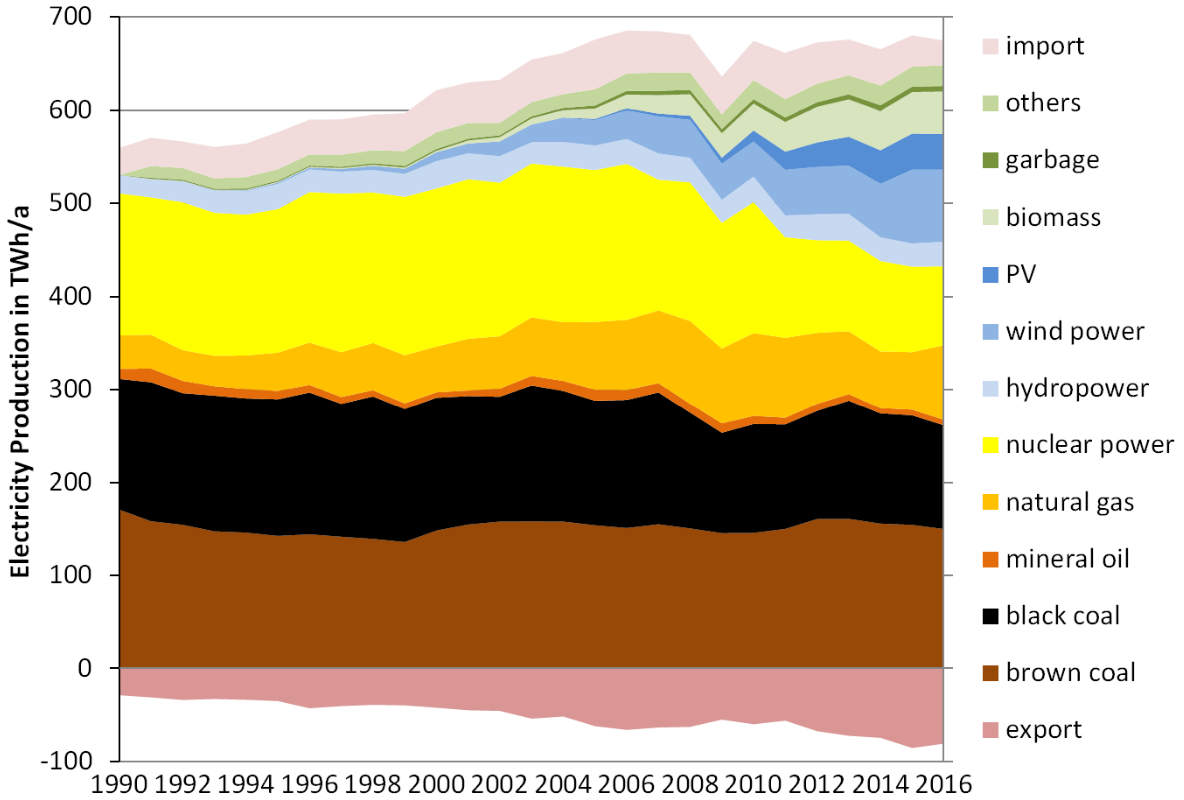


Figure 6: Electricity production (by fuel) and import in Germany, 1991 – 2016. Source: [Zahlen und Fakten Energiedaten, Bundesministerium für Wirtschaft und Energie, 2017]. For the year 1990, imported and exported electricity data are extrapolated values.

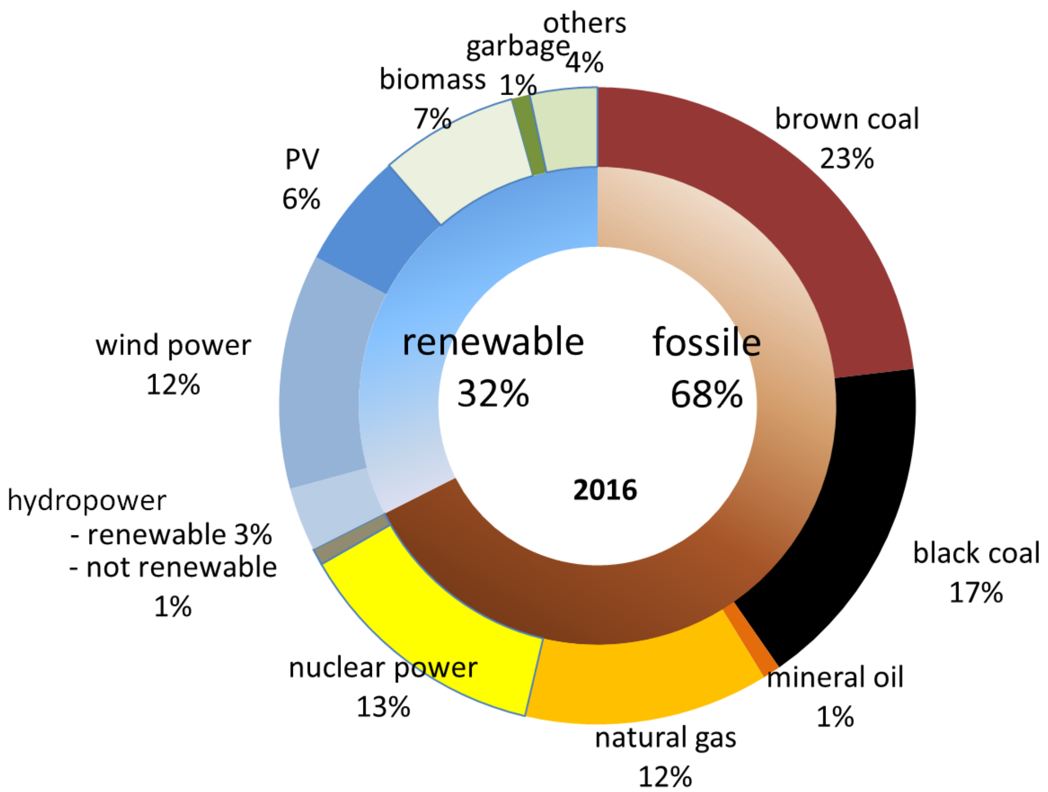


Figure 7 shows the share of fuels used for electricity generation in Germany in 2016. Without considering imported and exported electricity, roughly two thirds of the elecrtricity generation in 2016 was from non-rebewable sources, while almost one third has been produced from renewables.

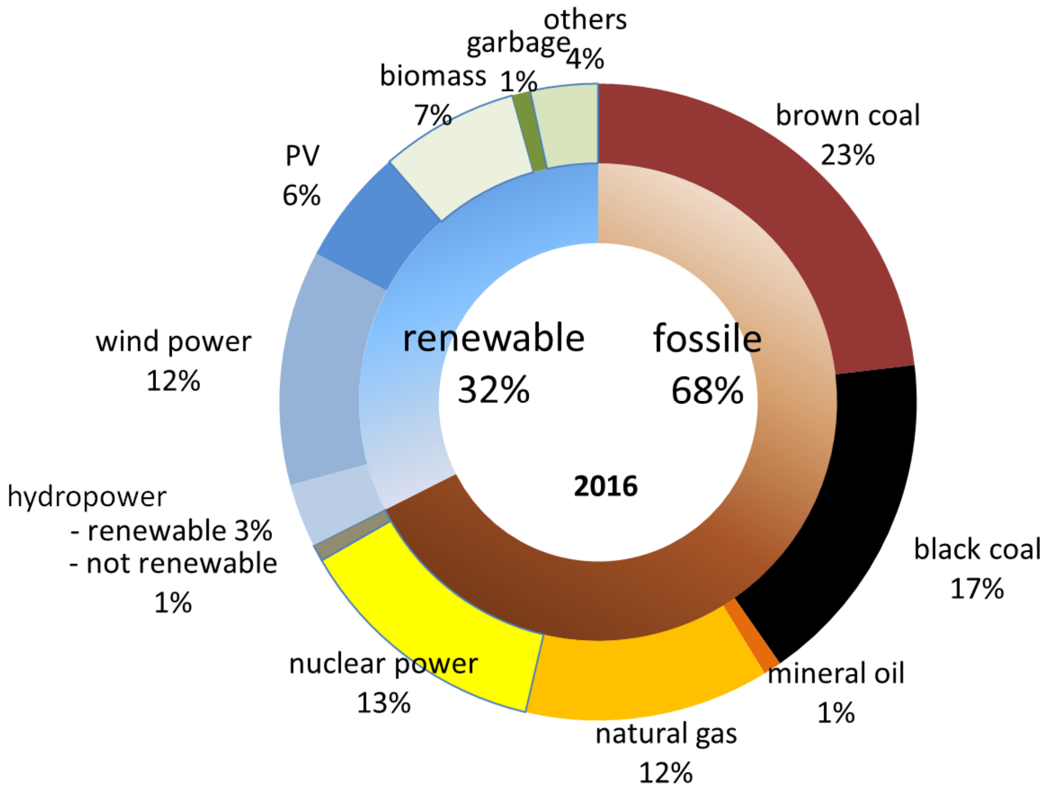


Figure 7: Electricity generation in Germany In 2016 by fuel. Source: [Zahlen und Fakten Energiedaten, Bundesministerium für Wirtschaft und Energie, 2017].

The average share of imported electricity in the total electricity consumption over the last ten years has been 7%, which shows a trend towards a decline. Considering the balance of imports and exports over the last decade, exports have exceeded imports with an average share of about 11%, which has increased to 14% by 2016, as shown in Figure 8.

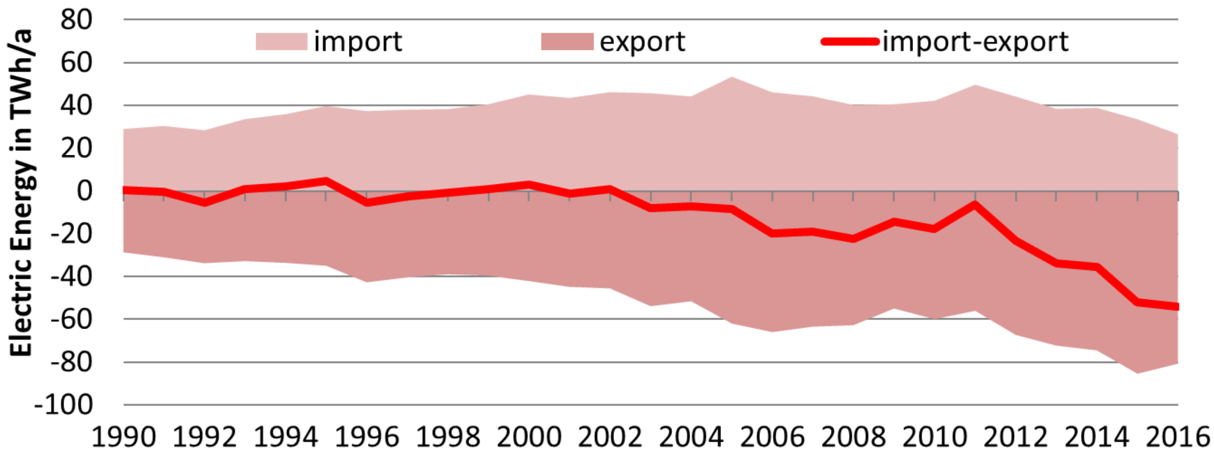


Figure 8: Balance of Electricity import and export in Germany, 1991-2015. Source: [Zahlen und Fakten Energiedaten, Bundesministerium für Wirtschaft und Energie, 2017].

1.1.3 German electricity consumption by sectors

Figure 9 shows the Electricity use in Germany from 1991 to 2015. The electricity consumption in Germany is dominated by the industry which consumed 46% of the total consumption (not considering losses and export surplus) in 2015. The domestic sector (private households) makes up the second largest share (25%), followed by trade and commerce (15%) and public services (10%).

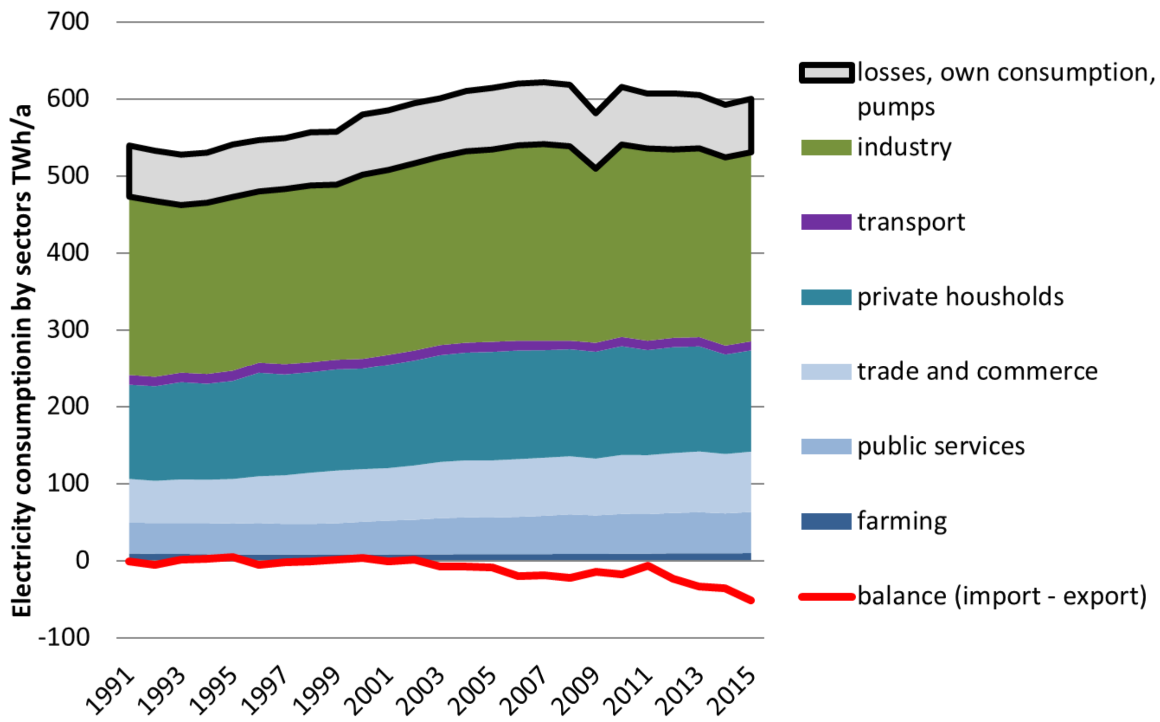


Figure 9: Electricity use in Germany. Source: [Zahlen und Fakten Energiedaten, Bundesministerium für Wirtschaft und Energie, 2017].

1.2 Climate Protection Scenarios for Germany

According to the project „Systemische Herausforderungen der Wärmewende", the sources of final energy demand in household and commercial buildings must change as well as the absolute final energy demand must decrease. In order to reduce greenhouse gas emissions by 95 % compared to 1990, especially the share of natural gas and heating oil must be significantly reduced. Figure 10 illustrates the development of the final energy demand in household and commercial buildings from 2008 to 2050. The "CMS" scenario forecasts the development on the basis of the current measures and the "CPS95" scenario calculates the development in order to achieve a greenhouse gas emission reduction of 95% compared to 1990 in a realistic way. It becomes clear that the final energy demand in buildings has to fall from around 840 TWh per year to around 280 TWh/a in the case of the CPS95 scenario. Natural gas (49.5%) and heating oil (24.0%) were the most important energy sources in 2008, and by 2050 their share of final energy demand and quantity will decrease over time. In contrast, the demand for ambient heat and electricity will increase, mainly due to more heat pumps. In addition, more solar thermal and biomass energy can replace natural gas and heating oil systems in buildings.

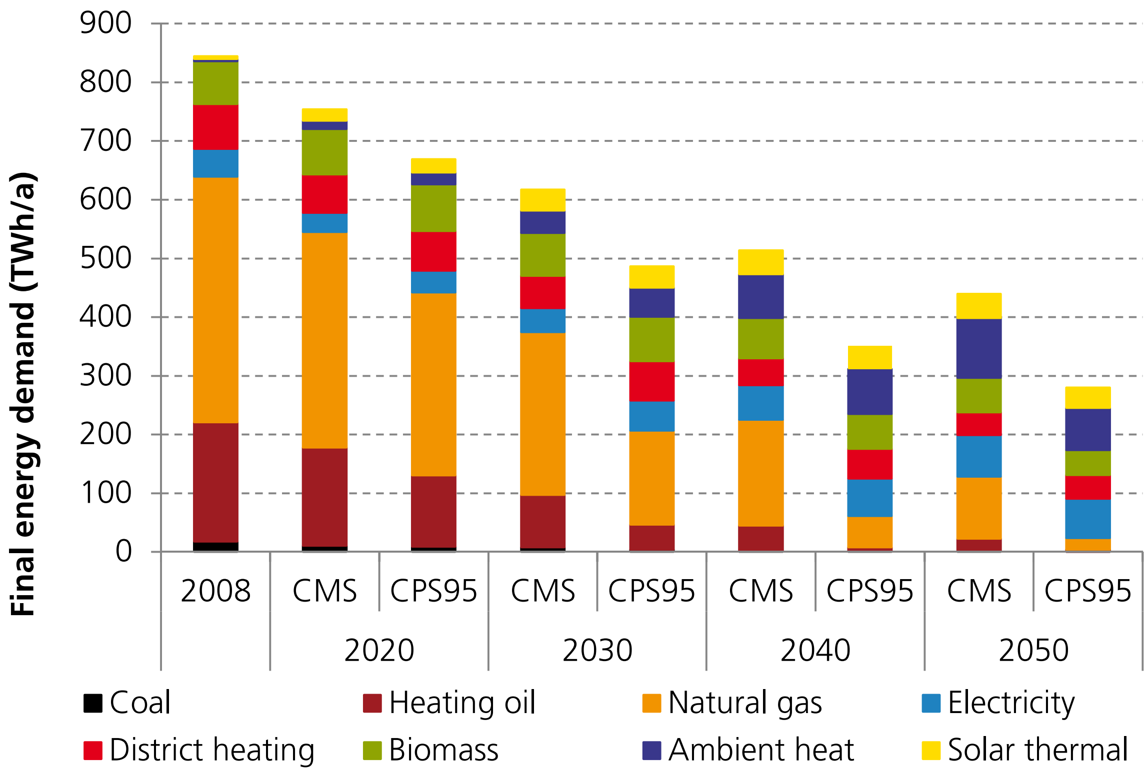


Figure 10: Final energy demand development 2008-2050 in household and commercial buildings; CMS: Current measures scenario; CPS95: Climate protection scenario with 95%greenhouse gas emission reductions. Source: [Systematische Herausforderungen der Wärmewende: Arbeitspaket 1 - Szenario Analyse; Fraunhofer ISE, 2018].

In addition, a comparison of available scenarios for the final energy development and the energy sources was part of the project „Systemische Herausforderungen der Wärmewende". Figure 11 shows the results of different scenarios for the year 2050. The scenarios were calculated to achieve a 95% reduced CO_2 emissions compared to 1990. Electricity and ambient heat play an important role, in each scenario one or both of them have a significant share in the final energy demand of the building sector compared to the 2008 level shown in Figure 10. The total final energy demand has to be reduced in any case, but the calculated amount vary between less than 100 to around 500 TWh/a. The use of heating oil and natural gas must be. But in the proportions for each technology there are large differences between the studies. Some calculations focus more on electricity and thus on the use of heat pumps, others more on an increase of the use of biomass. The same scenarios forecast the final energy demand for 2030 at a level between 500 and 650 TWh/a. The dominant heat source is natural gas, followed by heating oil and biomass. The differences between the scenarios for 2030 are smaller than for 2050. For 2030 the structures are essentially the same as for 2008, but the total quantity is smaller and the proportions slightly shifted, mainly from natural gas to electricity to ambient heat. For 2050, the scenarios show large differences and a completely new structure of energy sources was mostly forecast compared to 2008.

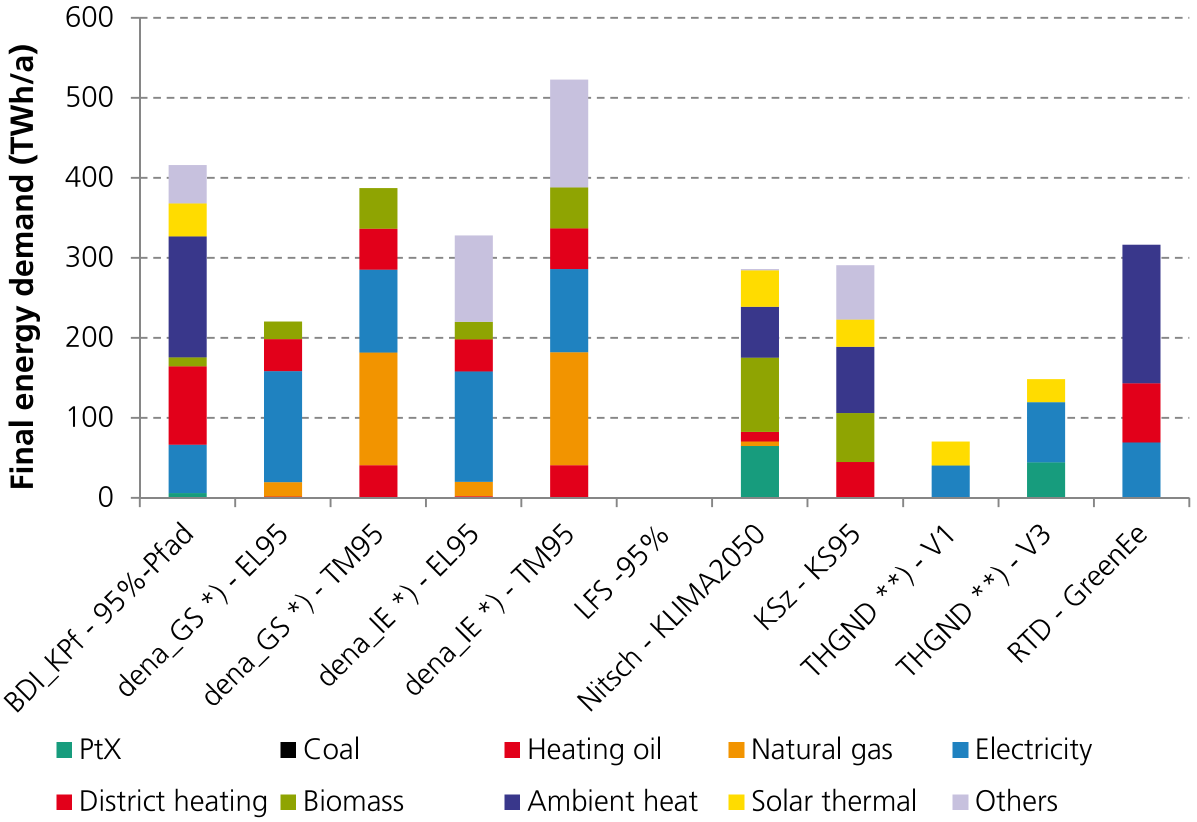


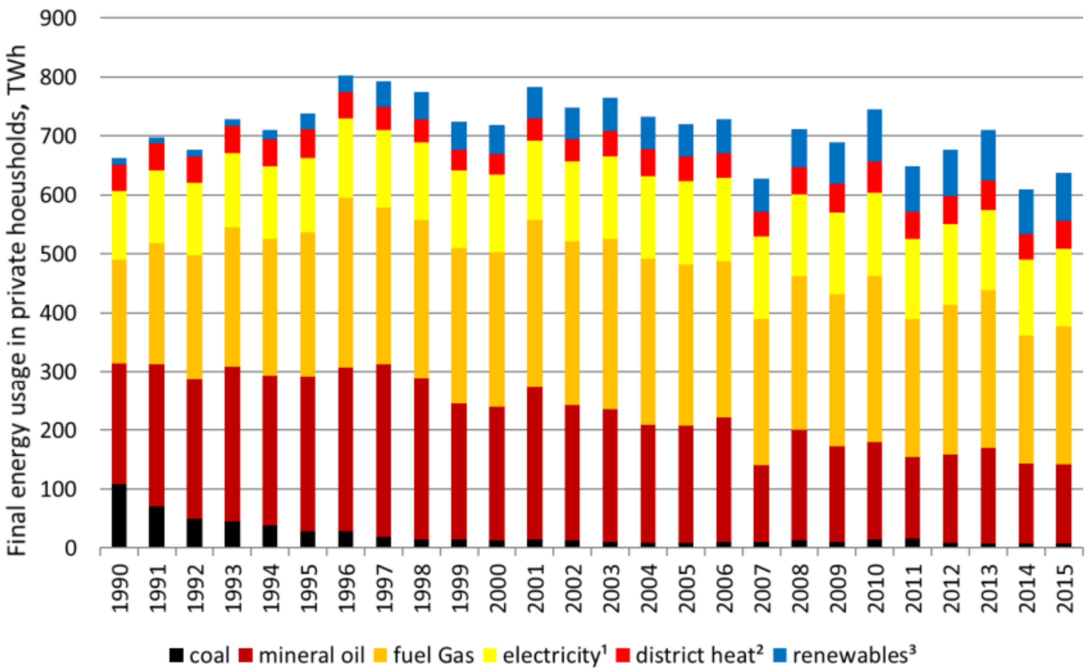
Figure 11: Scenario comparison final energy demand 2050 in household and commercial buildings – 95%-scenarios. Source: [Systematische Herausforderungen der Wärmewende: Arbeitspaket 1 - Szenario Analyse; Fraunhofer ISE, 2018].

1.3 Buildings sector

1.3.1 Domestic Sector

Figure 12 shows the final energy use of private households in Germany by fuels in the years 1990 – 2015. From 1990 to 1996 the domestic use of energy increased drastically from 662 TWh/a to more than 800 TWh/a in 1996. Since then the energy consumption in private households more or less decreased constantly until it recently fell under the 1990 values again to 636 TWh/a in 2015.

Mostly due to the retrofit programs for multi-family buildings in eastern Germany after the reunification, coal has almost disappeared as an energy carrier in the domestic sector. Since 1997, the use of mineral oil has been halved, showing a share of 21% in 2015. Fuel gas, after an increase in the early ‘90s, mainly due to the substitution of coal stoves, has a more or less constant share of 38% during the last decade and is in absolute values slightly decreasing in the recent years (37% in 2015). The uses of electricity (direct heating, driving energy for electric heat pumps, cooking etc.) and district heat are constant in absolute values and thus slightly increasing in relative shares (2015: 21% and 7%).



[1] Including renewably produced electricity. [2] Including ditrict heat produced with renewabels. [3] Biomass and renewable waste, solar thermal energy, ambient heat.

Figure 12: Final energy use of private households in Germany, by fuels 1990 – 2015. Source: [Arbeitsgemeinschaft Energiebilanzen, Auswertungstabellen zur Energiebilanz, Stand 07/2016].

Figure 13 shows the shares of the final energy use of private households.

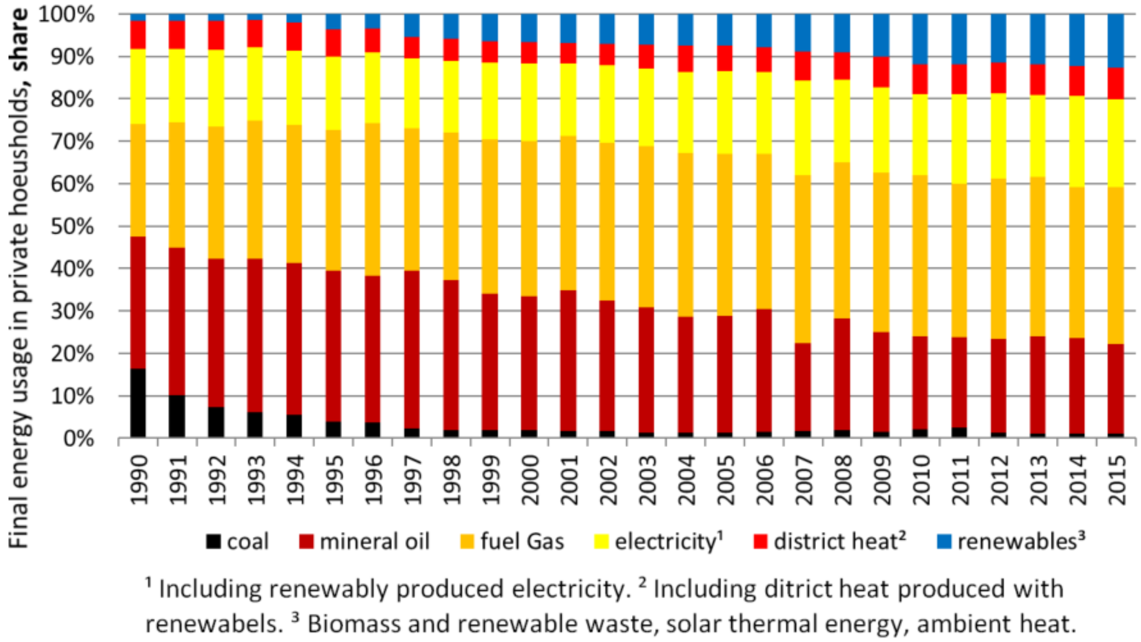


Figure 13: Shares of the final energy use of private households in Germany, by fuels 1990 – 2015. Source: [Arbeitsgemeinschaft Energiebilanzen, Auswertungstabellen zur Energiebilanz, Stand 07/2016].

Figure 14 shows the final energy use of private households in 2015 by fuels and purpose in more detail. As can be seen, in the residential sector heating with renewables mainly means the use of biomass, namely wood (64 TWh), followed by ambient heat activated by heat pumps (10 TWh) and solar thermal energy (7.5 TWh).

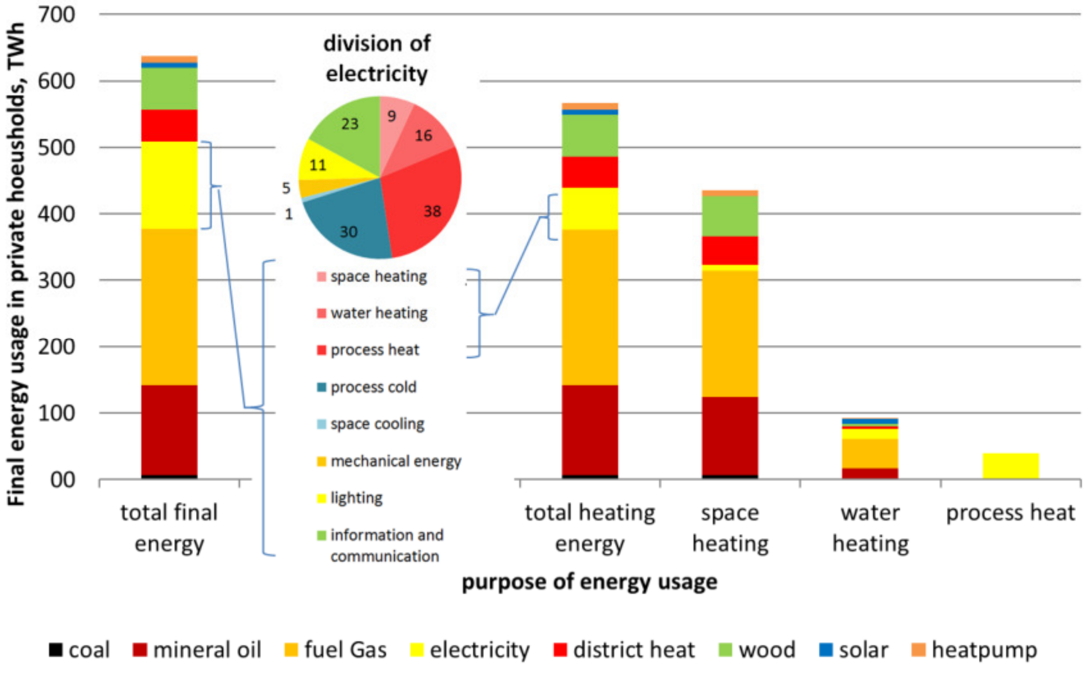


Figure 14: Total final energy usage, division of electricity usage, and heat usage of private households (total heat usage, divided into space heating, water heating and process heat (mainly cooking) by energy carrier in Germany, 2015. Different color codes for the inserted pie chart. Source: [Arbeitsgemeinschaft Energiebilanzen, Auswertungstabellen zur Energiebilanz, Stand 07/2016].

Electricity in households is mainly used for cooking (process heat, 38 TWh) and refrigerators (process cool, 30 TWh), followed by information and communication (23 TWh, also containing displays of kitchen stoves). Water heating takes account for 16 TWh and electric heating (direct electric and heat pump operation) for 9 TWh. Lighting needs 11 TWh of electricity and mechanical energy 5 TWh, while space cooling still plays a marginal role in German homes, only 1 TWh was used for space cooling in 2015. The bars on the right hand side of Figure 14 only deal with heating purposes of energy usage in households, where the bars for space heating, water heating and process heat sum up to the total heating energy. In Germany, up to now, electricity use for heating purposes in the residential sector has only a small role except for cooking, (process heat) where it dominates (Arbeitsgemeinschaft Energiebilanzen, 2016).

1.3.1.1 Energy prices for household consumers

Figure 15 shows the development of the energy prices (natural gas, electricity and district heating) for household consumers. The ratio between the electricity and the gas price varied between 3.0 and 4.5 within the last 20 years. Since 2008, the year with the lowest ratio, the ratio rises continuously up to 4.0 in 2013 (BMWI, 2017).

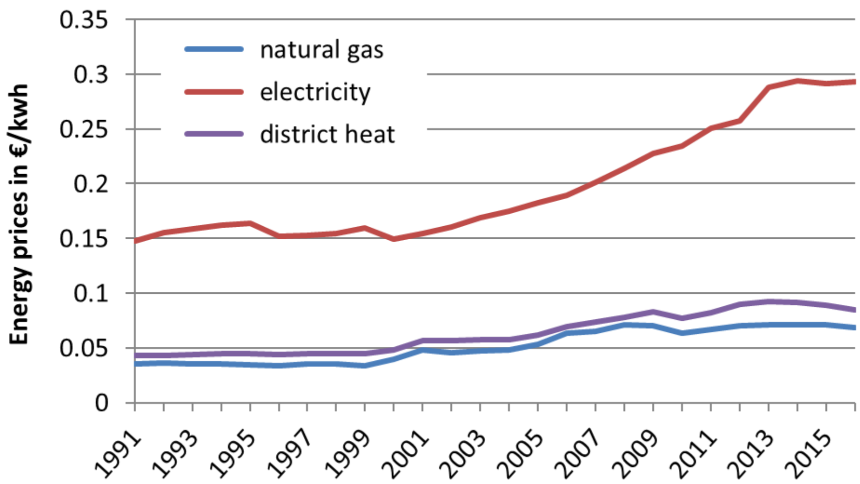


Figure 15: Energy prices for household consumers: District heating, Electricity (annual consumption: 3.9 MWh/a) and natural gas (annual consumption: 19.2 MWh/a). Source: [BMWi: Zahlen und Fakten Energiedaten 04.10.2017, page 26].

For the supply of the heat pump in domestic buildings two different types of tariffs can be used: a common household tariff or a special heat pump tariff with usually reduced prices. The price differences between both tariffs results from reduced power net charges for heat pumps. This tariff go along with the possibility for the utility to interrupt the electricity supply for the heat pump up to 3 times a day for a maximum duration of 2h each time via the ripple control signal. Various utilities do not make (fully) use of this option. Although there is no longer an obligation for the local utilities to offer a heat pump tariff it is still provided by more than 680 companies. The price for this tariff varies from utility to utility and might not be less expensive than a standard tariff from another utility.

According to German law (EnWG § 40 Abs. 3), utilities have to provide load variable or daytime related tariffs. So far, the legislator has not exactly defined the flexibility of these prices, yet. This is one reason, why currently only daytime variable tariffs with low differences exist. Another reason is the lack of an appropriate infrastructure such as smart meters. According the recommendation of the EU-Commission at least 80% of all households have to be equipped with smart meters until 2022. After that a cost-benefit analysis[2] Ernst & Young funded by the Federal Ministry of Economy and Technology assessed the nationwide rollout strategy as unjustifiable in an economically way. In the same study with the so-called "rollout scenario plus" a counter-proposal was described. The strategy aims a differenced application of smart meter and smart meter systems. In terms of heat pumps smart meter systems have to be applied if the overall electricity consumption exceeds 6000 kWh or interruptible applications (as heat pumps) are applied. Based on this results another study is currently led out by German Energy Agency (DENA) and eleven distribution grid operators to

[2] Ernst & Young; Cost-benefit analysis for a nationwide use of intelligent meters, 2013

examine the influences for an efficient and operative arrangement of the “rollout scenario plus”. The results are expected soon and probably the German legislator has to act next.

2. Policy framework

2.1 General

2.1.1 The German energy turnaround

With the adoption of its energy concept (September 2010), a comprehensive package of legislation and specific measures known as the "energy package” (July 2011) the Federal Government has set itself energy and climate goals which address the short-, medium- and long-term perspective of future policy. Table 1 illustrates the targets. Cornerstones are:

- specific targets for reducing greenhouse gas emissions that go beyond the objectives of the EU
- phase out of the use of nuclear power by the end of 2022
- the dynamic expansion of renewable energies
- the expansion and modernization of the power grid
- boosting the level of energy efficiency through modern technologies, particularly in the building sector, regarding the mobility and the consumption of electricity

TABLE 1: OBJECTIVES OF THE GERMAN ENERGY TURNAROUND SOURCES: [GERMAN FEDERAL MINISTRY FOR ECONOMIC AFFAIRS AND ENERGY, ENERGIEWENDE AUF ERFOLGSKURS, 2013, RESOLUTION OF THE FEDERAL CABINET AT 28TH SEPTEMBER 2010, DAS ENERGIEKONZEPT; (HTTP://WWW.ERNEUERBARE-ENERGIEN.DE)].

	Reference year	objective for the year ...			
		2020	2030	2040	2050
Reduction of greenhouse gas emissions	1990	-40%	-55%	-70%	-80% to -95%
Reduction of energy consumption					
… final energy for mobility	2005	-10%			-40%
… gross electricity consumption.	2008	-10%			-25%
… primary energy consumption	2008	-20%			-50%
Share of renewable energies …	-				
… of gross final energy	-	18%	30%	45%	60%
… of gross electricity consumption	-	35%	50%	65%	80%

2.1.2 EEG: German Renewable Energy Sources Act

The Renewable Energy Sources Act (Erneuerbare Energien Gesetz – EEG) promotes the generation of electricity based on renewable energy sources. It defines technology-specific and capacity-specific fix feed-in tariffs, which are paid to energy plant operators over an operation period of 20-years. The feed-in tariffs are decreasing continually. Network operators are required to preferentially feed- in this electricity into the grid over electricity from conventional sources. The costs of the EEG system are distributed to electricity consumers via the so-called EEG Surcharge. (For electricity-costs-intensive companies the payment of the EEG surcharge is limited or not demanded.). The regulation was updated repeatedly, with major changes in the support regime for renewable energy facilities, and leading to a significant calming of the expansion dynamics of renewable electricity production capacities. After 2012, when PV capacities have been expanding strongly, feed in tariffs were tightly reduced and expansion corridors for the further development of PV and Wind energy were limited. After the last update in 2016, tenders are the dominant instruments for the future market integration of renewable electricity production in the EEG amendment 2017 [6]. According to the Federal Ministry of Economics, offshore wind farms with an output of 15,000 MW are to be installed by 2030 (BMWI, EEG-Novelle 2017).

Extension corridor - wind onshore

In 2017, 2018 and 2019, 2,800 MW per year (gross) will be tendered, starting in 2020. There is a limit to the amount of additional wind on land in areas with grid bottlenecks.

Extension corridor - wind offshore

In the years 2021 and 2022, an expansion of 500 MW per year is planned and in 2023 to 2025 of 700 MW per year. In 2021, only wind farms in the Baltic Sea will be subsidized (due to grid bottlenecks). From 2026 the expansion will increase to 840 MW per year.

Expansion corridor - photovoltaics

600 MW are tendered annually. PV systems with an output > 750 kW in the categories open space systems, systems on buildings and systems on other construction sites (e.g. waste disposal sites) can participate. Citizen energy companies with local roots can participate in the tender for onshore wind energy under facilitated conditions. For all systems to be tendered, the 52-GW lid is omitted.

With a maximum limit of 750 kW, small and medium-sized PV systems are excluded from tenders and can continue to be remunerated in accordance with the provisions of the EEG.

Currently, the feed-in tariff for systems up to 100 kW_p is between 0.08 and 0.12 Euro/kWh. For plants larger than 100 kW_p to 750 kW_p, revenue ceilings are set at a similar level in accordance with the market premium model, which is intended to provide an incentive for direct marketing.

Extension corridor - biomass

In 2017, 2018 and 2019 150 MW per year and in 2020, 2021 and 2022 200 MW per year (gross) will be tendered. Participation is open to systems from 150 kW upwards. All existing plants (also < 150 kW) can participate in the tender to receive a 10-year follow-up subsidy if electricity is generated flexibly and in line with demand. Biogas plants receive subsidies for only half the hours of a year. Therefore, they will produce electricity in times when the wholesale price is high because there is little wind and sun available and there is great demand.

Figure 16 graphically summarizes the expansion of renewable power generation in the past and the future expansion aimed for by the Federal Government with the amendment to the Renewable Energy Sources Act (EEG) in 2017.

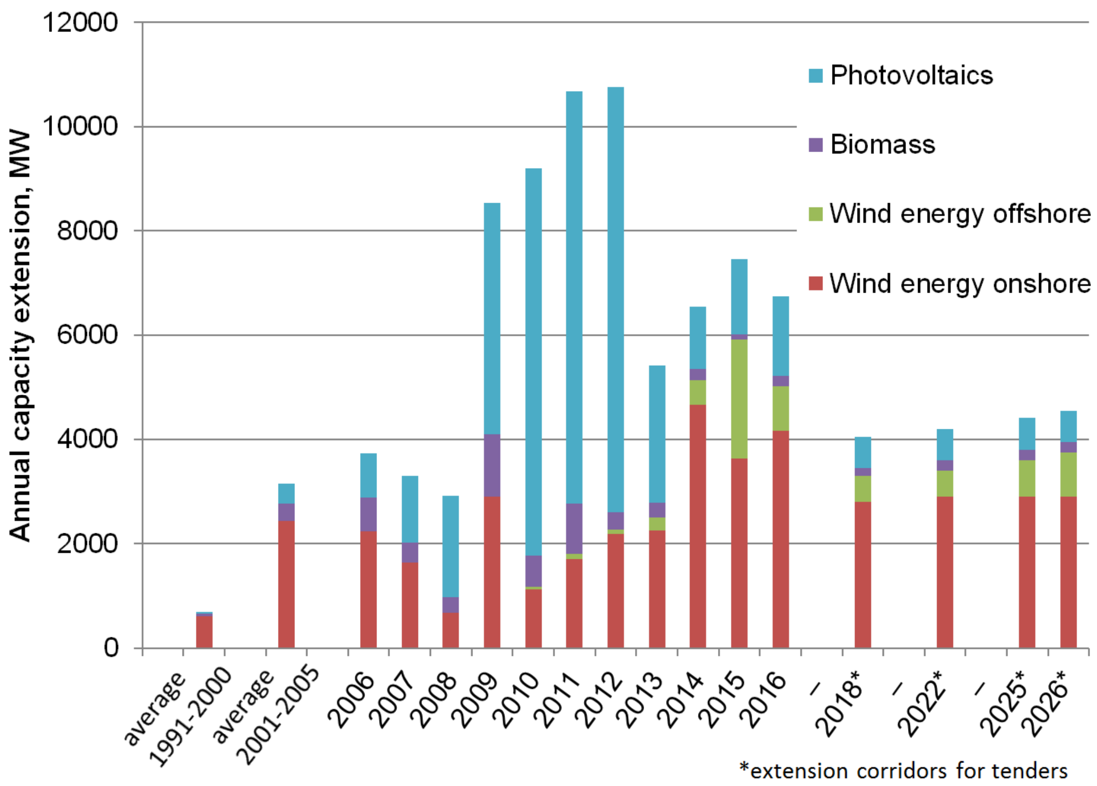


Figure 16: Annual capacity extension of PV, biomass and wind energy plants in Germany, 1991 to 2016 and future expansion corridors for tenders according to EEG 2017 for the years 2018, 2022, and 2025 to 2026 (marked with asterisks, 80% of aimed future additions are thus recorded). Data Sources: [Bundesministerium für Wirtschaft und Energie (BMWi), Erneuerbare Energien in Zahlen Nationale und internationale Entwicklung im Jahr 2016, Berlin 2017, EEG-Novelle 2017, Bundestagsbeschlusses vom 8.7.2016, own calculations].

2.2 Buildings Regulations

As in the other European countries there are two different regulatory mandatory requirements for new homes and large renovations given by the European legislation, the renewable energy directive and the European energy performance of buildings directive, which were implemented in German regulatory (EEWärmeG and EnEV). The EEWärmeG oblige house builders to use renewable heating systems for a proportion of the dwellings' total requirements. The EnEV regulates the maximum value of primary energy consumption in new buildings. Additionally an obligation to exchange old heaters (older than 30 years) is imposed as well as energetic requirements in case of renovations.

The maximum annual primary energy demand of a residential building to be constructed is 75% of the annual primary energy demand of a reference building of the same geometry, building area and orientation as the residential building to be constructed, related to the building effective area and calculated according to one of the methods specified in the EnEV. The reference building must comply with the requirements specified in the EnEV. The most parameters are listed in Table 2.

TABLE 2: KEY PARAMETERS REFERENCE BUILDING ACCORDING TO ENEV 2016[3]

Component/system	Heat transmission coefficient
Outside wall, storey ceiling against outside air	$U = 0.28\ W/(m^2\cdot K)$
Exterior wall against earth, floor slab, walls and ceilings to unheated rooms	$U = 0.35\ W/(m^2\cdot K)$
Roof, top floor ceiling, walls to sides	$U = 0.20\ W/(m^2\cdot K)$
Windows, French doors	$U_W = 1.30\ W/(m^2\cdot K)$
Total energy transmittance of the glazing	$g^{\perp} = 0.60$
Outer doors	$U = 1.80\ W/(m^2\cdot K)$
Central exhaust air system	
No cooling system	
Small solar thermal system	
Heater with condensing technology 55/45°C	

Additionally maximum values of the specific transmission heat loss related to the heat-transferring enclosure surface are given in the EnEV, as shown in Table 3.

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[3] Energieeinsparverordnung (ENEV) 2016: Energieeinsparverordnung German energy saving regulation

TABLE 3: MAXIMUM VALUES OF THE SPECIFIC TRANSMISSION HEAT LOSS RELATED TO THE HEAT-TRANSFERRING ENCLOSURE SURFACE ACCORDING TO ENEV 2016 (AE: BUILDING EFFECTIVE AREA)

Building type		**Maximum value of specific transmission heat loss**
Detached residential building	with $A_E \leq 350m^2$	$H'_T = 0.40\ W/(m^2 \cdot K)$
	with $A_E > 350m^2$	$H'_T = 0.50\ W/(m^2 \cdot K)$
Residential building attached on one side		$H'_T = 0.45\ W/(m^2 \cdot K)$
All other residential buildings		$H'_T = 0.65\ W/(m^2 \cdot K)$
Extensions of residential buildings		$H'_T = 0.65\ W/(m^2 \cdot K)$

Modifications to existing buildings and installations must also be carried out in such a way that the heat transfer coefficients of the affected exterior building components specified in EnEV 2016 are not exceeded if the area of the modified components covers more than 10% of the total respective component area of the building. This requirement is also deemed to be met if the total annual primary energy requirement of the reference building and the maximum value of the specific transmission heat loss for new buildings related to the heat-transferring enclosure surface are not exceeded by more than 40%.

The use of heat pumps for heating buildings is made more interesting by the PE factor for electricity, which has been reduced from 2.4 to 1.8 in EnEV 2016. Heat pump heaters thus meet the 25% reduction in the permitted primary energy requirement for building heating, which came into force on 1 January 2016, simply by applying the reduced primary energy factor in the fuel requirement calculation. Table 4 lists the primary energy factors to be applied for selected energy sources according to EnEV 2016.

TABLE 4: PRIMARY ENERGY FACTORS TO BE APPLIED SELCTED ENERGY SOURCES ACCORDING TO ENEV 2016

Energy carriers	**PE factors**
Heating Oil	1.1
Natural gas	1.1
District heating, from CHP, fossil	1.3
District heating, CHP, renewable Fuel	0.0
Wood, wood pellets	0.2
Electricity, previously	2.4
Electricity	1.8
Solar heat, environmental heat	0.0

2.3 Regulation concerning DHW Preparation in Multi-Family Buildings

Energy Conservation

The efficiency of water heating in water heaters is subject to the limits set out in Regulation (EU) No. 814/2013[4] (European Commission 02.08.2013b). In addition to supply efficiency, Regulation (EU) No. 814/2013 defines maximum values for standing losses/ heat retention losses of hot water storage tanks. Regulations for the energy efficiency labeling of water heaters with a maximum rated heat output of 70 kW, hot water storage tanks with a storage capacity of no more than 500 liters and combined units of water heaters with a maximum heat output of 70 kW and solar installations are given in 812/2013.

While the above mentioned EU regulations defining specifications for devices, the Energy Saving Ordinance (EnEV) sets out energy requirements for the installation and operation of the hot water system. According to §10, section 2 of the currently valid Energy Saving Ordinance (EnEV) (Government of the Federal Republic of Germany 18.11.2013) previously uninsulated hot water pipes, and fittings in existing buildings must be subsequently insulated if they are accessible and not in heated rooms. The DIN 1988-200: 2012 formulates requirements for the insulation thickness of hot water pipes, which are included in the circulation circuit or equipped with a temperature-retaining strap. The minimum thicknesses[5] are identical to the requirements of the EnEV. For hot water pipes that are neither integrated in the circulation system nor equipped with a temperature-retaining strap (e.g. storey or individual supply lines with a water content ≤ 3 l), there are no insulation requirements against heat loss[6].

Temperatures

In the guidelines, there are requirements for the temperature in the domestic hot water installation, for reasons of hygiene and comfort. The specifications from different guidelines are summarized below.

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[4] This Regulation lays down ecodesign requirements for the placing on the market and/or putting into service of water heaters with a rated thermal output ≤ 400 kW and of water heaters with a storage capacity ≤ 2 000 l, including appliances in interconnected water heaters and solar installations. The minimum insulation thicknesses indicated may be reduced if an equivalent limitation of heat emission can be ensured with other forms of insulation. The manufacturer has to prove the equivalence with a general building supervisory approval.

[5] The minimum insulation thicknesses indicated may be reduced if an equivalent limitation of heat emission can be ensured with other forms of insulation. The manufacturer has to prove the equivalence with a general building supervisory approval.

[6] Exceptions: For concealed installation, insulation is required (e.g. installation as pipe-in-pipe or 4 mm as mechanical protection or corrosion protection).

According to DIN 1988-200, the following basic requirements for the temperature in domestic hot water installations exist from a hygienic point of view. For hygienic reasons, a temperature of at least 60° C must be maintained at the water outlet of the drinking water heater. For pipeline contents of > 3 l, circulation pipes or self-regulating temperature retaining strips must be installed. In the circulating drinking water installations, a temperature drop of 5 K may not be exceeded. Exceptions to the above-mentioned requirements are drinking water heaters with high water exchange and decentralized DHW heaters. In principle, it is possible to ensure drinking water hygiene with other technical measures and procedures. In these cases the perfect conditions must be proven by microbiological examinations.

The requirements are described in more detail below:

- In the case of large systems[7], the water at the hot water outlet of the DHW heater must maintain a minimum temperature of 60 °C. Short-term reductions in the minute range are tolerable; systematic underruns unacceptable. (DVGW worksheet W 551, DIN 4708, DIN 1988-200: 2012, Sect. 9.7.2.5).
- The entire drinking water content of preheating stages is to be heated once a day to at least 60°C. (DVGW worksheet W 551).
- As an exception of the above mentioned specifications, central DHW heaters with high water exchange, e.g. in detached and semi-detached houses, or flow systems with a downstream line volume > 3 l must be planned and constructed in such a way that a DHW temperature of ≥ 60 °C and 55 °C is possible at the outlet from the DHW heater at the inlet of the circulation line into the DHW heater. The controller temperature at the domestic hot water heater must be set to 60 °C. If water exchange in the drinking water installation for hot drinking water is ensured within 3 d during operation, operating temperatures can be set at ≥ 50 °C. Avoid operating temperatures < 50 °C. The operator must be informed about the possible health risk (legionella proliferation) during commissioning and instruction (DIN 1988-200:2012).
- For small systems, a temperature of 60 °C is recommended; Operating temperatures below 50 °C should be avoided in any case. (DVGW worksheet W 551).
- Decentralized flow heaters can be used without further requirements if the downstream line volume does not exceed 3 liters. (DVGW worksheet W 551, DIN 1988-200 Sect. 9.7.2.4).
- Decentral DHW heaters, which serve to supply one tap (individual supply), can be operated without further requirements. In the case of decentralized DHW storage

[7] In DIN 1988-200, the term “large systems” is not used. The requirements listed here apply in DIN 1988-200 for central DHW heaters.

heaters, which serve the supply of a group of withdrawal points (group supply), e.g. inside a bathroom of an apartment, the drinking water temperature at the outlet from the DHW cylinder must be ≥ 50 °C. (DIN 1988-200: 2012 Sect. 9.7.2.4)

- As already mentioned, in principle, it is also possible to ensure drinking water hygiene with other technical measures and procedures. In these cases the perfect conditions must be proven by microbiological tests. (DIN 1988-200:2012)
- Circulation pipe:
  - Circulation systems must be installed in large systems and pipeline contents > 3 l between DHW heater outlet and the remotest exit point. As an alternative to the circulation line, trace heating systems (self-regulating temperature retaining strips) can be installed.
  - Exception: Floor and/ or individual supply lines with a water content <= 3 l can be carried out without circulation line/ heat tracing (DVGW worksheet W 551). (DIN 1988-200: 2012)
  - The circulation system[8]/ trace heating must be operated in such a way that the water temperature in the system does not drop by more than 5K below the temperature at the outlet.
  - In hygienically perfect conditions, circulation pumps can be switched off for a maximum of 8 hours in 24 hours. (DVGW worksheet W 551, DIN 1988-200: 2012 Sect. 9.7.2.5))

There are further requirements for the temperature in domestic hot water installations for reasons of comfort and requirements for the discharge times (maximum time until water with useful temperature flows out of the extraction point):

- 30 s after full opening of a sampling point, the water temperature should not be lower than 60 °C for hot water supply points, unless contrary to local or national regulations (DIN EN 806-2, 3.6)
- During normal operation, the temperature of the drinking water must be at least 55 °C for a maximum of 30 s after full opening of an extraction point. Exceptions are the DHW heaters with high water consumption and decentralized DHW heaters. (DIN 1988-200: 2012, section 3.6).
- According to a court ruling (file reference 102 C 55/94 District Court Berlin-Schöneberg 29.04.1996) warm water must flow after 45 seconds at the latest 10 seconds, with a maximum of 5 liters of water consumption from the sampling point.

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[8] After domestic water meters, circulation pipes must not be installed.

- VDI 6003: 2012 lists comfort criteria for three different requirement levels, including discharge times for the individual sanitary objects at the specified service temperature.

Obligation to Investigate

The Drinking Water Ordinance (TrinkwV 2001)[9] [10] specifies specifications for the quality, treatment and monitoring of drinking water and specifies obligations for operators of drinking water installations. The operators of drinking water installations, in which there is a large-scale system for drinking water heating, which is supplied from this drinking water as part of an exclusively commercial activity (e.g. in apartment buildings), must have the drinking water routinely examined every three years. If concentrations of legionella above the technical value of the measure are determined, further investigations, a risk analysis and follow-up examinations as well as the notification to the health authority are necessary.

Specifications for the hygienic-microbiological examination and evaluation are listed in DVGW worksheet W 551 and the VDI/ BTGA/ ZVSHK 6023 Part 2 also provides assistance for the professional implementation and documentation of a hazard analysis according to the Drinking Water Ordinance.

Terms used above

In the guidelines (for example Drinking Water Ordinance (TrinkwV 2001) and DVGW Worksheet W 551) systems for DHW heating are subdivided into two categories, large-scale systems and small systems. Large-scale systems are defined by

- combined DHW heater and storage or central DHW pass heater, each with a capacity of more than 400 l and / or
- a water volume of more than 3 l in at least one pipeline between the outlet of the DHW cylinder and the withdrawal point (the contents of the circulation line are not taken into account)

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[9] In addition to the Drinking Water Ordinance, the legal basis is the Infection Protection Act (IfSG), which came into force on 01.01.2001, supplemented by the Foodstuffs and Commodities Act.
[10] The Drinking Water Ordinance (TrinkwV 2001) transposes the EC Directive on the quality of water intended for human consumption (Directive 98/83/EC) into national law. When this report is published (December 2017), the Drinking Water Ordinance in the version of the Third Amendment Ordinance of 18 November 2015 applies: The Drinking Water Ordinance specifies requirements for the quality, treatment and monitoring of drinking water and specifies obligations for operators of drinking water installations.

Systems with smaller volumes of water are accordingly classified as small systems[11].

2.4 Incentive Schemes

Marktanreizprogramm (MAP) "Heat from renewable energies" for private individuals

The main incentive program for heat pumps is the Marktanreizprogramm (market incentive programme, MAP) provided by the Bundesamt für Wirtschaft und Ausfuhrkontrolle (BAFA).

Homeowners who switch to a heating system using renewable energies receive high state subsidies: Depending on whether they choose a solar thermal system, a biomass system or a heat pump with geothermal probe, the funding amounts to between 2,000 and 4,500 euros. If you combine several technologies, additional subsidies are added, as is the optimization of the entire heating system.

The "heating package", which is part of the Energy Efficiency Incentive Programme (APEE), offers even more support: If an outdated oil or gas heating system without condensing technology is replaced by a modern heating system that uses renewable energies and combined with a simultaneous review and optimization of the entire heating system, the support may increase by a lump sum of 20%. In addition, a lump sum of 600 euros will be granted as an investment subsidy for the optimization. All in all, a heat pump with geothermal probe and optimization of the heating system can be subsidized by the state with up to 8,750 euros. Funding will be provided for the construction of efficient heat pumps with a nominal heat output of up to and including 100 kilowatts:

- Combined water heating and space heating of buildings
- Exclusive space heating of buildings, if the hot water supply of the building is to a large extent provided by other renewable energies
- Exclusive space heating of non-residential buildings
- Provision of process heat
- Provision of heat for heating networks

Air/air heat pumps and other heat pumps that transfer the heat generated directly to the air cannot be conveyed. Heat pumps for heating water only (hot water or domestic hot water heat pumps) are also not eligible.

For electric heat pumps with air as the heat source, the basic subsidy amounts to 40 euros per kilowatt of installed nominal heat output, but at least 1,300 euros per system. For output-

[11] In addition, systems in detached and semi-detached houses must be regarded as small systems, irrespective of the water volume in the TWE or the pipelines.

controlled and/ or monovalent heat pumps, the basic subsidy amounts to 1,500 euros per system.

If the heat source is earth and water, the basic production rises to 100 euro per kilowatt of installed nominal heat output, at least however on 4.000 euro (heat sources terrestrial heat or water) and/ or 4,500 euro with the heat source terrestrial heat, with simultaneous terrestrial probe drilling. Sorption heat pumps and gas-engine heat pumps are also pumped at the same level.

Drilling companies must be certified according to the quality requirements of the technical rule DVGW W120-2 and provide proof of the conclusion of a no-fault insurance to cover damage caused by drilling.

Technical prerequisites for pumping are the installation of an electricity or gas meter to record all quantities of electricity or fuel absorbed by the heat pump and the installation of at least one heat meter. The measurement of all quantities of heat emitted by the heat pump is required.

The COP value of electrically operated heat pumps and the heating coefficient for gas engine or gas absorption heat pumps must comply with the minimum values specified in the European "Euroblume" eco-label.

For brine/water heat pumps it is at least 3.8 (for space heating in non-residential buildings 4.0), for water/water heat pumps at least 3.8 (for space heating in non-residential buildings 4.0) and for air/water heat pumps at least 3.5. Gas motor heat pumps require proof of the annual heating factor of at least 1.25 (for space heating in non-residential buildings 1.3).

Further eligibility requirements are a hydraulic balancing of the heating system (except 1-circuit systems with direct evaporation by geothermal heat and direct condensation in the heated building) and the adaptation of the heating curve of the heating system to the corresponding building.

Under certain conditions, a combination bonus of an additional 500 euros is possible for the simultaneous construction of a solar thermal or biomass plant. Additional 500 euros can be granted if the system has interfaces to activate the heat pump for use on the grid (load management capability).

The building efficiency bonus of 50% of the basic subsidy can be granted if the facility is built in an efficient (requirements for a KfW Efficiency House 55) residential building that is part of the existing building stock. A KfW-Effizienzhaus 55 consumes 55% of the primary energy of a comparable new building according to EnEV (see chapter 2.2).

For optimization measures in connection with the simultaneous installation of a heat pump an investment subsidy can be granted once ("optimization bonus"). The subsidy amounts to 10 percent of the eligible investment costs (net), but not more than 50 percent of the basic subsidy for the heat pump.

The subsequent optimization of an already subsidized plant, which is between 3 and 7 years old, and the quality control of an existing heat pump are also subsidized.

Further information is available in German language under http://www.bafa.de/DE/Energie/Heizen_mit_Erneuerbaren_Energien/Waermepumpen/Gebaeudebestand/Basis_Zusatzfoerderung/basis_zusatzfoerderung_node.html;

A tabular summary in German language can be found in the file "Förderübersicht Wärmepumpe"
http://www.bafa.de/SharedDocs/Downloads/DE/Energie/ew_waermepumpen_foerderuebersicht.pdf;jsessionid=CA009093A9E9DED4D65C25D76C695FB1.2_cid387?__blob=publicationFile&v=5

Other incentive schemes

The KfW promotional bank offers low-interest loans and repayment subsidies for

- Large heat pumps from 100 kW
- Efficient new buildings (KfW houses),
- All-round modernization and individual refurbishment measures

In addition to the federal government's BAFA and KfW promotion programs, many federal states, municipalities and energy suppliers also offer support for efficient heat pumps. https://www.foerderdata.de/foerdermittel-suche

2.5 Energy Savings Certificates

Building Energy Certificate

According to the German Energy Saving Ordinance, the heating energy consumption of buildings must be shown in building energy certificates. In addition to the markings of primary and final energy demand on the color gradient scale from green to red ("band tachometer"), since 1 May 2014 the energy performance certificate for buildings must also show the energy efficiency class of the entire building on a scale from A+ to H. This system has been established in electrical appliances such as refrigerators or washing machines for many years.

In addition, the seller and landlord are obliged to present the building energy certificate at the time of the inspection. The characteristic values must also be indicated in real estate advertisements. After conclusion of the contract, the building energy certificate must be handed over.

The use of a heat pump can improve the building efficiency class compared to heating with a fossil boiler. However, purely fossil heating systems are not permitted for new buildings anyway.

There are two different types of building energy certificates, the energy demand certificate and the energy consumption certificate. They differ in terms of both quality and price. Owners of properties with more than four residential units can choose freely between the two types of identification. For houses with less than four residential units, the year of construction or the energy status determines whether there is still freedom of choice: House owners whose house was built at least in accordance with the first Heat Insulation Ordinance of 1977 or was renovated accordingly can also choose freely between the two passes. If the house was not built in accordance with the first Heat Insulation Ordinance, the energy requirement certificate is mandatory.

Energy label for heaters

Since 26 September 2015, energy efficiency labelling according to the EU energy label has also been mandatory for heating appliances throughout the EU. The EU energy label compares the efficiency rates of various water heaters, heaters and heating systems and classifies them on a common efficiency scale.

3. Building stock Characteristics[12]

3.1 German Building Stock

In 2016, the housing stock in Germany will consist of 18.8 million buildings with 39.8 million apartments. Unfortunately there are no detailed data available for 2016 as for 2009, therefore the following figures and tables refer to data for 2009 (Diefenbach and Cischinsky, 2016).

Figure 17 shows the structure of the German housing stock by type of the building in three main categories: Single/ double family houses with one or two flats, small multi-family houses and large multi-family houses with more than 12 flats per building. While only 18 % of the residential building stock are multi-family buildings (MFB), these MFBs count for more than two fifth of the living area in Germany.

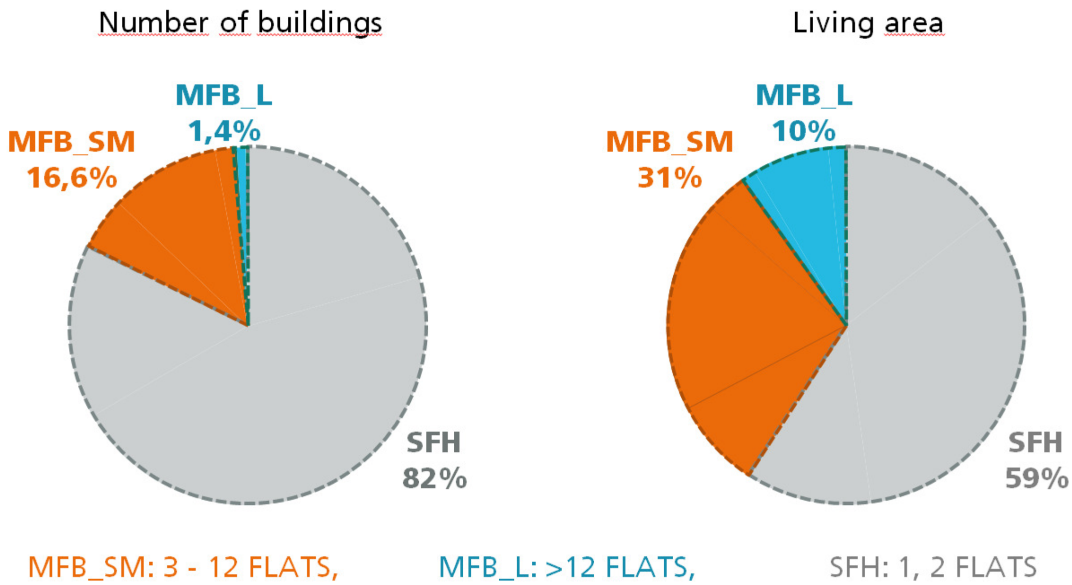

Figure 17 : German Housing Stock Characteristics - German dwelling stock in 2009. Source: [Bürger, V.; Hesse, T.; Quack, D.; Palzer, A.; Köhler, B.; Herkel, S.; Engelmann, P. (2015): Klimaneutraler Gebäudebestand 2050], [CLIMATE CHANGE 06/2016. Umweltbundesamt (Hrsg.). Dessau-Roßlau (ISSN: 1862-4359)].

Table 5 shows the number of multi-family residential buildings/ living units and living space according to German residential building typology, divided by classes of the age of

[12] Sources:
Erarbeitung einer Integrierten Wärme- und Kältestrategie: Arbeitspaket 1 - Bestandsaufnahme und Strukturierung des Wärme- und Kältebereichs; Fraunhofer ISE, 2011;
Datenbasis Gebäudebestand - Datenerhebung zur energetischen Qualität und zu den Modernisierungstrends im deutschen Wohngebäudebestand; IWU; 2010;

construction and gives also mean values for the living space per flat. Figure 18 summarizes these numbers graphically, divides by the categories “small” and “large” MFBs and three age clusters.

TABLE 5: NUMBER OF MULTI-FAMILY RESIDENTIAL BUILDINGS/LIVING UNITS AND LIVING SPACE ACCORDING TO GERMAN RESIDENTIAL BUILDING TYPOLOGY, STATUS: MAY 2011, SOURCES: [LOGA, T.; STEIN, B.; DIEFENBACH, N.; BORN, R. (2015): DEUTSCHE WOHNGEBÄUDETYPOLOGIE. BEISPIELHAFTE MAßNAHMEN ZUR VERBESSERUNG DER ENERGIEEFFIZIENZ VON TYPISCHEN WOHNGEBÄUDEN. 2. ERWEITERTE AUFLAGE. DARMSTADT: INSTITUT WOHNEN UND UMWELT GMBH (IWU).; DIEFENBACH, NIKOLAUS: BASISDATEN FÜR HOCHRECHNUNGEN MIT DER DEUTSCHEN GEBÄUDETYPOLOGIE DES IWU; IWU, OKTOBER 2013].

MFB_SM (3 to 12 flats)							
Class of the age of construction			Number of buildings	Number of flats	living area [m²]	flats per building	Living space per flat [m²]
A	…-	1860	54.000	214.000	16.000.000	4	74.8
B	-1861	1918	442.000	2.177.000	163.000.000	5	74.9
C	-1919	1948	388.000	1.911.000	129.000.000	5	67.5
D	-1949	1957	356.000	2.003.000	125.000.000	6	62.4
E	-1958	1968	586.000	3.348.000	225.000.000	6	67.2
F	-1969	1978	412.000	2.313.000	169.000.000	6	73.1
G	-1979	1983	146.000	852.000	64.000.000	6	75.1
H	-1984	1994	309.000	1.826.000	133.000.000	6	72.8
I	-1995	2001	244.000	1.390.000	104.000.000	6	74.8
J	-2002	2009	85.000	461.000	39.000.000	5	84.6
A-J	…-	2009	3.022.000	16.495.000	1.167.000.000	-	70.7

MFB_L (more than 12 flats)							
Class of the age of construction			Number of buildings	Number of flats	living area [m²]	flats per building	Living space per flat [m²]
A	…-	1860	600	11.000	700.000	18	63.6
B	-1861	1918	28.700	526.000	35.800.000	18	68.1
C	-1919	1948	7.400	126.000	7.900.000	17	62.7
D	-1949	1957	17.300	308.000	17.000.000	18	55.2
E	-1958	1968	34.000	818.000	47.100.000	24	57.6
F	-1969	1978	50.100	1.366.000	86.700.000	27	63.5
G	-1979	1983	15.000	356.000	21.900.000	24	61.5
H	-1984	1994	28.700	605.000	34.800.000	21	57.5
I	-1995	2001	20.900	408.000	25.500.000	20	62.5
J	-2002	2009	7.600	151.000	10.400.000	20	68.9
A-J	…-	2009	210.300	4.675.000	287.800.000	-	61.6

As the scope of this Report are multi-family buildings (MFB), Figure 18 shows the distribution of types of MFBs – in two categories with up to 12 flats and more than 12 flats per building – and in three age categories – construction date earlier than 1949, from 1949 to 1994 and newer than 1995, both in numbers of buildings and living area.

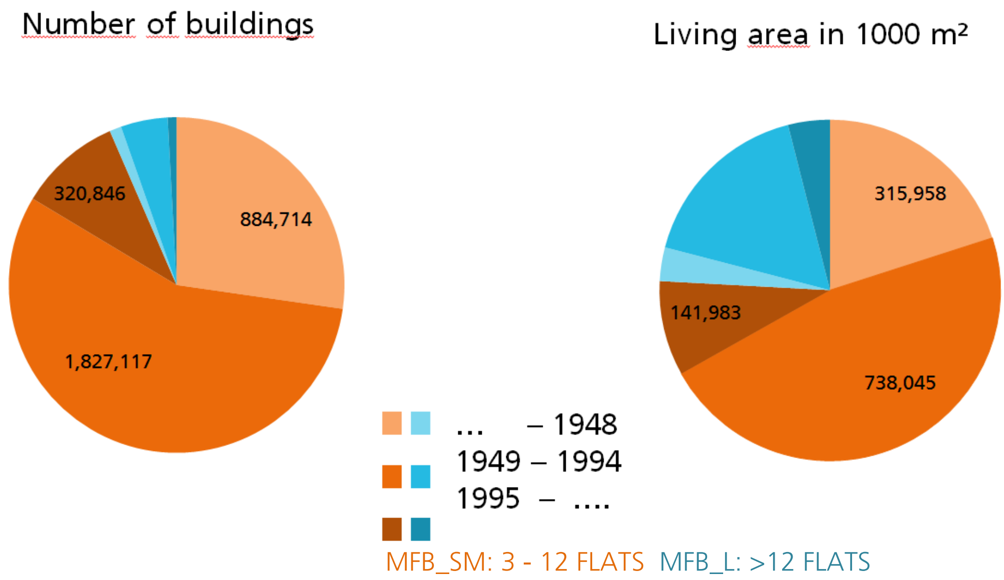

Figure 18: German Housing Stock Characteristics - type and age of MFB. Source: [Bürger, V.; Hesse, T.; Quack, D.; Palzer, A.; Köhler, B.; Herkel, S.; Engelmann, P. (2015): Klimaneutraler Gebäudebestand 2050. CLIMATE CHANGE 06/2016. Umweltbundesamt (Hrsg.). Dessau-Roßlau (ISSN: 1862-4359)].

Compared to 2016, in 2009 there is a total living space of 3.415 million square meters in Germany distributed among 39.4 million homes in 18 million residential buildings.

With a share of 83% one- and two-family homes are predominant. These building types represent 47% of the number of buildings or 59% of the living space in Germany.

Figure 19 shows the structure of the German housing stock by type of the building and its age. Round about 52% of the buildings (50% of the living area) has been built before 1969 and 31% of the building (34% of the living area) within the time period from 1969 to 1995. Considering the segment of one- and two-family houses and the one of small and middle multi familiar houses separately, there is just a slight difference regarding the distribution of the building stock to one or the other of the mentioned building age classes.

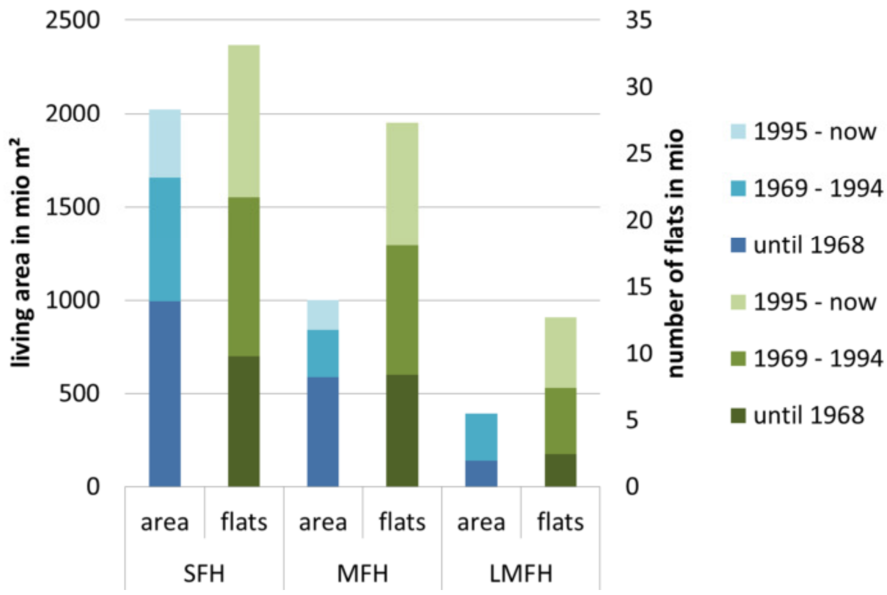

Figure 19: German Dwelling Stock in 2009 by Type (*) and Age (*)SFH: single or douple family house ((semi)detached / raw houses); MFH_SM: small and mittle sized multy family house (3 - 12 flats); MFH_L: large multy family house (more than 12 flats); note: in the class "1996 – now" buildings of the segment MFH_L are allocated to MFH_SM because the segmentation would be to inaccurate. Source: [Erarbeitung einer Integrierten Wärme- und Kältestrategie: Arbeitspaket 1 - Bestandsaufnahme und Strukturierung des Wärme- und Kältebereichs; Fraunhofer ISE, 2011].

3.2 Customer types

The dwelling stock is dominated by individual owners. 96% of the single or double family houses are owned by individual owners and 51% of the multi-family houses. The other multi-family houses are owned by housing companies, including housing associations (29%), by owner companies (19%) and others (2%). Related to the number of the flats the allocation is as follows: Individual owners 33%, housing companies 39% and owner companies 27%. Source: Annex 42; 2014.

Compared with the numbers identified in Annex 42 (2014), some changes in the proportion of customer types have occurred by 2016. Individual owners continue to dominate the dwelling stock, the share for single or two-family houses is still 96%, but the share of multi-family houses in individual ownership fell to 40.5% (51% before). The housing companies own the remaining multi-family houses, 33.6% the housing companies, 23.5% the owner companies and the remaining 2.3% the others (e.g. church). The updated shares for the apartments in Germany are as follows: Housing associations 35.6%, individual owners 30.6% and owner companies 31.8% (Diefenbach and Cischinsky, 2016).

3.3 Energy for heating & Domestic Hot Water in the Building Stock

3.3.1 Space heating

3.3.1.1 Heating demand

In 2010, less than 5% of the domestic buildings have a primary energy demand which accounts to not more than the requirements for new buildings given in the EnEV 2009 (German implementation of the EPBD). The edition of the EnEV in 2009 permitted a maximum of 80 to 90 kWh/(m²*a) primary energy demand[13].

Half of the building stock have had a primary energy demand of more than 260 kWh/(m²*a) and 20% have had a primary energy demand of more than 375 kWh/(m²*a).

For new buildings, the requirements specified in the EnEV regulation are binding. In the event that the buildings have a higher energy efficiency standard, the Kreditanstalt für Wiederaufbau (KfW Reconstruction Loan Corporation) provides subsidies for the construction. Specific KfW standards that exceed the requirements of the EnEV must therefore be met. For the buildings erected in Germany between 2010 and 2016, 78.5 %, i.e. more than three quarters of the new buildings, reached an efficiency house standard and of these only slightly more than half (41.9 %) received subsidies. Only 21.5% of new buildings do not meet any of the efficiency house standards and only meet the EnEV requirements.

The energy requirement for heating buildings has developed over time. Figure 20 illustrates the development of the approximate heat demand of buildings in Germany from 1859 to 2009 for single and multi-family houses. In general, the heat demand decreases with the newer buildings in their original condition. But for renovated buildings, the energy demand for heat is almost the same regardless of the year of construction. For multi-family buildings built between 1918 and 2009, the energy consumption is more or less at the same level, depending only on the renovation intensity ("conventional" or "future-oriented"). In the case of single-family houses, the heat demand of renovated buildings shows only minor differences between the years of construction, but is almost constant. The regulations concerning the heating in new buildings are listed in chapter 2.

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[13] As reference area 0.32 * V_{heated} is used.

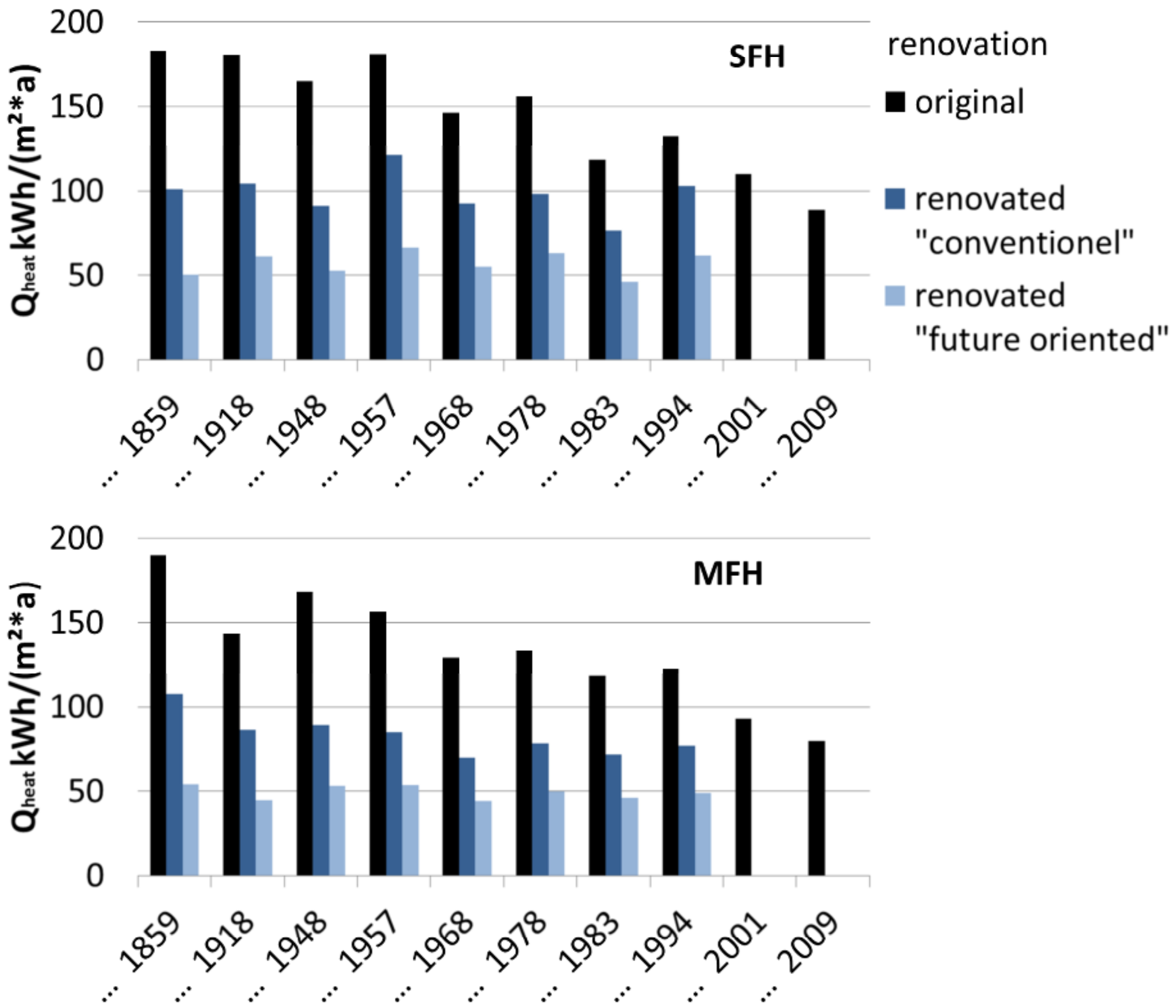


Figure 20: Approximated heating demand divided by year of construction and level of renovation for an exemplary SFH (240 m² heated living area) and an exemplary MFH (4 floors, 34 flats) Note 2: status of insulation/glazing "original" * / "conventional" / "future oriented": e.g. for wall in SFH build 1959 – 1968: 1,2 / 0,23 / 0,13 W/(m²*K); * only for insulation no renovation has been taken into account but for windows a replacement to wooden double glaze is assumed. Source: [TABULA: Deutsche Gebäudetypologie - Beispielhafte Maßnahmen zur Verbesserung der Energieeffizienz von typischen Wohngebäuden; IWU; 2011].

3.3.1.1 Insulation

Thermal Insulation plays a significant role in making buildings more energy-efficient by reducing energy losses. Table 6 shows the statistics for thermal insulation in multi-family buildings in Germany, subdivided into the building components external wall, roof/upper floor and floor/cellar ceiling as well as the time of construction. Comparing new buildings from 2010 to 1978, they show higher thermal insulation in each category. For example, the exterior wall is insulated in 79.9% of cases, compared to 52.1% for old buildings. There is also a trend towards more thermal insulation in terms of insulated surfaces and insulated component areas; new buildings have insulated more than 90% of the surface in all three categories. For the insulated component area, new buildings have significantly higher insulation compared to the overall average of the building stock with 77.2% for the exterior wall compared to 44.4%. In the IWU report 2016[14], the same data are also available for single-family houses. In addition, the report provides more detailed data on subsequent thermal insulation and region-specific data.

TABLE 6: MULTI-FAMILY BUILDINGS WITH THERMAL INSULATION. SOURCE: [DATENBASIS GEBÄUDEBESTAND - DATENERHEBUNG ZUR ENERGETISCHEN QUALITÄT UND ZU DEN MODERNISIERUNGSTRENDS IM DEUTSCHEN WOHNGEBÄUDEBESTAND; IWU; 2016].

	External wall	Roof/upper floor	Floor/cellar ceiling
	Residential building with insulation of the relevant component		
All residential buildings	54.3%	81.8%	37.0%
Old buildings built up to 1978	52.1%	78.4%	28.9%
New buildings from 2010 onwards	79.9%	98.9%	92.0%
	Insulated surface areas (if insulation available)*		
All residential buildings	81.6%	93.2%	91.3%
Old buildings built up to 1978	76.0%	90.7%	85.4%
New buildings from 2010 onwards	96.6%	99.7%	92.0%
	Insulated component area (building weighted with area shares)		
All residential buildings	44.4%	76.2%	33.8%
Old buildings built up to 1978	39.6%	71.1%	24.7%
New buildings from 2010 onwards	77.2%	98.6%	89.8%

Important for the effectivity of the thermal insulation is the thickness of the insulation materials. For the German building sector Figure 21 can give an overview of the insulation thickness of the external wall for all residential buildings subdivided into three age classes (old buildings up to 1978, years 1979-2009, new buildings from 2010). The diagram shows the proportionate distribution of insulation thicknesses within the respective building age class, i.e. the columns for one and the same building age class add up to 100 % in each case. The left-hand column describes the situation for all residential buildings with external wall insulation: About 4% have insulation thicknesses of up to 2 centimeters (cm) and 21% of 3-5 cm. In the categories 6-9 cm and 10-13 cm, the percentages are highest at 30% and 27%. Around 11% of buildings have insulation thicknesses of 14-17 cm, in the 18-21 cm

[14] Datenerhebung Wohngebäudebestand 2016; IWU

class it is around 5%. Higher insulation thicknesses (from 22 cm) are represented only with small portions of altogether approximately 2 %.

With regard to the building age, clear differences are to be recognized as expected: While, for example, in old buildings almost one third of the walls are insulated with a maximum of 5 cm, in newer buildings the higher insulation thicknesses occur proportionately more frequently. In the new building - if insulating materials were used with the exterior wall insulation - material thicknesses of 14 cm and more are represented with a portion of about two thirds.

In the IWU report also data for insulation thicknesses of other building components (roof/upper floor and floor/cellar ceiling) are available. Furthermore, data for installed and renovated windows in all German residential buildings are available. Considered types of windows are single-, double- and triple-glazing.

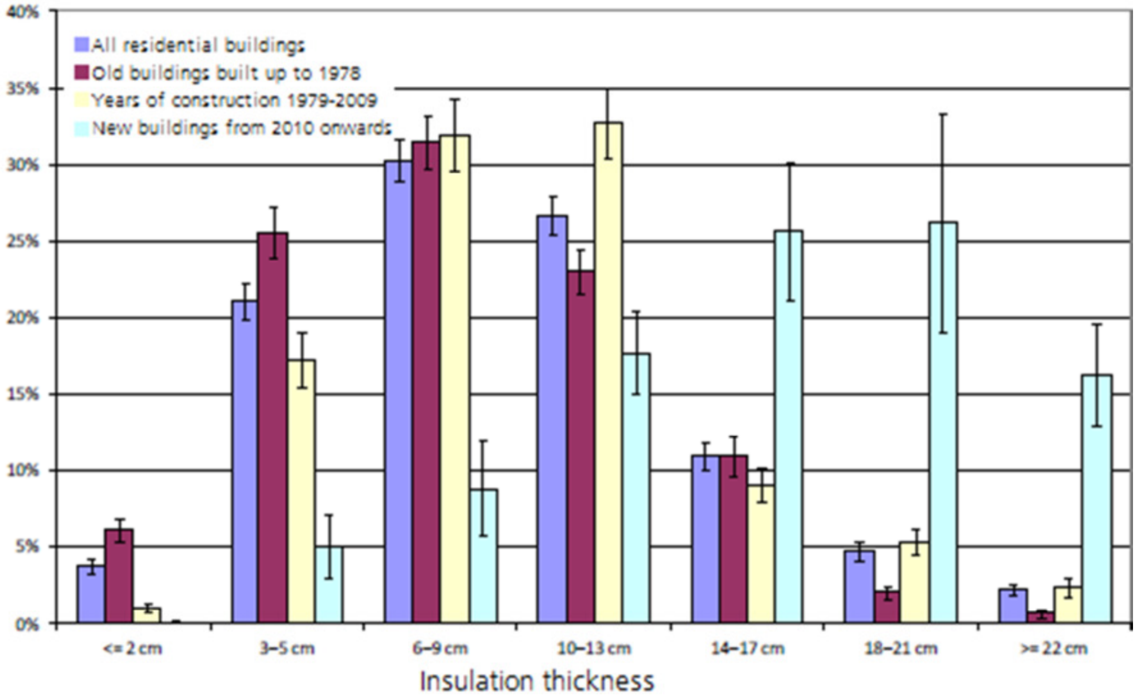


Figure 21: Thickness of insulation material for external wall insulation (all types of insulation). Source: [Datenbasis Gebäudebestand - Datenerhebung zur energetischen Qualität und zu den Modernisierungstrends im deutschen Wohngebäudebestand; IWU; 2016].

3.3.1.2 Renovation

In order to improve the energy efficiency of existing buildings, insulation can be renovated and modernised. Especially for older buildings, this can be an effective way to reduce the energy consumption in the building. To get an overview for multi-family houses, Table 7 shows the annual modernisation rates from 2010 for thermal insulation in buildings built before 1978. It refers to the renovation of the exterior wall, roof, floor and windows. These data show that the renovation of windows at 2.15% per year (2010-2016) and the roof at 2.78% in old multi-family buildings is more focused than the renovation of the external wall (1.21%) or the floor (0.76%). In general, the renovation rate for all four categories was the highest in the 2010-2012 volume. The annual rate then fell in all four cases. In addition, the IWU report also includes data for single-family houses and all buildings built after 1978.

TABLE 7: AVERAGE ANNUAL AREA-WEIGHTED MODERNIZATION RATES FOR THERMAL INSULATION IN OLD BUILDINGS UP TO CONSTRUCTION YEAR 1978 - MULTIFAMILY BUILDINGS. SOURCE: [DATENBASIS GEBÄUDEBESTAND - DATENERHEBUNG ZUR ENERGETISCHEN QUALITÄT UND ZU DEN MODERNISIERUNGSTRENDS IM DEUTSCHEN WOHNGEBÄUDEBESTAND; IWU; 2016].

	Average annual modernization rates for thermal insulation (with weight per unit area) in multi-family buildings			
	External wall	Roof/upper floor	Floor/cellar ceiling	Windows
2010-2012	1.47%	3.41%	0.98%	2.34%
2013-2015	1.15%	2.54%	0.77%	1.85%
2010-2015	1.31%	2.97%	0.88%	2.09%
2010-2016[15]	1.21%	2.78%	0.76%	2.15%

3.3.2 Domestic Hot Water

In the absence of comprehensive studies on the real energy demand for TW heating in Germany, the authors of the Country Report quote typical design recommendations from guidelines and standards applied in Germany.

The energy demand for domestic hot water for larger apartment buildings or for multi-family buildings is based on various standards. The data relate to person-specific values in some cases and to living area-specific values in others.

Table 8 shows the mentioned energy requirements for domestic hot water. For a better comparability, the characteristic values of the VDI guidelines VDI 6002 Part 1 and VDI 2067 Part 12 were converted from personal to area-specific data and the other way around. The calculated values are written in brackets. The value of 30 m² living space per person proposed by (Jürgen Zeisberger 2017) was used as the calculation key between area and personal data. This assumption is based on data from the “Statistisches Bundesamt” of 2011, where the average living space per person for single-person and senior households is 42.7

[15] Until the date of data collection

m². The average value for housing units with several residents, such as couples with at least one child, is 30.2 m² [Statistisches Bundesamt, 2011].

TABLE 8: OVERVIEW OF VARIOUS CONSUMPTION PARAMETERS FOR DOMESTIC HOT WATER HEATING. THE VALUES IN BRACKETS ARE CONVERTED FROM THE SOURCE SPECIFICATION WITH A CONVERSION KEY OF 30 M²/PERS. VALUES WITHOUT BRACKETS ARE ORIGINAL VALUES FROM THE SOURCE. SOURCE: [DATENBASIS GEBÄUDEBESTAND - DATENERHEBUNG ZUR ENERGETISCHEN QUALITÄT UND ZU DEN MODERNISIERUNGSTRENDS IM DEUTSCHEN WOHNGEBÄUDEBESTAND; IWU; 2016].

Source	Specific useful energy demand Q_{DHW} [kWh/(m²·a)]	Specific useful energy demand $Q_{DHW,P}$ [kWh/(Pers·a)]	Daily amount of water per person at 60 °C [l/(Pers·d)]
DIN V 4701 – 10 [16,p. Fehler! Textmarke nicht definiert.] (02/2004) (EnEV 2016)	12.5	(375)	28.75
DIN V 18599[17,p. 41] – 10 (10/2016)	15.0	(450)	(21.3)
DIN EN 13203 – 2[18,p. Fehler! Textmarke nicht definiert.] (08/2015)	(25.3)	(760)	36
	(23.5)	(706.0)	33.4
	(46.9)	(1407.7)	66.6
DIN EN 15450[19, p. 41] (12/2007)	17.6	(528.4)	25
VDI 2067 Blatt 12[20, p. 41](09/2012)	(ca.15.3)	460	(21.8)
VDI 3807-3[21] (11/2015)	(17.4)	(518.9)	26.0
VDI 6002[22, p. 41] Blatt 1 (03/2014)	(18.9)	(568.2)	26.88

[16] DIN V 4701-10: Standard applies to buildings with normal internal temperatures in the sense of the EnEV (TInnen ≥ 19 °C); serves to determine the energy requirement at an early planning stage. The annual demand values determined according to this procedure cannot be used for dimensioning individual components. Average location in Germany according to DIN V 4108-6 (tTW = 350 d/a); θK = 10 °C; Conversion of the daily water quantity per person to 60 °C; Water volume from original source: VWW = 23 l/(Pers·d) at 50 °C; Assumption: EnEV area AN = 0.32·Ve; Here a usable area per person of 48,61 m² is taken as a basis (self-calculated PRe).

[17] DIN V 18599 is suitable for determining the long-term energy demand for buildings or parts of buildings and for estimating the possible uses of renewable energies for buildings; applicable for residential and non-residential buildings, new buildings and existing buildings; calculation according to formula: qw,b = max[16.5-(ANGF,WE,m·0.05);8.5]kWh/(·a); assumed for ANGF, WE, m 30 m²; annual days of use: dUse,a: 365 d/a; θK = 10 °C

[18] DIN EN 13203-2: Cold water temperature: 10 °C; ambient air temperature: 20 °C; profiles: S (average daily tap pattern for 1 person), M (average daily tap pattern for family with shower use), L (average daily tap pattern for family with 3 persons with bathtub and shower use)

[19] DIN EN 15450: Standard takes into account the heating requirements of all connected systems (e.g. DHW) that are decisive for the planning of heat generation, but does not cover the planning of these systems; θK = 10 °C; Spec. useful energy requirement specified as 1.45 kWh/(Pers·d)

[20] VDI 2067-12: Guideline regulates the calculation of the energy consumption of hot water production systems. θK = 10 °C; dUse,a: 345 d/a; θw = as a rule 45-60 °C (depends on the type of system and the location in the system).

[21] VDI 3807-3: The reference area is the sum of all heatable gross floor areas of a building and is calculated according to BGF = (n+m)·a·b. n: Number of storeys; m: Number of basements; a,b: Area dimensions; θW converted from 50 °C to 60 °C, original value: 11.2 m²/(Pers·a); θK = 10 °C assumed; dUse,a: 345 d/a;

[22] VDI 6002-1: The guideline deals with the solar support of domestic hot water heating and indicates demand values for domestic hot water heating. With 30 m² living space per person; For comparability with the other table values, θK = 12 °C from the original source on θK = 10 °C was set for calculation

The demand characteristic values for hot water supply depend strongly on the user behaviour and are therefore only rough guide values. The values given in

Table 8 are those suggested by the relevant standards. The footnotes contain the boundary condition or what was taken into account during the conversion. To show how user behaviour influences the demand, Table 9 shows the demand for different user behaviour.

TABLE 9: PERSON-SPECIFIC HOT WATER AND ENERGY DEMAND PARAMETERS. SOURCE: [VDI 2067-4].

	Special hot water demand		Specific energy requirements	Annual energy demand
	$T_{DHW,45°C}$	$T_{DHW,60°C}$	$Q_{DHW,Pers,d,60°C}$	$Q_{DHW,Pers,a,60°C}$
	[l/(Pers·d)]	[l/(Pers·d)]	[Wh/(Pers·d)]	[kWh/(Pers·a)]
Low demand	15-30	10-20	600-1200	207-414
Medium demand	30-60	20-40	1200-2400	414-828
Very high demand	60-120	40-80	2400-4800	828-1656
				mit 345 d/a

3.4 Space heating types[23]

In 2016 central heaters (one heater in the building) represent the most common heating system in domestic buildings (85.6% in one- or two-family houses (SFH) and 56.9% in multi-family houses (MFH)). In MFH the two further relevant heating systems are district heating (18.6%) and flat-wise heaters (14.1%). The share of room-wise heaters (most of them biomass heaters or direct electric heaters) is about 5.3% in one- or two-family houses and 4.3% (most of them oil or gas heaters) in MFH. The mentioned proportions of heating systems in the German building sector are illustrated in Figure 22.

In table 9: MFH with > 40 pers; 28 litres per person corresponds to the course of the day on average over the year

[23] Sources:
Erhebungen des Schornsteinfegerhandwerks; Bundesverband des Schornsteinfegerhandwerks – Zentralinnungsverband (ZIV), 2011;
Erarbeitung einer Integrierten Wärme- und Kältestrategie: Arbeitspaket 1 - Bestandsaufnahme und Strukturierung des Wärme- und Kältebereichs; Fraunhofer ISE, 2011;
Datenbasis Gebäudebestand - Datenerhebung zur energetischen Qualität und zu den Modernisierungstrends im deutschen Wohngebäudebestand; IWU; 2016

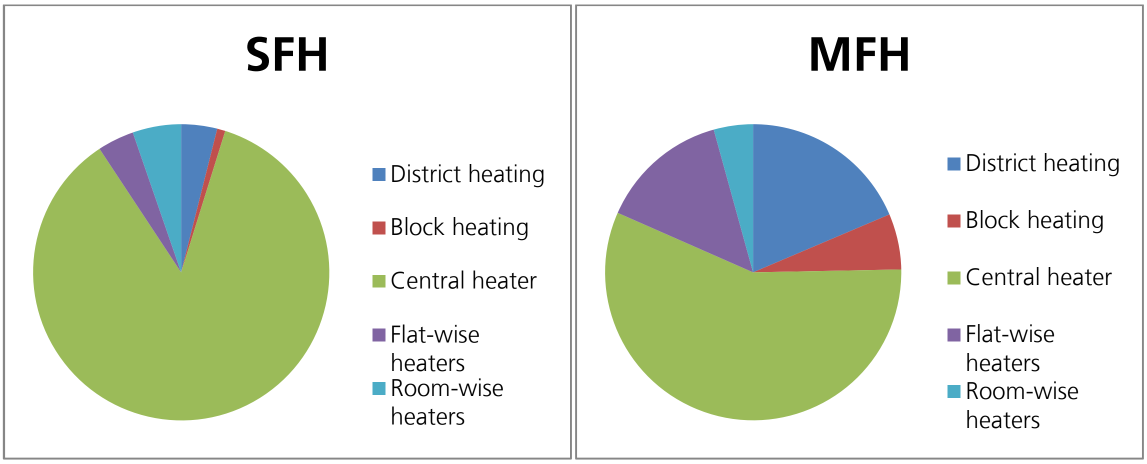


Figure 22: Space heating: Type of heaters. Source: [Datenbasis Gebäudebestand - Datenerhebung zur energetischen Qualität und zu den Modernisierungstrends im deutschen Wohngebäudebestand; IWU; 2016].

Figure 23 shows the energy sources used in SFH and MFH. Natural gas is dominating the heating sector in domestic buildings, over the half of the heating systems are based on it (SFH 51.6%; MFH 56.7%). Heating oil also plays an important role in the moment with shares of 29.5% (SFH) and 17.4% (MFH). District heating mainly plays a role in multi-family buildings with a proportion of 18.6%. In the moment electricity (heat pumps) and biomass only play little role. Together they have shares of 12.9% (SFH) and 6.1% (MFH).

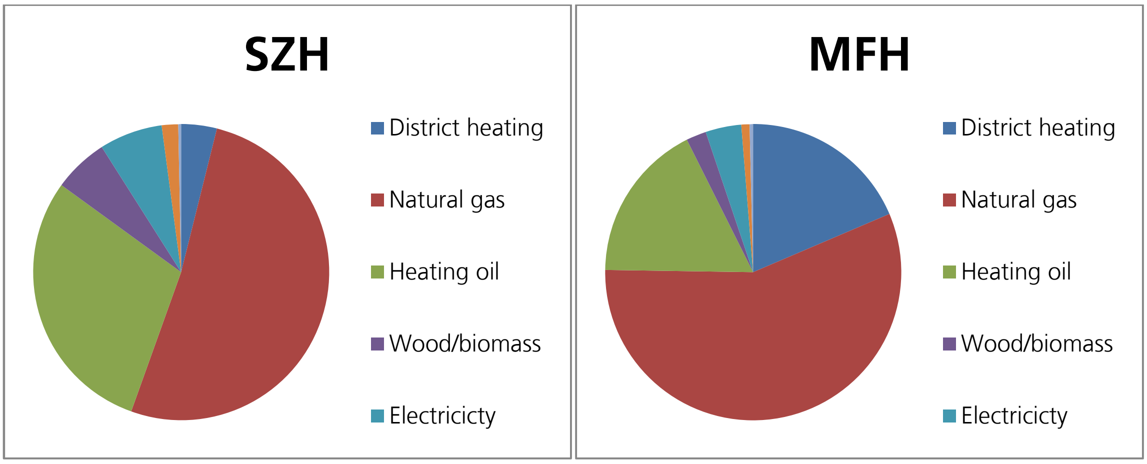
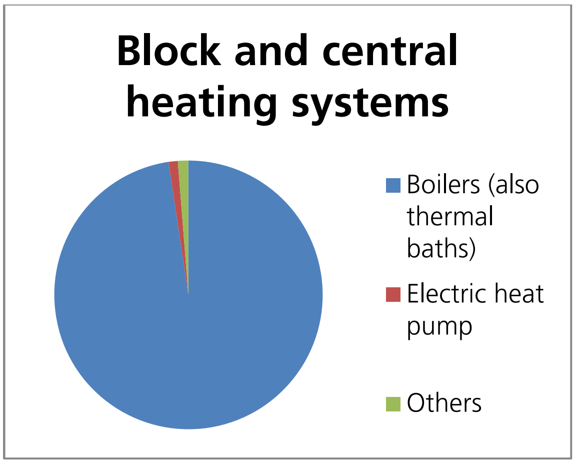


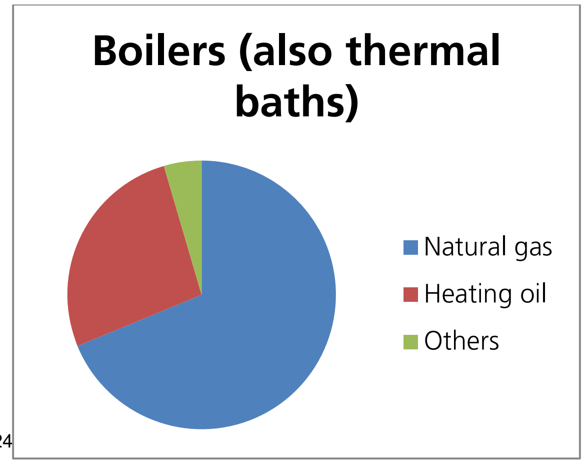
Figure 23: Energy sources for heating. Source: [Datenbasis Gebäudebestand - Datenerhebung zur energetischen Qualität und zu den Modernisierungstrends im deutschen Wohngebäudebestand; IWU; 2016].

Since the central and block heating systems together dominate the heat supply for residential buildings, it may be useful to take a closer look at the structure of these buildings. Figure 24 shows the proportions of the different types used as central or block heating systems in multi-family buildings. Boilers (97.6%) dominate and are mainly based on natural gas (67.1%). Boilers fuelled by heating oil (26.0%) also have a significant share of the total boiler. Electric heat pumps (1.1%) have only a small share of the central and block heating system.

The oven and room-wise heaters are dominated by natural gas with a share of 46.2%, followed by coal (30.8%) and heating oil (15.4%).



[24]



[25]

Figure 24: Block and central heating systems in multi-family buildings. Source: [Datenbasis Gebäudebestand - Datenerhebung zur energetischen Qualität und zu den Modernisierungstrends im deutschen Wohngebäudebestand; IWU; 2016].

Segmenting the heating market by year of construction the trend towards building-wise heaters is evident: In the building stock built before 1978 such heaters have a share of about 77.3% while in new buildings (built after 2010) those heating systems have a share of approx. 87.2%. Besides, the change in the used fuel is evident: In buildings built before 1978 gas was used in little less than half of the buildings and in new buildings it makes up 42.9% while the share of oil decreases from 31.2% to 0.8%. Table 10 shows the shares of the different types of heat generators subdivided in the age of the buildings. Significant is the increase of heat pumps amounting to less than 1% in the mentioned group of old buildings and 39% in the mentioned group of new buildings. The mentioned trend in the heating market (type of heaters and fuels) is also present when considering the substitution of heaters in old buildings. The share of heating oil decreased from the buildings built before 1978 with 30.2% to less than 1% for buildings after 2010 (Diefenbach and Cischinsky, 2016).

TABLE 10: SHARES OF HEAT GENERATORS IN RESIDENTIAL BUILDINGS SUBDIVIDE BY THE CONSTRUCTION TIME. SOURCE: [DATENBASIS GEBÄUDEBESTAND - DATENERHEBUNG ZUR ENERGETISCHEN QUALITÄT UND ZU DEN MODERNISIERUNGSTRENDS IM DEUTSCHEN WOHNGEBÄUDEBESTAND; IWU; 2016].

[24] Others: Wood/Biomass, liquefied petroleum gas and coal
[25] Others: Combined heat and power unit, fuel heat pump, direct-electrical

		Old buildings built up to 1978	Year of construction 1979-2009	New buildings from 2010 onwards
District heating		6.7% +/- 0.8%	5.9% +/- 0.9%	7.1% +/- 1.3%
Block/central heating				
Heating boilers (also thermal baths)	Natural gas	42.7% +/- 1.4%	53.7% +/- 1.7%	41.3% +/- 4.5%
	Heating oil	30.2% +/- 1.2%	23.4% +/- 1.4%	0.8% +/- 0.6%
	Wood/Biomass	4.2% +/- 0.5%	3.9% +/- 0.6%	6.6% +/- 1.5%
	Liquefied petroleum gas	0.8% +/- 0.2%	2.3% +/- 0.5%	1.1% +/- 0.3%
	Coal	0.2% +/- 0.1%	0.1% +/- 0.1%	0.0% +/- 0.0%
Combined heat and power plant	Natural gas/fuel oil/biomass	0.2% +/- 0.1%	0.2% +/- 0.1%	0.8% +/- 0.3%
Fuel heat pump	Natural gas/heating oil	0.1% +/- 0.1%	0.0% +/- 0.0%	0.1% +/- 0.1%
Electric heat pump	Electricity	0.6% +/- 0.2%	3.9% +/- 0.6%	39.0% +/- 4.9%
Direct electric	Electricity	0.1% +/- 0.1%	0.3% +/- 0.1%	0.0% +/- 0.0%
Apartment/floor heating				
Boilers (also thermal baths)	Natural gas	6.4% +/- 0.2%	3.6% +/- 0.2%	0.8% +/- 0.4%
	Heating oil	0.3% +/- 0.1%	0.3% +/- 0.1%	0.0% +/- 0.0%
	Other fuels	0.2% +/- 0.1%	0.3% +/- 0.2%	0.0% +/- 0.0%
Electric heat pump/direct electric	Electricity	0.0% +/- 0.0%	0.0% +/- 0.0%	0.9% +/- 0.4%
Oven/room heating				
Ovens	Natural gas	0.6% +/- 0.2%	0.1% +/- 0.1%	0.0% +/- 0.0%
	Heating oil	0.7% +/- 0.2%	0.0% +/- 0.0%	0.0% +/- 0.0%
	Wood/Biomass	1.6% +/- 0.3%	0.2% +/- 0.1%	0.4% +/- 0.2%
	Liquefied petroleum gas	0.2% +/- 0.2%	0.0% +/- 0.0%	0.0% +/- 0.0%
	Coal	0.3% +/- 0.1%	0.0% +/- 0.0%	0.0% +/- 0.0%
Direct-electric (incl. night storage)	Electricity	4.0% +/- 0.5%	1.6% +/- 0.4%	1.0% +/- 0.4%
In total		100%	100%	100%

In 2016 the housing sector energy needs represent 2,394 PJ or 26.2% of the national final energy consumption (BMWI, 2017). The evolution of the household sector shows an increase between 2014 and 2016.

Table 11 shows the German heating stock in 2012 (Ragwitz et al., 2015). It illustrates the installed capacities in MW. As already identified, oil and gas boiler are dominating.

TABLE 11: GERMAN HEATING STOCK FOR 2012, INSTALLED CAPACITIES IN MW. SOURCE: [RAGWITZ, M. ET AL. (2015): MAPPING AND ANALYSES OF THE CURRENT AND FUTURE (2020 - 2030) HEATING/COOLING FUEL DEPLOYMENT (FOSSIL/ RENEWABLE);, DATA ANNEX, 1: HEATING AND COOLING TECHNOLOGIES IN BUILDINGS - PROCESSED DATA; EUROPEAN COMMISSION (ED.). BRUSSELS. 2015].

	Installed capacities in MW			
	<25 kW	25 - 50 kW	51 - 250 kW	>250 kW
Gas boiler	72,712	31,340	27,036	0
Oil boiler	32,042	76,141	23,856	0
Coal furnace and stove	107	330	0	0
CHPIC	218	144	269	1,053
Direct electric	n.a.	n.a.	n.a.	n.a.
Biomass furnace	889	8	12	0
Biomass stove	30,141	9,664	0	0
Heat pump aerial	2,142	238	n.a.	n.a.
Ground source heat pump	3,060	230	n.a.	n.a.

To have a deeper look on the dominating heating systems based on oil and gas boiler, Figure 25 gives an overview of the year of installation of the oil and gas fired heaters being in operation in 2012. Some more than 60% of those heaters are older than 15 years and round about 5% older than 30 years.

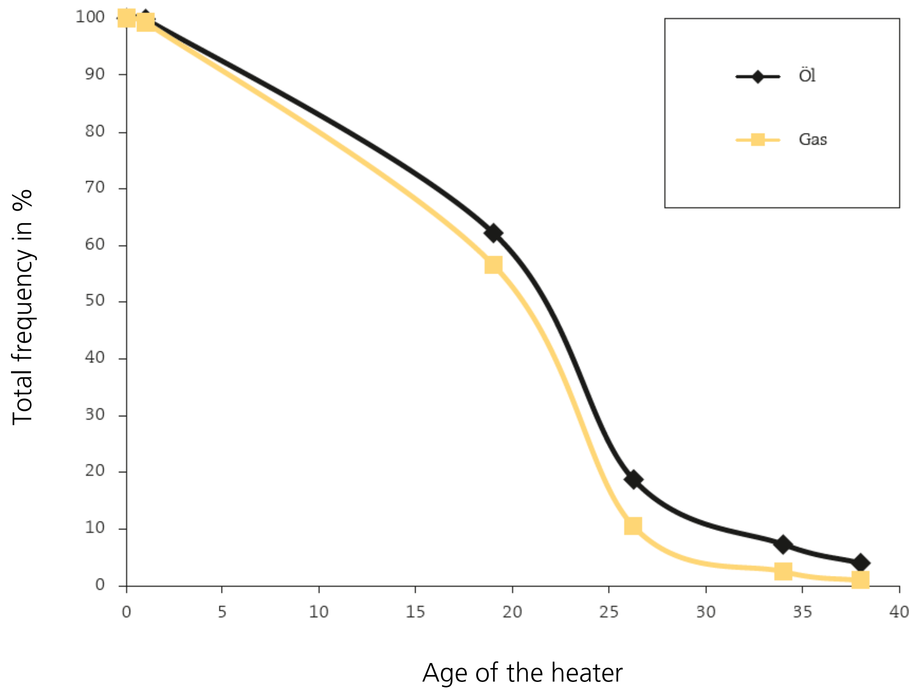


Figure 25: Space heating: age of the installed gas and oil fired heaters (which are subjected to an inspection commitment; roughly speaking heater capacity > 4kW) in Germany in 2016 Source: [Erhebungen des Schornsteinfegerhandwerks; Bundesverband des Schornsteinfegerhandwerks – Zentralinnungsverband (ZIV); 2016].

There are also other investigations besides the IWU report for energy sources in residential buildings. Microzensus 2014 has also recorded the types of energy used in apartments in Germany. There are small percentage differences between the two surveys. When recording current market data, from 2011 to 2015, the figures from the IWU report can be compared with those from the official building statistics. The comparison can be found in Figure 26. The percentage shares here refer to the number of buildings. The two sources show a similar structure of the frequency distribution. However, there are noticeable deviations in detail, especially for gas and environmental heat/heat pumps Similar deviations between the sample survey and construction activity statistics had already been found in the previous 2010 study "Datenbasis Gebäudebestand" (cf. [Diefenbach et al. 2010], p. 88 f.). In this context, the study referred to the general nature of the survey in the construction activity statistics. This takes place primarily at the time of the building permit. Changes after completion of construction can be indicated by the client in a free text field without the individual survey variables (in particular the type of energy) being explicitly queried again. It would therefore at least be conceivable that, for example, a property developer would generally set a certain type of energy (e.g. natural gas) for a building area when a building permit is issued, but in individual cases buyers would opt for a different variant (e.g. heat pump).

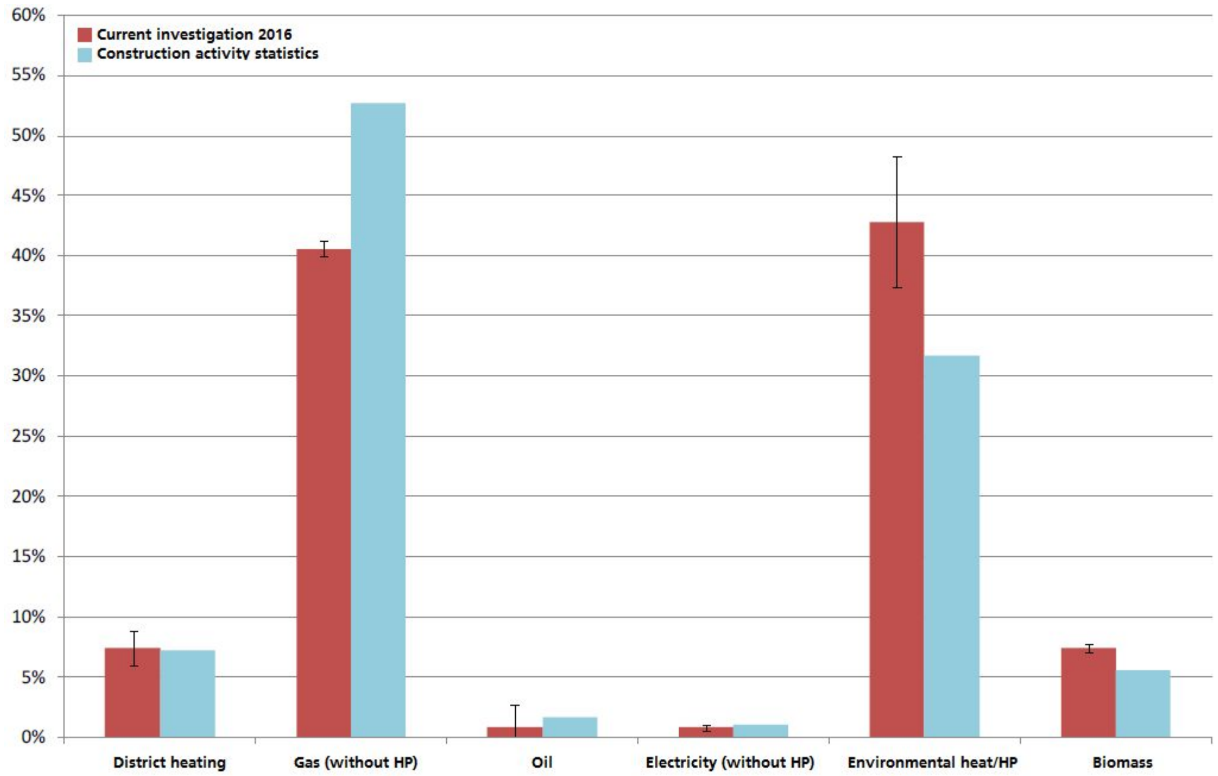


Figure 26: New buildings of the years of construction 2011-2015 according to the predominant energy type of the heating: comparison of the current data collection with the official construction activity statistics. Sources: [Datenbasis Gebäudebestand - Datenerhebung zur energetischen Qualität und zu den Modernisierungstrends im deutschen Wohngebäudebestand; IWU; 2016], [Statistisches Bundesamt: Fachserie 5, Reihe 1 (2011–2015): Bautätigkeit und Wohnungen – Bautätigkeit].

At some point it makes sense to modernize the heating system, with a more efficient and therefore more energy costs effective. Table 12 shows the results for the residential building stock subdivided between old buildings (older than 1978) and newer buildings (1978-2009) and divided by the size of the buildings (Single- and multi-family building). The modernization rate of the heater system (the yearly share of buildings, which renewed the main heater) for residential buildings was about 3.15% in average during the years 2010 to 2015. Considering only the building stock built before 1978 the modernization rate amounts to 3.37%. For the period from 2010 to 2016, the same modernization rate was about 3.05% and for the buildings built before 1978 about 3.27%. The buildings constructed between 1979 and 2009 had a lower annual modernization rate with an average of 2.78% between 2010 and 2015. Single- and multi-family buildings both have modernization rates are nearly at the level of 3% per year. The difference is little, but a little higher for single-family buildings.

Heat pumps accounted for around 0.2% of buildings constructed before 1978 and 1.3% of buildings constructed between 1979 and 2009. But in buildings where the heating system has been modernized since 2010, the shares have increased. Heat pumps have a share of

1.1% instead of 0.2% for old buildings and 2.1% instead of 1.3% for buildings built after 1979 (Diefenbach and Cischinsky, 2016).

TABLE 12: AVERAGE ANNUAL MODERNIZATION RATES OF THE HEAT SUPPLY: RENEWAL OF THE MAIN HEAT GENERATOR (INCLUDING INITIAL CONNECTION TO DISTRICT HEATING). SOURCE: [DATENBASIS GEBÄUDEBESTAND - DATENERHEBUNG ZUR ENERGETISCHEN QUALITÄT UND ZU DEN MODERNISIERUNGSTRENDS IM DEUTSCHEN WOHNGEBÄUDEBESTAND; IWU; 2016].

	Old buildings built up to 1978	Year of construction 1979-2009
2010–2012	3.10% +/- 0.09%	2.53% +/- 0.11%
2013–2015	3.64% +/- 0.10%	3.03% +/- 0.11%
2010–2015	3.37% +/- 0.07%	2.78% +/- 0.08%
2010–2016[26]	3.27% +/- 0.16%	2.69% +/- 0.19%
	SFH	MFH
2010–2012	2.87% +/- 0.08%	2.77% +/- 0.10%
2013–2015	3.54% +/- 0.09%	3.01% +/- 0.10%
2010–2015	3.21% +/- 0.06%	2.89% +/- 0.07%
2010–2016[27]	3.09% +/- 0.15%	2.85% +/- 0.19%

[26] Until the date of data collection
[27] Until the date of data collection

4. Analysis of the German domestic heat pump market[28]

According to the Association for Efficiency and Renewable Energies (BDH), a total of 0.9 million heat pumps were installed in 2016 in Germany. Thus, heat pumps account for about 4% of the total of 20.7 million heat generators (BDH 2017a). The number of stock refers to systems that serve as exclusive and partial heating of rooms (in combination with DHW heating) in all types of buildings, viz. also in non-residential buildings.

Figure 27 shows the annual sales of heating heat pumps (absolute and relative in terms of sales of all heat generators) since 2010 (BWP 2018). Following the small decrease since 2013, sales have risen significantly in the last two years. In 2017, with 78,000 heat pumps, they were 17% higher compared to the previous year. The greatest increase was made by air-to-water heat pumps with an increase of 20% and brine-to-water heat pumps with an increase of 15%. Water-to-water heat pumps show a small decrease. Air-to-water heat pumps, with a market share of 71%, continue to make up the majority of heat pump sales. The “Bundesverband Wärmepumpe e.V.” (BWP) sees the tightening of the energy saving regulations since the beginning of 2016 as well as the good conditions for production as an important reason for the current increase in heat pump sales numbers (BWP 2018). For 2018, the sector association expects stable sales figures. According to Martin Sabel, Director of “Bundesverband Wärmepumpe e.V.”, there are signs that the new construction sector is not growing as fast as in the recent past. At the same time, too few consumers change to renewable heat in building stock due to lower fuel prices (BWP 2018).

The share of heat pumps in total sales of heat generators is still low: In 2016, heat pumps only accounted for 9.6% of all 693,500 sold heat generators (BDH 2017b). In the new building sector, the market share of heat pumps is higher than in the renovation sector. Thus, in the building permits, the construction of one- and two-family houses in 2016 declares a heat pump as the primary heat generator in over 40% of the buildings. For new building projects in the field of multi-family buildings, the proportion is at 20%, so only half of that (StatBa 2017). Despite the relatively high share of new buildings, only 1.8% of all apartments in Germany are heated by heat pumps in 2016 (BDEW 2107).

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[28] Sources:
Positionspapier Smart Grid und Smart Market; BWP; 2012
BWP-Branchenstudie 2013; BWP; 2013
European Heat Pump Market and Statistics Report 2013; EHPA; 2013
http://www.waermepumpe.de

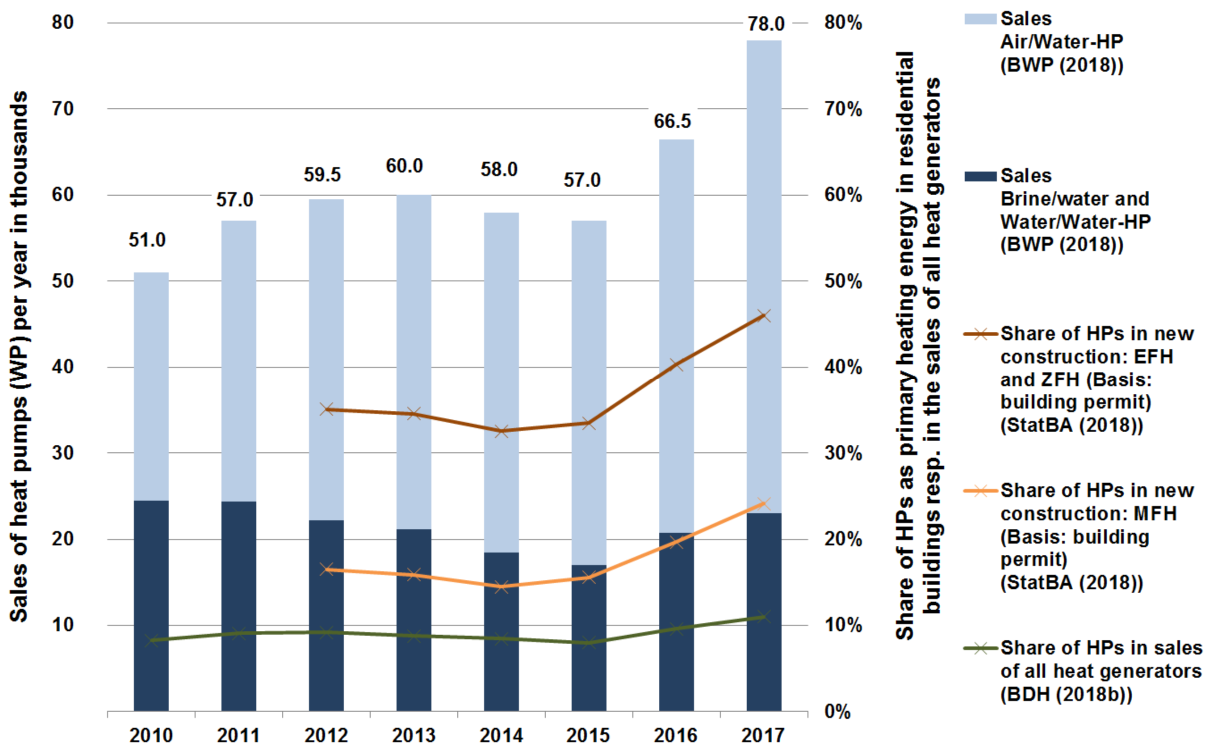

Figure 27: Development of the sales figures and shares of heat pumps as the primary heat generator in the new construction of residential buildings.

Hot water heat pumps, i.e. heat pumps that are exclusively used for the heating of drinking water, are not supported by BAFA. In the illustration and the figures mentioned before, hot water heat pumps are not included. For the sake of completeness, it should be mentioned that their sales volume increased by 8% with 13,500 sold systems in 2017 compared to the previous year (BWP 2018).

There were an absolute Number of 223.000 air-source heat pumps installed in Germany 2012, of which 93% had a capacity below 20 kW and about 7% above this value. Figure 28 shows the relative Distribution of installed heat pumps below and above 20 kW in European Countries (EU-28).

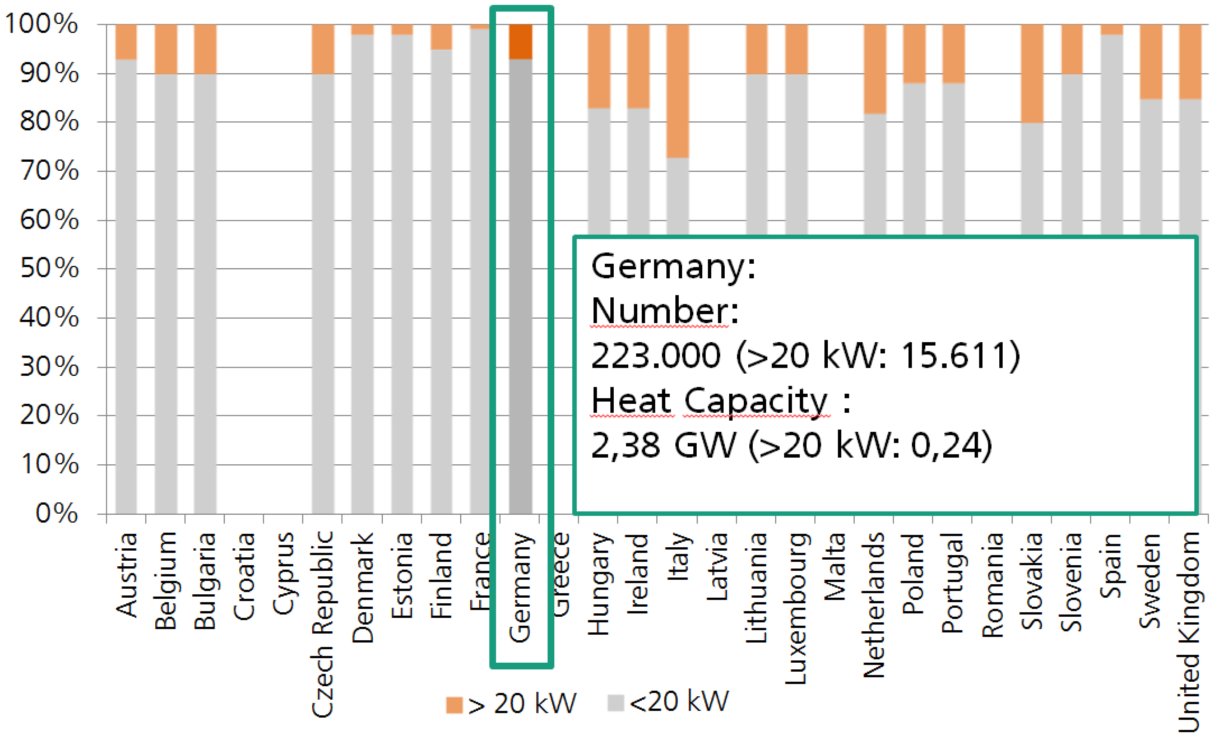

Figure 28 : Distribution of Installed Heat Pumps – Air-Source HP (2012). Source: [Ragwitz, M. et al. (2016): Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/ renewable) – Work package 2: Assessment of the technologies for the year 2012 (Final report March 2016). European Commission (ed.). Brussels].

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Appendix

A.1 Fuel deployment for heating and cooling in selected European countries (all sectors)

Figure 29Figure 13 shows the fuel deployment for heating and cooling in selected European countries for the year 2012. The structure of the heating and cooling systems appears very different when looking at different countries. While technologies based on natural gas supply dominate in the United Kingdom and the Netherlands, biomass stoves and district heat are the important heat suppliers in Poland, e.g..

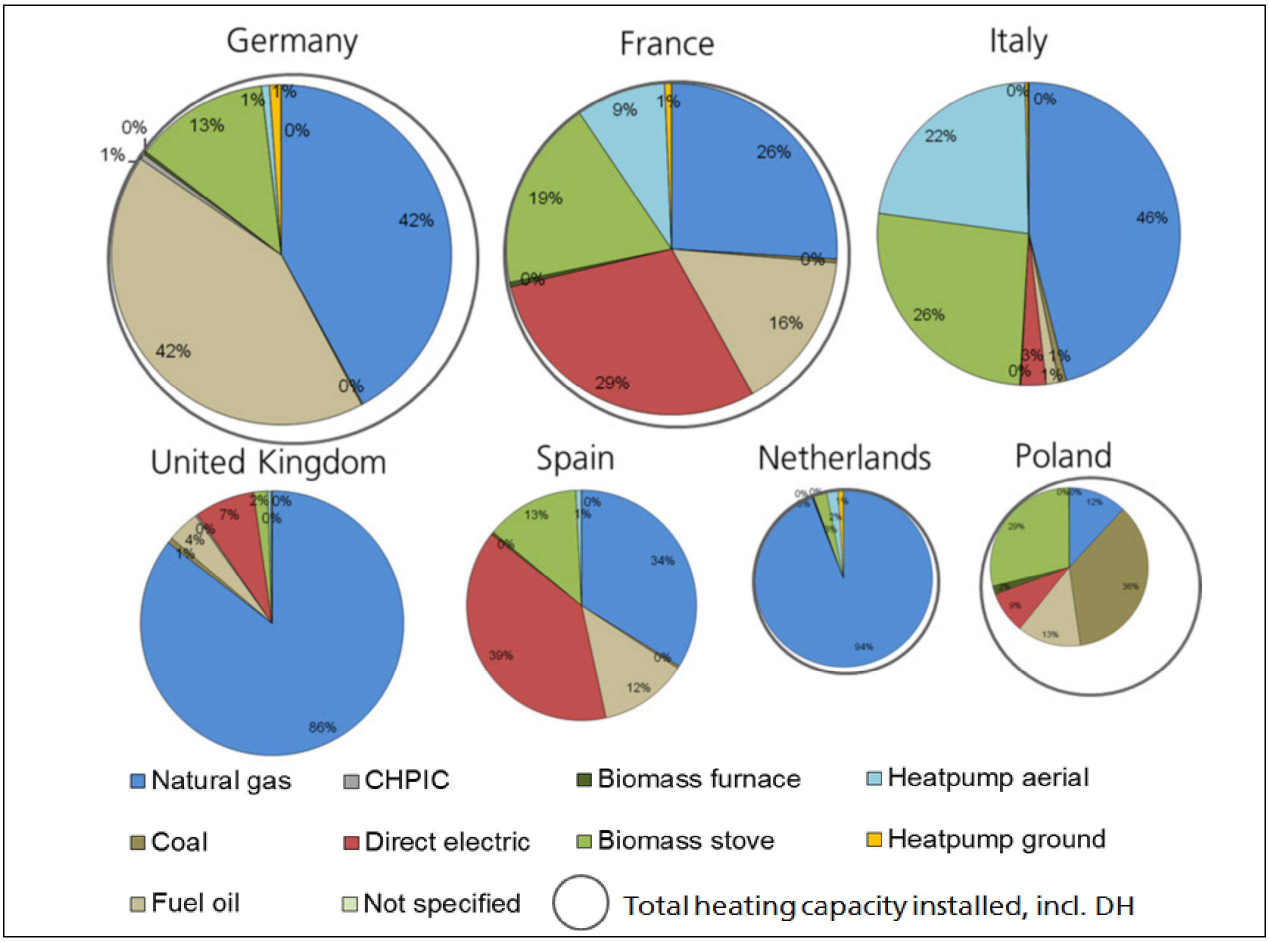

Figure 29: Fuel deployment for heating and cooling in all sectors in selected European countries in terms of installed capacities 2012. Coloured pie charts: individual heating and cooling devices, not considering district heating (DH), black circles: total capacities installed. The Area of pies and cycles is proportional to total capacities. Data source: [4]

Figure 30Figure 13 depicts the fuel deployment for heating and cooling in buildings in 2012 – for all countries in the EU 28. The shares of heat pumps are accentuated in red. In Germany, heat pumps still played a minor role in the heating and cooling technology portfolio in 2012.

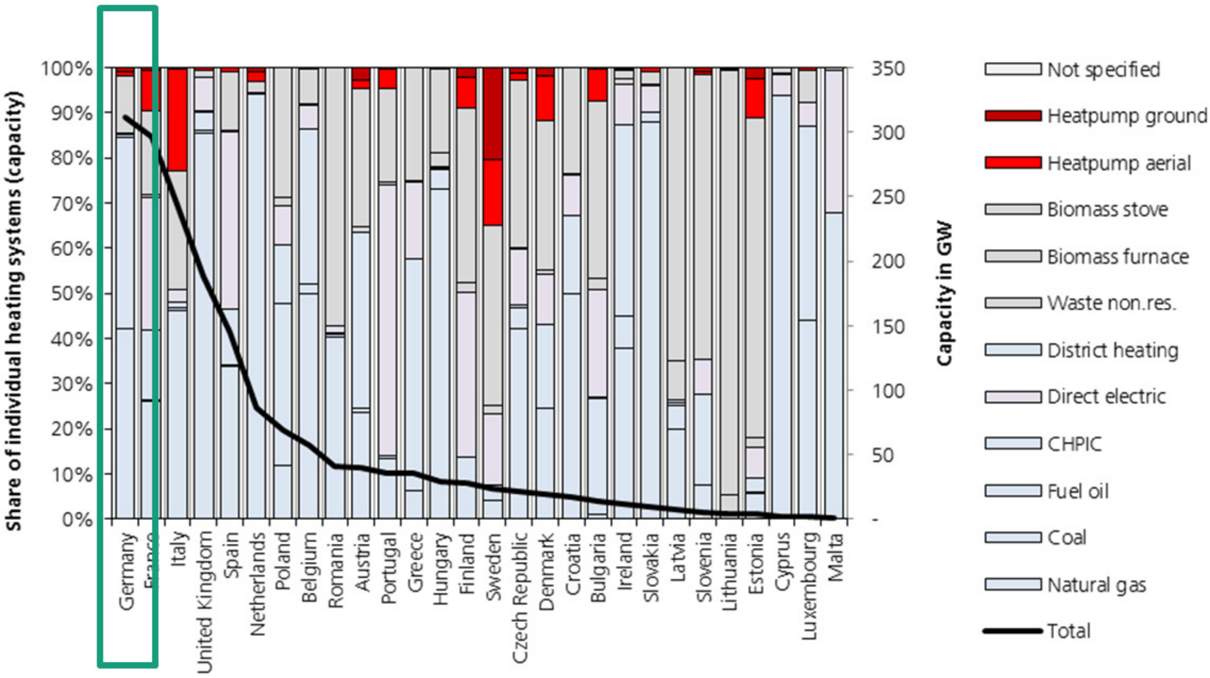

Figure 30 : Mapping of current heating fuel deployment – Capacity (2012). Source: [5]

A.2 European Legislation (texts extracted from EHPA 2016)

A.1 Greenhouse gas emission reduction

A.1.1 F-Gas Regulation

A.1.2 Ecolabel

A.2 Energy efficiency

A.2.1 Energy Efficiency Directive