Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

Annex 42

Heat Pumps in Smart Grids

Market overview: Country report for Germany

Appendix to the Final report

Operating Agent: The Netherlands

2017

Report no. HPT-AN42-2c

Market overview

Country report for GERMANY

Report compiled by

Fraunhofer ISE

Abstract
This appendix provides the detailed summary report discussing the market overview for Germany.

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1 Executive Summary

1.1 Germany energy market context

- 34% of the German final energy is used for space heating and DHW. Within this field the domestic sector accounts for round about two third.
- The electricity consumption in Germany is dominated by the industry (43% of the total consumption in 2012), followed by the domestic sector (27%).
- The German electricity supply is dominated by fossil fuels (57% in 2013). The share of renewable energy increased within the last years to 24% in 2013.
- The phase-out of nuclear power in Germany by 2022 offers the chance to substitute a base load component by flexible ones.
- The Federal Government aims that the renewable energies achieve a share of 50% in the electricity consumption of 30% in the final energy demand in 2030.
- According the scenario simulations 80 % renewables in the electricity sector till 2050, mainly intermitting Wind and PV, seems to be achievable.
- For the energy turnaround, significant expansion of the electricity network is required in the transmission grid level as well as in the distribution grid level.
- The ratio between the electricity and the gas price rises since 2008, the year with the lowest ratio, continuously up to 4.0 in 2013.

1.2 German heat pump market development

- The market share of space heating heat pumps in the total market of space heaters amounts to 9% in 2012. Concerning the sector of new build houses the share comes to 30%.
- According to a market forecast for 2030 the market share is estimated to be between 17% and 28%. Thereby the share of space heating heat pumps in respect to the total installed heaters would rise from 2.6% nowadays to 9% - 15% in 2030.
- The share of air to water heat pumps in the heating heat pump market volume have raised continuously and comes to 63% in 2012.
- By now no market models have been established by the utilities for the grid reactive operation of heat pumps, whereas so-called smart heat pumps have been introduced to the market at the beginning of 2013. Those models are marked by the “SG ready” label that stands for a uniform interface and had been granted to 441 models from 21 manufacturers by the middle of 2014.

1.3 Challenges for heat pumps which need to be overcome to realise the potential and capture the flexibility

- the current lack of importance of heat pumps in the electricity market
- the lack of necessary incentives such as flexible tariffs
- the lack of necessary communication infrastructure such as smart metering
- the lack of useful control strategies for “smart” heat pumps

2 Overview of the German Energy Sector

2.1 German electricity generation[1]

German electricity supply is dominated by fossil fuels. Since 1990 the share of fossil fuel in the total energy generation in Germany decreases continuously from 65% in 1990 to 57% in 2013. Whereas the amount of electricity generation based on coal decreases, the amount of electricity generation based on gas increases. The share of nuclear power decreased in the last years amounting to 16% in 2013. 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 24% in 2013. Within the renewable energy wind has the greatest share (36%), followed by biomass[2] (31%), PV (20%) and the renewable share of hydrogen (14%).

Figure 1 – Electricity production (by fuel) and import in Germany, 1991 – 2012. Source: [Zahlen und Fakten; BMWI, 2014].

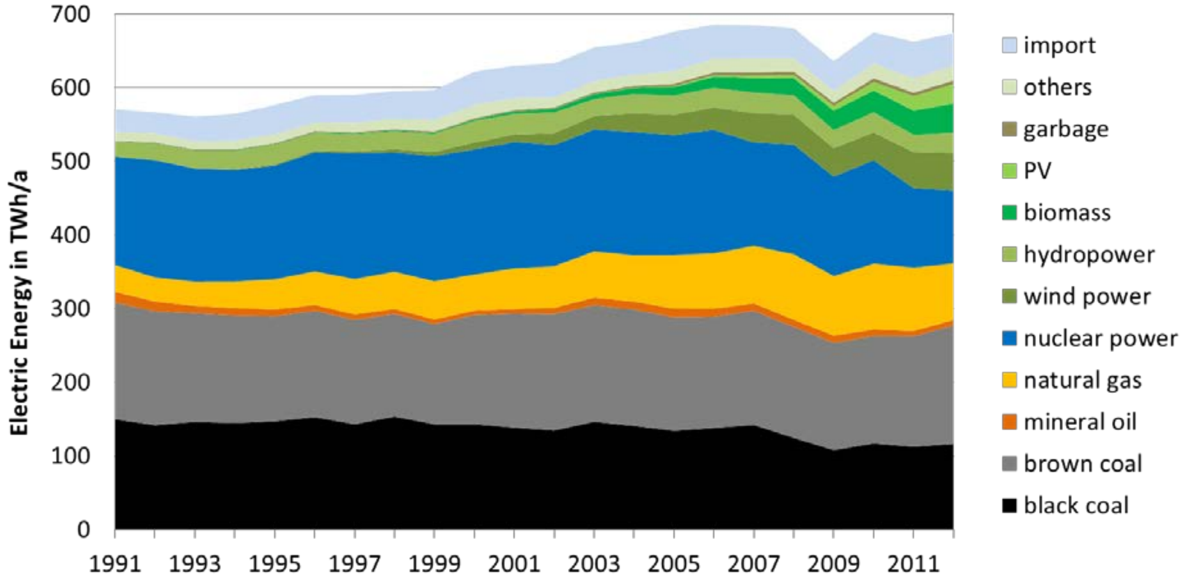
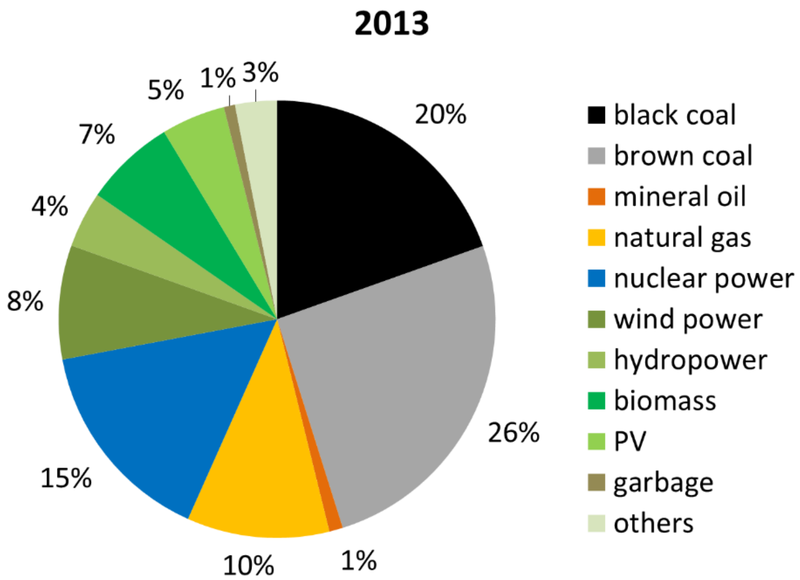


Figure 2 – Electricity generation in Germany in 2013 by fuel. Source: [Zahlen und Fakten; BMWI, 2014].

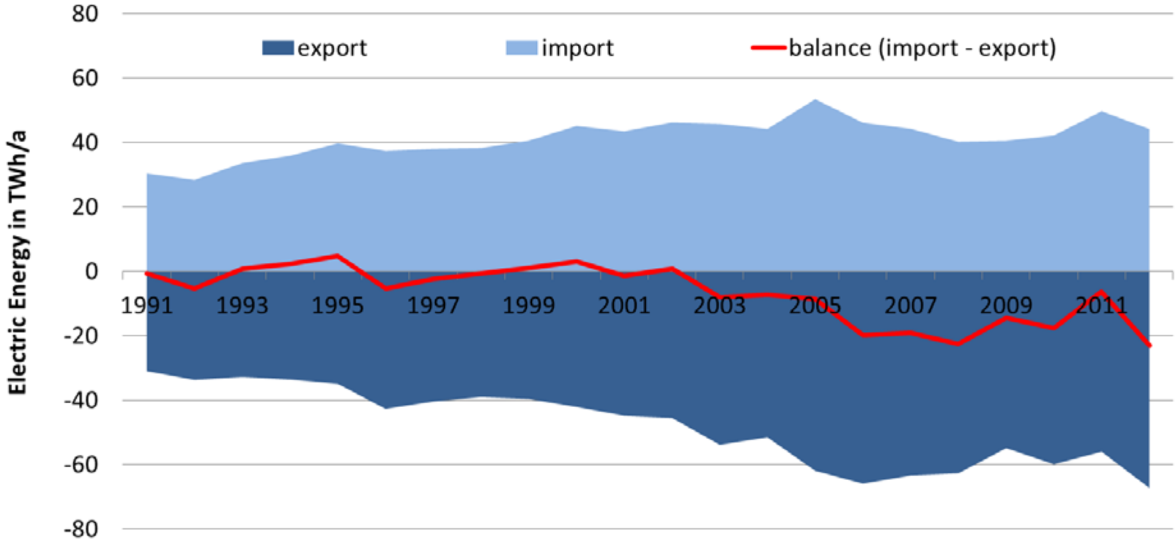


[1] Source: Zahlen und Fakten, BMWI, 2014; "Klimaschutzszenario 2050" (Climate Protection Scenario 2050); Öko-Institut et. al.; 2014

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

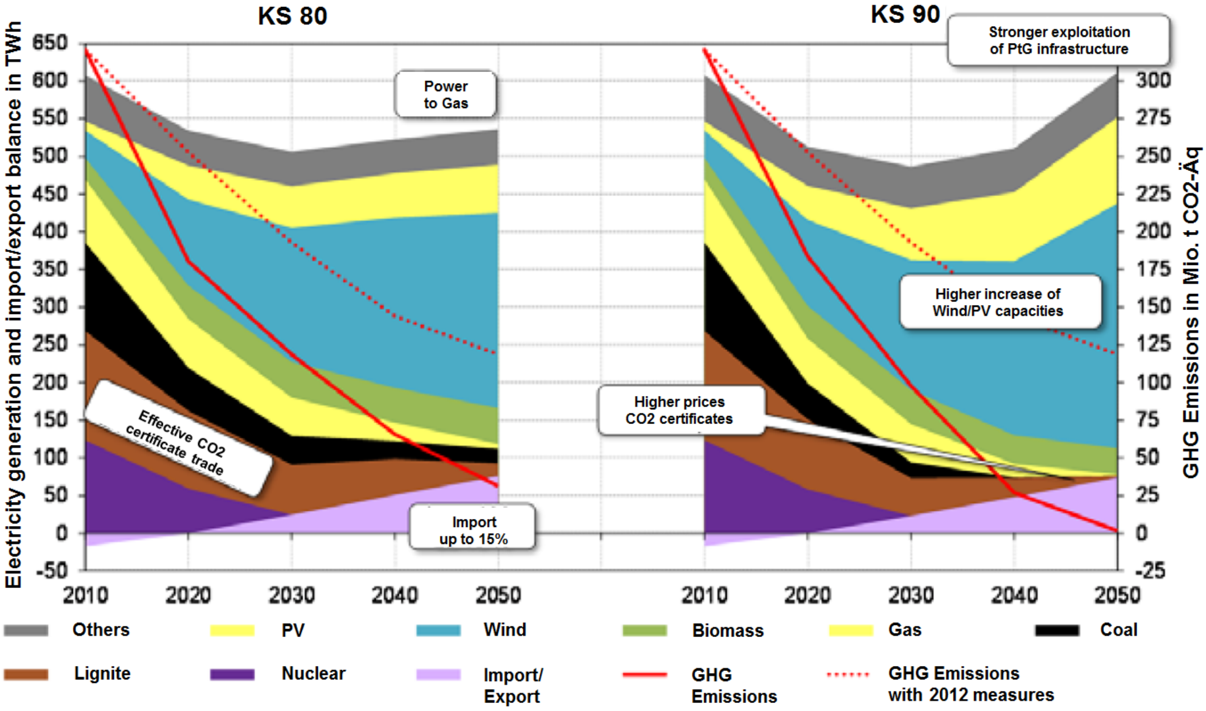
The share of imported electricity in the total electricity consumption has been about 7% within the last years. Considering the balance of import and export within the last decade the export has exceeded the import (in 2012 by 50%).

Figure 3 – Balance of Electricity import and export in Germany, 1991 – 2012. Source: [Zahlen und Fakten; BMWI, 2014].



Based on the “Energy Concept 2010/11” of the German government Öko-Institut et. al. led out the study “Klimaschutzszenario 2050” (Climate Protection Scenario 2050) which e.g. aims the possible GHG emission reduction and necessary measures and strategies. The energy concept aims a share of 80 % for renewables in the electricity sector until 2050. The current share is about 25 %. For two scenarios Figure 4 shows the development of the primary energies, the GHG emissions and the electricity consumption. Scenario KS 80 aims the objective of the German government with GHG emission reduction by 80 %. Scenario KS 90 is more ambitious with a target reduction by 90 %. In both scenarios, the way for reaching the goals are primarily wind and PV power. The current Atomic Energy Act makes provisions for the complete phase-out of nuclear power in Germany by 2022. It is planned that 80% of the national energy demand should come from renewable energy sources by 2050. Eight nuclear power plants have already been removed from the grid, and the remaining nine will be gradually switched off in the years up to 2022. The electricity import increases and, especially in scenario KS 90, the use of fossil fuels decrease to a very small share. For this reason, the GHG emission nearly reaches a value of zero.

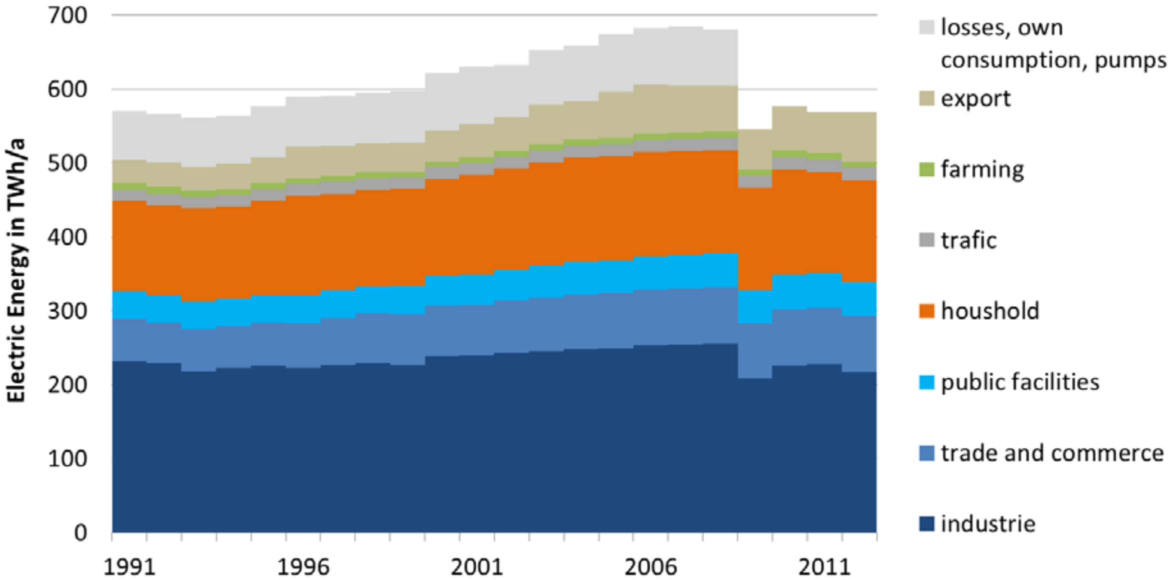
Figure 4 – Electricity production and import 2010-2050 according to "Klima Schutzscenario 2050". Source: [KLIMASCHUTZSZENARIO 2050, ÖKO-INSTITUT; FRAUNHOFER ISI, 2014].



2.2 German Energy Demand

The electricity consumption in Germany[3] is dominated by the industry which consumed 43% of the total consumption in 2012. The domestic sector makes up the second largest share (27%), followed by trade and commerce (15%) and public facilities (9%).

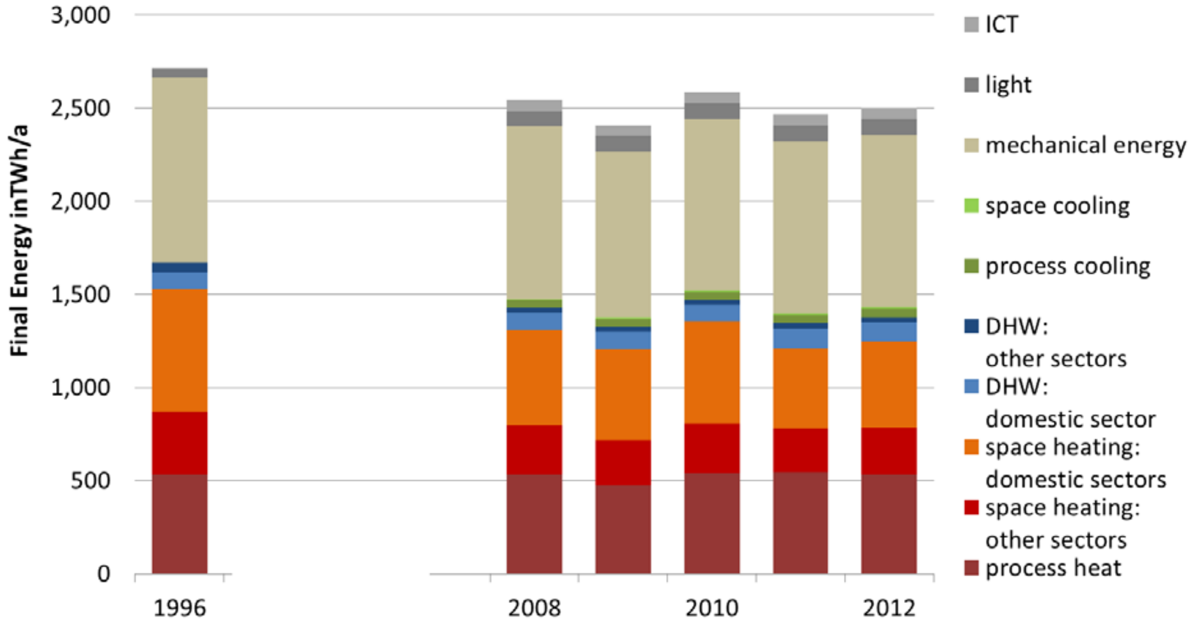
Figure 5 – Electricity use in Germany (NOTE: no data available for item "losses" in 2009 – 2012). Source: [Zahlen und Fakten; BMWI, 2014].



The German final energy consumption has been 2,500 TWh/a in 2012, 34% of which is used for space heating and DHW. Within this field the domestic sector accounts for round about two thirds. The other main fields are mechanical energy (37%) and process heat (21%).

[3] Source: Zahlen und Fakten; BMWI, 2014

Figure 6 – Final energy consumption in Germany by sector (NOTE: no data available for items "ICT" and "Cooling" in 1996). Source: [Zahlen und Fakten; BMWI, 2014].



2.3 German Electricity Infrastructure [4]

2.3.1 Structure of grid operators

In Germany, there are four transmission system operators (TSOs) who are responsible for the nationwide supply and transmission of electricity at extra-high voltage: 50Hertz, Amprion, TenneT TSO and TransnetBW. Figure 7 displays the allocation of the German transmission network to the four companies. The four transmission system operators are responsible for the modernization and expansion of the high-voltage and extra-high voltage networks in Germany. The transmission system operators plan and maintain the extra-high voltage grid as well as regulating network operations.

The distribution grid companies oversee the operation, maintenance and development of an efficient electricity distribution networks (low and middle voltage level) and the delivery of electric energy to the end-users. In Germany, there have been little less than 900 distribution grid operators in 2013.

[4] Sources: http://www.netzentwicklungsplan.de;
Bundesnetzagentur, Marktbericht 2013;
Dena, press release 11.12.2012: http://www.dena.de/en/press-releases/pressemitteilungen/electricity-distribution-grids-require-significant-expansion-for-the-energy-turnaround.html

Figure 7 – German electricity transmission network: four control areas and its system operators.
Source: [http://www.netzentwicklungsplan.de].

Figure 8 – German electricity transmission network: 380 kW (orange), 220 kW (green), 150 kV (blue), HVDC (purple); for each type: solid line (existing), dashed line (in process of construction), dotted line (in process of planning).
Source: [2014 VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V.].

2.3.2 Development needs in the electric network

As part of the turnaround in German energy policy, the current Energy Industry Act (EnWG) requires that the German transmission system operators (TSOs) collaborate to develop a grid development plan every year. This plan "must contain all effective measures for the necessary optimization, development and expansion of the network, which are required over the next ten years to ensure safe and reliable network operation". In the first stage of preparing the grid development plan is the market simulation, which looks at energy transits in due consideration of other European countries as well as the generation and consumption situation within Germany. Following this, the results are then transferred into the network planning and used to determine the need for action in terms of the grid. The final stage generates an action plan, in which the transmission system operators present solution proposals for the optimization of the grid and for ensuring security of supply. An external consultant supervises the entire process of drawing up the grid development plan. At least every three years, based on the grid development plan a Federal Requirement Plan is enacted which includes details of the grid expansion needed in the extra-high voltage network.

The supervised version of the grid development plan 2013 considers the following activities be to necessary: round about 2,800 km of the existing power lines has to be optimized or enhanced and 2.650 km of power lines has to be constructed new.

For the energy turnaround, significant expansion of the electricity network is not only required in the transmission grid (extra-high voltage level) but also in the distribution grid. According to "dena's Distribution Grid Study", which was published in 2012, the German distribution grids (low, medium and high voltage levels) require significant expansion and modernisation. As part of the expansion of renewable energy and decentralised electricity generation the present capacity of the distribution grids will no longer be sufficient to transport electricity from renewable energy sources, which is not needed locally, to other regions. By 2030, the electricity distribution grids in Germany are expected to require expansions of between 135,000 km and 193,000 km, and 21,000 to 25,000 km must be converted. This will entail investments of between € 27.5 billion and € 42.5 billion. Relative to the existing grid infrastructure, the expansion requirements are greatest at the medium and high-voltage levels: At the high-voltage level, up to 19 percent must be built from scratch and at the medium-voltage level, this figure is up to 24 percent. The Study examined various technical options, which can contribute to reducing grid expansion in future, but stated that these technical options and their economy must be examined in greater detail.

2.4 German Energy Policy[5]

2.4.1 The German energy turnaround ("Energiewende")

With the adoption of its Energy Concept (September 2010) and 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. 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: [http://www.erneuerbare-energien.d); German Federal Ministry for Economic Affairs and Energy, Energiewende auf Erfolgskurs, 2013; Resolution of the federal cabinet at 28th September 2010, Das Energiekonzept].

	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%

2.4.2 EEG: German Renewable Energy Sources Act

The Renewable Energy Sources Act (Erneuerbare Energien Gesetz – EEG) promotes the generation of electricity using 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 is updated in 2014.

2.5 Energy Prices, Tariffs & Structures[6]

In 2013 the electricity price for household costumers (standard electricity tariff) averages out to 29 cent/kWh. In this tariff round about half of the price comprises taxes, surcharges and levies, from which one third is a percentage of the price whereas two thirds are fixed amounts. The other half comprises energy procurement

[5] Sources: Information platform of the German Federal Ministry for Economic Affairs and Energy (http://www.erneuerbare-energien.de); German Federal Ministry for Economic Affairs and Energy, Energiewende auf Erfolgskurs, 2013
Resolution of the federal cabinet at 28th September 2010, Das Energiekonzept

[6] Sources: Monitoringbericht 2013, Bundesnetzagentur, 2014; BMWi; Zahlen und Fakten Energiedaten 2014; Ernst & Young; Kosten-Nutzen-Analyse für einen flächendeckenden Einsatz intelligenter Zähler, 2013

(21% of total), net power grid charge (20% of total) as well as sale, distribution, billing and metering (10% of total).

Figure 9 – Indicative structure of electricity costs to household customers (annual consumption: 3.5 MWh) at 1st of April 2013 in Germany (in total: 29.39 €ct per kWh). Source: [Bundesnetzagentur: Monitoringbericht 2013, table 35].

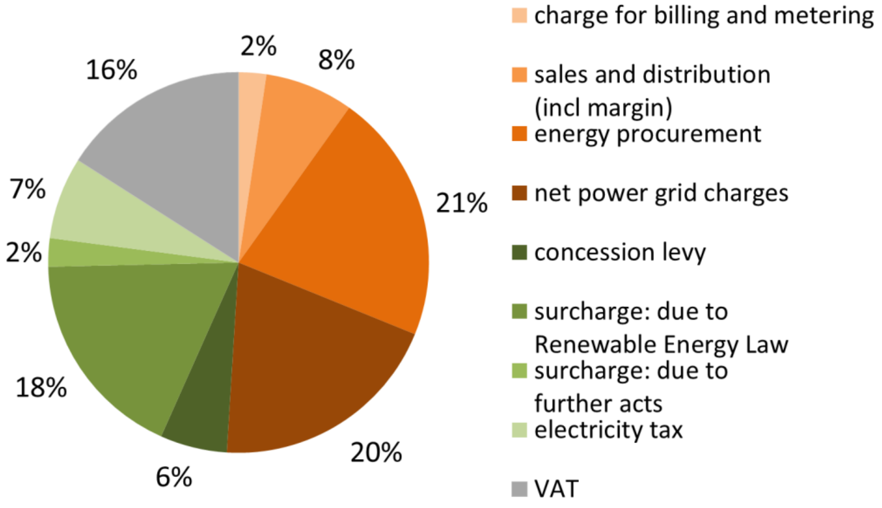
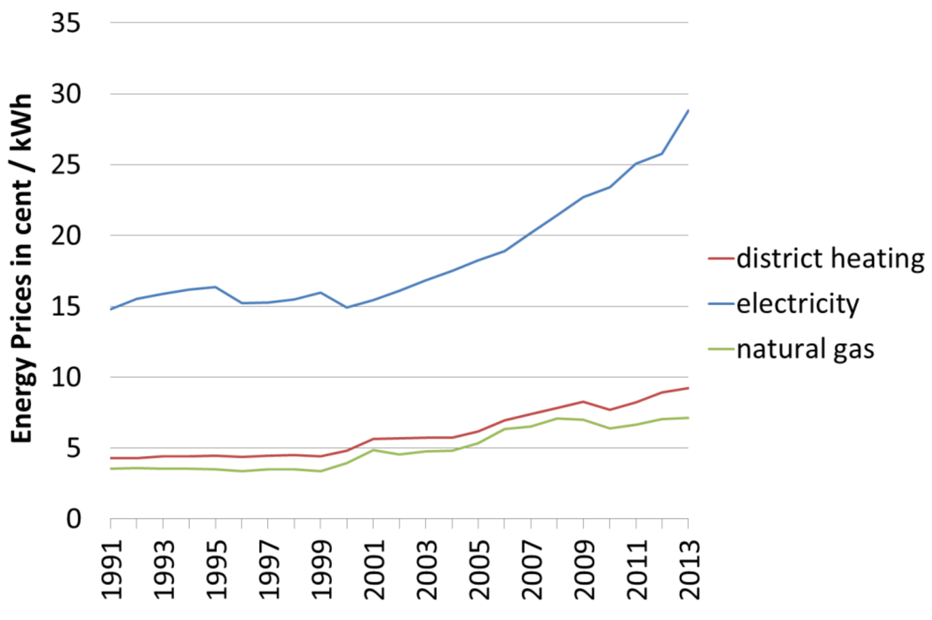


Figure 10 shows the development of the energy prices (natural gas, electricity and district heating) for household consumers. The ratio between the electricity and the gas price varied between 3.0 and 4.5 within the last 20 years. Since 2008, the year with the lowest ratio, the ratio rises continuously up to 4.0 in 2013.

Figure 10 – Energy prices for household consumers: District heating, Electricity (annual consumption: 3.9 MWh) and natural gas (annual consumption: 19.2 MWh). Source: [BMWi: Zahlen und Fakten Energiedaten 2014, 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 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[7] 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 examine the influences for an efficient and operative arrangement of the “rollout scenario plus”. The results are expected soon and probably the German legislator must act next.

3 Analysis of the German housing stock & heating market

3.1 Overview of main challenges in the German[8]

- 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 permits maximum 80 to 90 kWh/(m²*a) primary energy demand[9].
- Half of the building stock have a primary energy demand of more than 260 kWh/(m²*a) and 20% have a primary energy demand of more than 375 kWh/(m²*a)
- In about one fourth of the domestic buildings the heating system has been installed before 1990.

3.2 German Housing Stock Characteristics[10]

3.2.1 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%.

3.2.2 Type and Age of building

Overall, in 2009 there is a total living space of 3415 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 11 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.

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[7] Ernst & Young; Kosten-Nutzen-Analyse für einen flächendeckenden Einsatz intelligenter Zähler, 2013

[8] Sources:

Der dena-Gebäudereport, dena, 2012

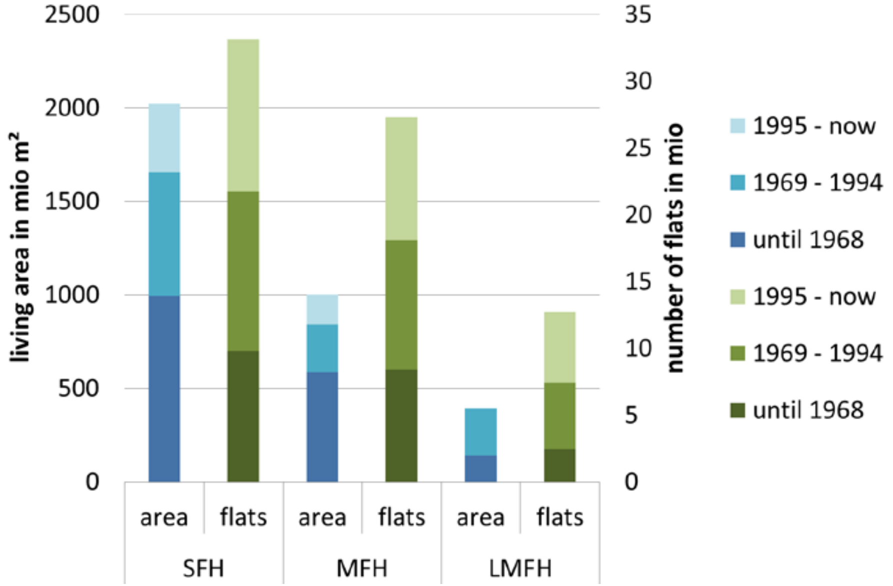
[9] As reference area 0.32 * V_{heated} is used.

[10] 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;

Figure 11 – German dwellings stock in 2009 by type and age. Source: [Erarbeitung einer Integrierten Wärme- und Kältestrategie: Arbeitspaket 1 - Bestandsaufnahme und Strukturierung des Wärme- und Kältebereichs; Fraunhofer ISE, 2011].



SFH: Single or double family house [(semi)-detached / raw houses]
MFH: Small and middle-sized multifamily house (3-12 flats)
LMFH: Multifamily house (>12 flats)
NOTE: For total living area, buildings from LMFH class "1995-now" have been allocated to MFH, out of statistical necessity.

3.2.3 Thermal Performance

Figure 12 shows the approximate share of energetic renovation (in terms of the mounting or improving the insulation of the building shell) of the housing stock divided by the part(s) of the building which were renovated (none, roof only, roof + walls, roof + walls + cellar) and by age of the building. Some more than half of the old buildings which have been built before 1979 have not been energetically refurbished at all. Round about one fourth of the buildings of this age have had an enhancement of the insulation of the roof and about 10% have had an enhancement not only of the roof but also of the cellar und walls. Regarding the old buildings, which has been built between 1979 and 1994, in round about one third of those buildings at least the roof has been refurbished.

It can be assumed, that the renovation of windows is not contemporaneously done with the renovation of the further parts of the building envelope. The replacement ratio of windows is significantly higher.

By now practically all of the windows of old buildings have been replaced (in some cases more than once) by those type of windows, which are state-of-the-art in the respective year of replacement. Good half of those old buildings, which were built before 1978, have double glazing manufactured before 1994 (predominant insulating glazing without infra-red reflecting coating) and round about one third have double glazing manufactured after 1995 (predominant heat insulation glazing).

Figure 12 – Living area, approximately divided by year of construction and type of renovation; NOTE: SFH: single or double family house [(semi)detached / raw houses]; MFH: small, middle and Large sized multifamily house. Source: [Erarbeitung einer Integrierten Wärme- und Kältestrategie: Arbeitspaket 1 - Bestandsaufnahme und Strukturierung des Wärme- und Kältebereichs; Fraunhofer ISE, 2011].

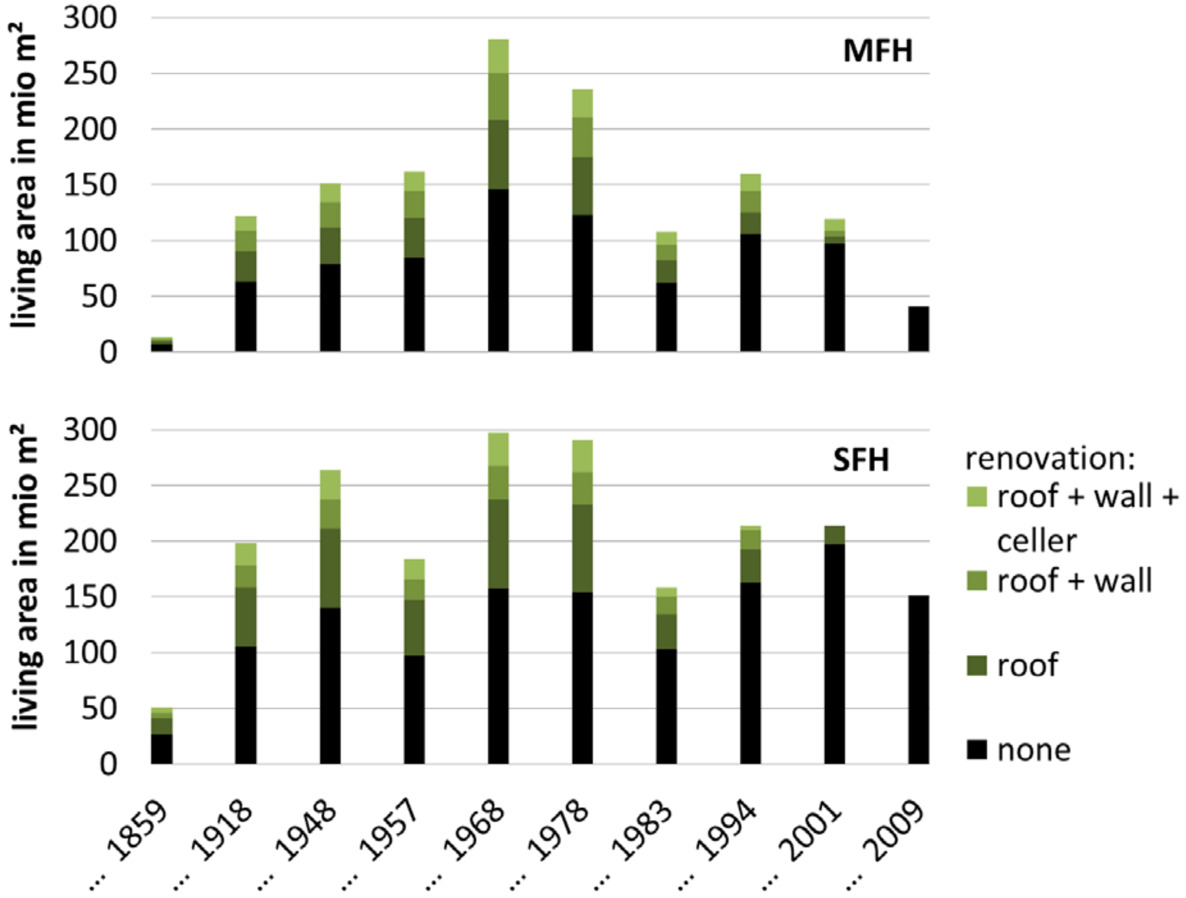
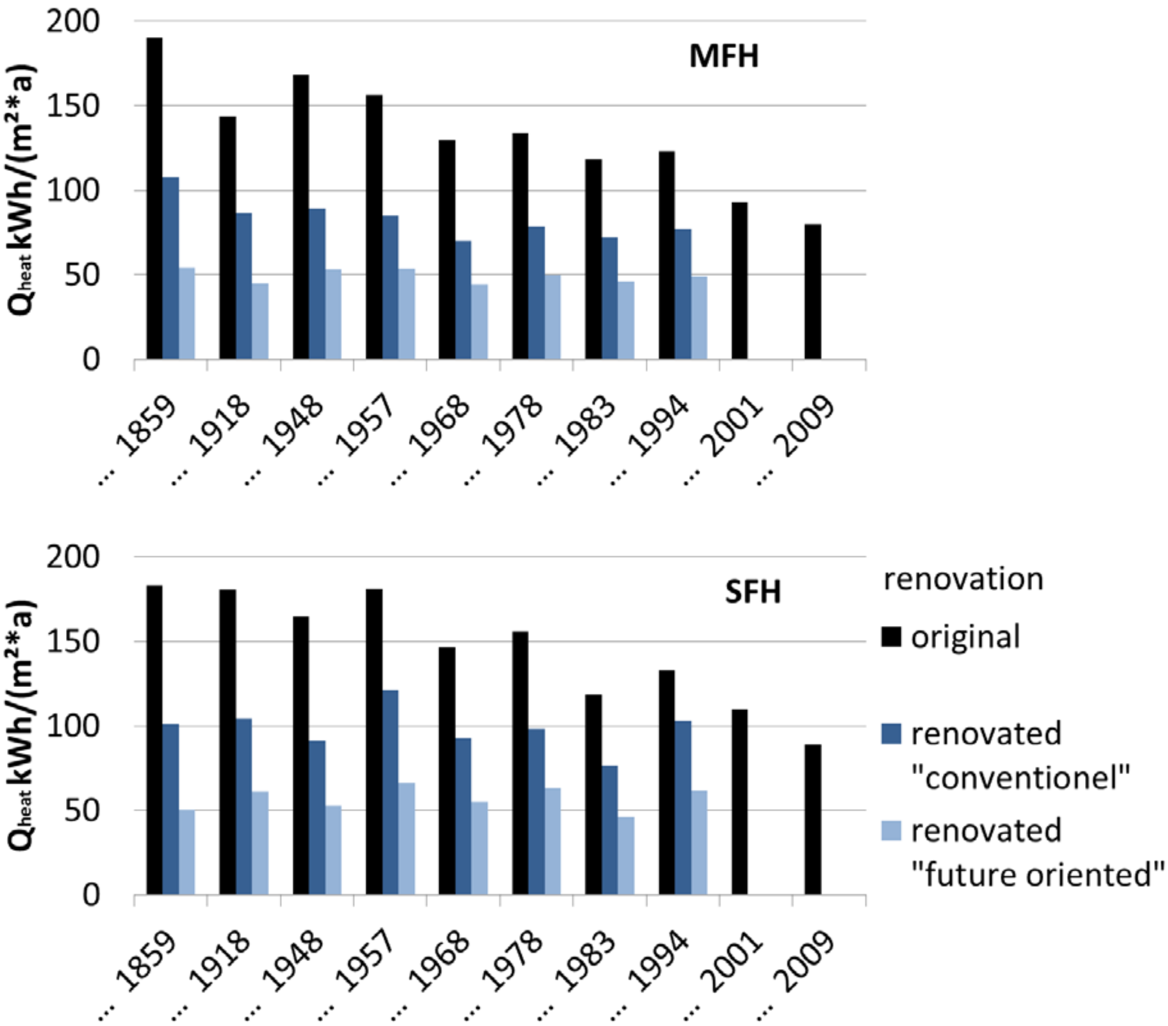


Figure 13 shows the approximated heating demand for an exemplary familiar house and an exemplary multifamily house.

Figure 13 – Approximate heating demand segmented by year of construction and level of renovation for an examplary SFH (240 m^2 heated living area) and an exemplary MFH (4 floors, 34 flats). Source: [TABULA: Deutsche Gebäudetypologie - Beispielhafte Maßnahmen zur Verbesserung der Energieeffizienz von typischen Wohngebäuden; IWU; 2011].



3.3 Trends in the Heating Market[11]

In 2010 central heaters (one heater in the building) represent the most common heating system in domestic buildings (89% in one or two family houses (SFH) and 62% in multifamily houses (MFH)). In MFH the two further relevant heating systems are flat-wise heaters (19%) and district heating (13%). The share of room-wise heaters (most of them biomass heaters or direct electric heaters) is about 8% in one or two family houses and 4% (most of them oil or gas heaters) in MFH. Concerning the flat-wise heaters gas is used almost entirely as fuel. More than half of the building-wise heaters are fired with gas as well. But the share of building-wise heaters which use oil almost comes to some more than one third. Biomass makes up less than 5% of the fuels in building-wise heaters. The share of heat pumps accounts for 2% in SFH and less than 1% in MFH.

[11] 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; 2010

Segmenting the heating market by year of construction the trend towards building-wise heaters is evident: in the building stock build before 1978 such heaters have a share of about 80% while in new build houses (build after 2005) those heating systems have a share of approx. 92%. Besides, the change in the used fuel is evident: in buildings build before 1978 gas was used in little less than half of the buildings and in new build houses it makes up 60% while the share of oil decreases from 37% to 6%. Significant is the increase of heat pumps amounting to less than 1% in the mentioned group of old building and 20% 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 modernization rate of the heater system (the yearly share of buildings, which renewed the main heater) was about 2.8% in average during the years 2005 to 2009. Considering only the building stock build before 1978 the modernization rate amounts to 3.1%.

Figure 14 – Space heating: type of heaters and type of fuel. NOTES: SFM includes single & double family houses. The percentages refer to the number of buildings. Source: [Erarbeitung einer Integrierten Wärme- und Kältestrategie: Arbeitspaket 1 - Bestandsaufnahme und Strukturierung des Wärme- und Kältebereichs; Fraunhofer ISE, 2011].

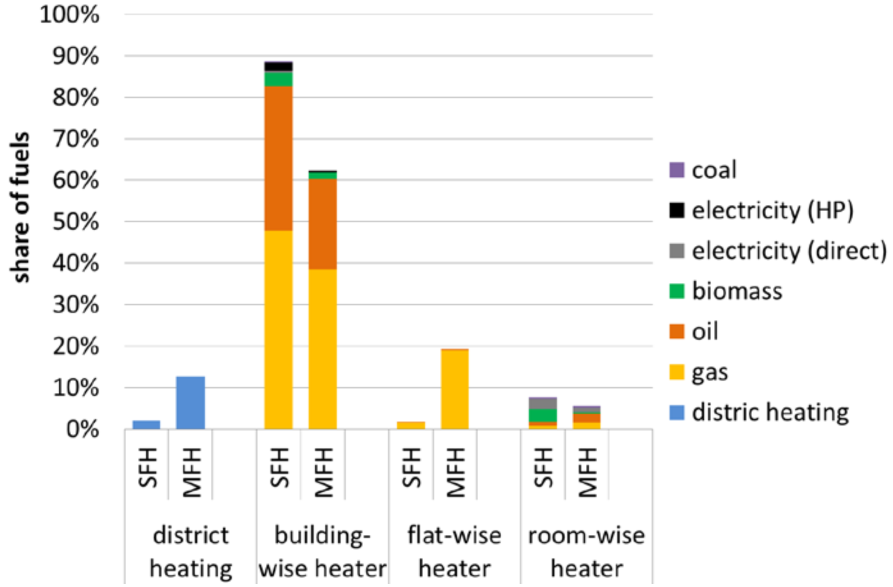
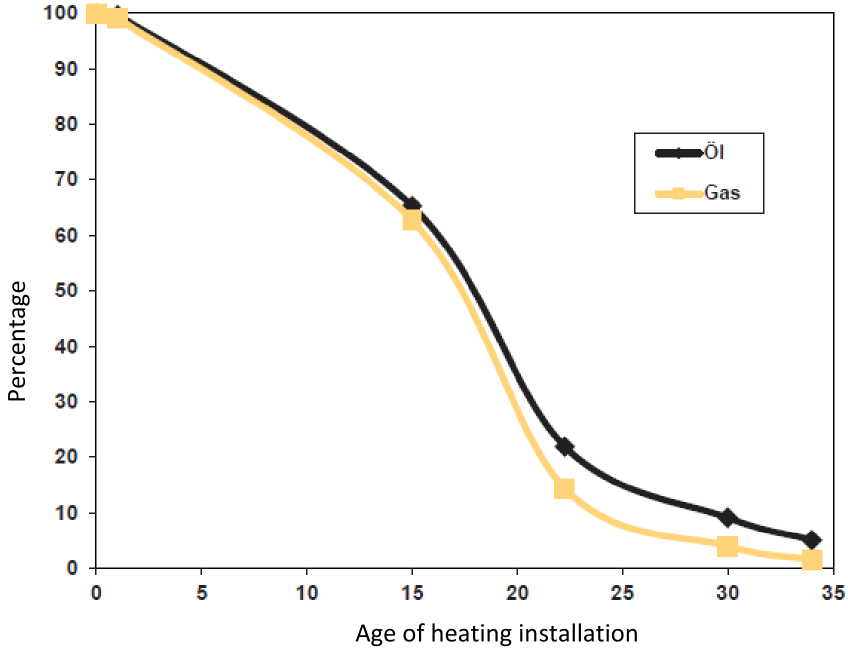


Figure 15 gives an overview of the year of installation of the oil and gas fired heaters being in operation in 2012. Some more than 60% of those heaters are older than 15 years and round about 5% older than 30 years.

Figure 15 – 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 2012. Source: [Erhebungen des Schornsteinfegerhandwerks; Bundesverband des Schornsteinfegerhandwerks – Zentralinnungsverband (ZIV); 2011].

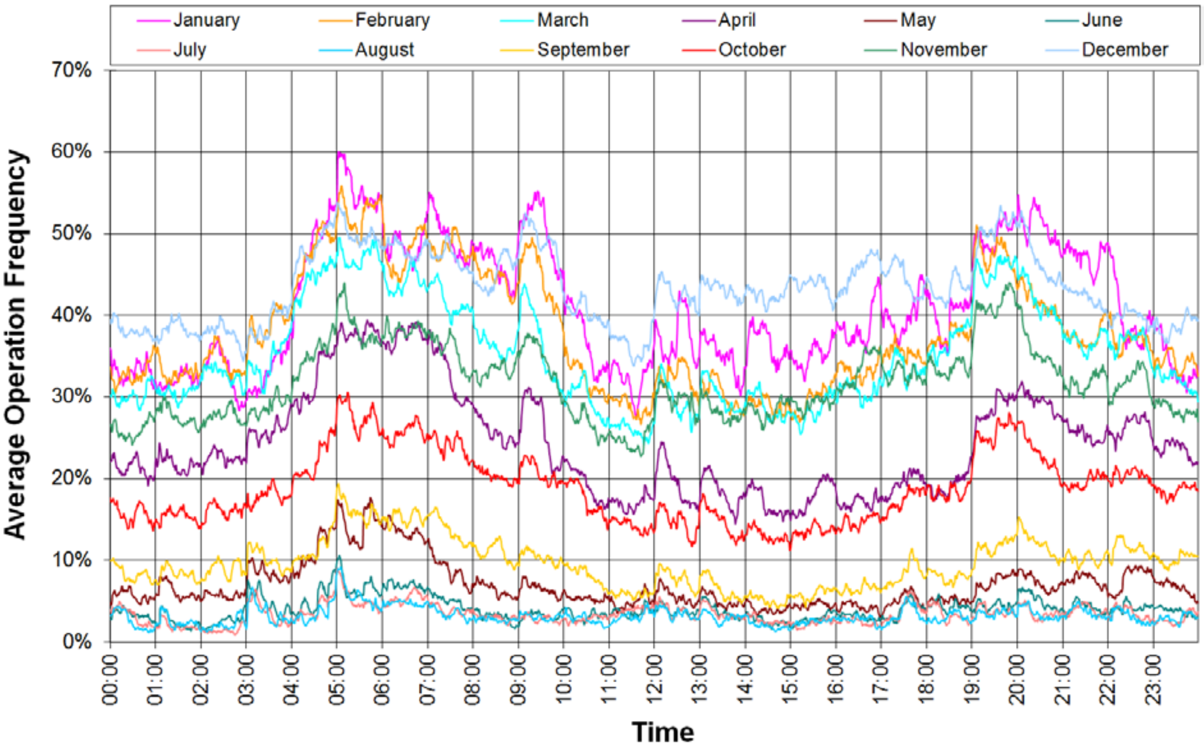


3.4 Customer Preferences[12]

Individual daily load profiles differ a lot for many different reasons. Instead of single load Figure 16 shows average load profiles of 75 ground source heat pumps. The differences between the months show the varying heat demand during the year. During the summer, most heat pumps only work for domestic hot water. The curves are quite constant with a small peak in the morning hours. During the heating period two peaks are visible: one in the morning and one in the evening hours. Also visible are the influences of load shedding which are applied at few of the evaluated heat pumps. Load shedding provokes rising operation frequency at noon and 7pm.

[12] Source: field monitoring project "HP EFFICIENCY", Fraunhofer ISE, unpublished

Figure 16 – Monthly average load profiles for 75 ground-source heat pumps as average operation frequencies. Source: [field monitoring project "HP EFFICIENCY", Fraunhofer ISE, unpublished].



4 Analysis of the German domestic heat pump market[13]

4.1 Installed Heat Pump Capacity

It is estimated that at the end of 2011 there were approximately 450,000 space heating heat pumps installed in Germany. At an average capacity of 11.8 kW_{th} per heat pump, the total installed (thermal) heat pump capacity in Germany was around 5.3 GW_{th}. The total installed electrical power of the heat pump amounts to ~1.7 GW_{el}.

According to a market forecast of the German Heat Pump Association (BWP) the installed base of heat pumps in Germany will reach approximately 1.1 Mio to 1.4 Mio units in 2020 with an average thermal capacity of 9.8 kW_{th} per heat pump. The estimated installed heat pump capacity amounts to 6.9 – 8.7 GW_{th} and 3.6 - 4.6 GW_{el}.

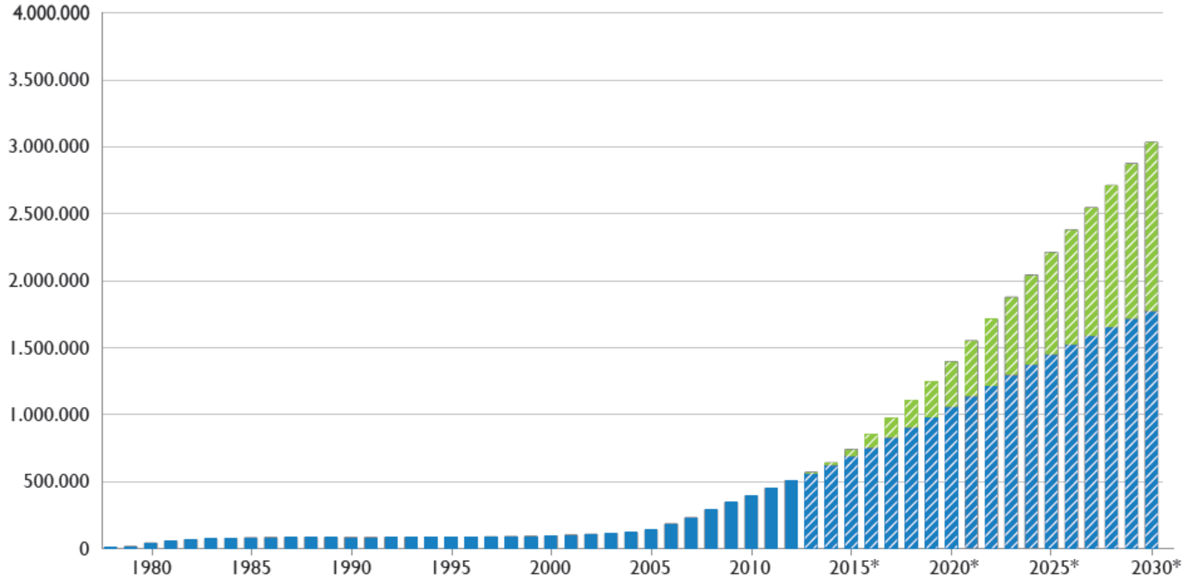
4.2 Trends in the Heat Pump Market

After the significant rise of the sales volume of heat pumps in 2006 (approx. doubling) within the last years the sales of space heating heat pumps ranged between 42,000 and 63,500 units. In 2012 a moderate rise in the volume of space heating heat pumps and sanitary heat pumps sold in Germany exits after the reduction in 2009 and 2010. The sold space heating heat pumps amount to 59,600 units in 2012 and the sanitary water heat pumps to 10,700 units. The market share of space heating heat pumps in the total market of space heaters amounts to 9% in 2012. Concerning the sector of new build houses the share comes to 30%. Whereas the share of heat pumps in the sector new building rises the one in existing buildings decreased significantly in the last years. The trend might be caused by the development of the electricity prices. In new buildings, the heat pump is still competitive due to low additional investment costs. In the sector of renovation, the additional investment costs compared to a not renewed heater bring a return of investment ever later. The reasons for the increasing sales volumes in new building sector cannot be found in changed political or

[13] 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

administrative circumstances. More likely it is based on a changed consciousness of the costumers towards efficient “renewable” heating systems.
According to a market forecast of the German Heat Pump Association (BWP) the sales figures are expected to increase in the coming years. For 2020 the market share of space heating pumps in the total market of space heaters is estimated to be between 12% and 18% (3% - 10% in the sector of renovation und 48% - 59% in the sector of new buildings). For 2030 the market share is estimated to be between 17% and 28%. Thereby the share of space heating heat pumps in respect to the total installed heaters would rise from 2.6% nowadays to 9% - 15% in 2030.

Figure 17 – Historic and future trends in the German HP market: number of installed HPs, from 2013 a prediction is given for 2 different scenarios (hatched blue/green). [BWP-Branchenstudie 2013; BWP; 2013].



Within the last 10 years there was an ongoing market change concerning the type of heat pumps. The share of air to water heat pumps in the heating heat pump market volume have raised continuously and comes to 63% in 2012. The conditions for ground source heat pumps continue to be difficult due to high costs for drilling and a lot of regional differences in administrative regulations and practices. Air to water heat pumps become more and more popular because of their low installation costs and their increasing efficiency. In new buildings, the low heating load makes for the trend towards smaller and more compact heat pumps. This benefits in particular the air to water heat pumps.
More and more buildings use heat pumps combined with photovoltaics. For some years now the own consumption of electricity produced on site is more favorable than the feed-in to the grid. Concerning smart grid and smart market several pilot projects have been done in the recent years and a label for heat pumps has been introduced but there are several obstacles impeding the extensive use of smart heat pumps. By now no market models have been established by the utilities, whereas smart heat pumps have been introduced to the market at the beginning of 2013. Those models are marked by the “SG ready” label that stands for a uniform interface and had been granted to 441 models from 21 manufacturers by the middle of 2014.

4.3 Market conditions

Distribution channels

Depending on the company’s preferred strategy, various distribution channels exist at present in the German market. Major approaches are distribution via wholesalers to retailers and final consumers or via dedicated retrial networks. So far, the German utilities are not engaged in the distribution and installation of heat pumps.

Building 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.

Incentive schemes

The main incentive program for heat pumps is the Marktanreizprogramm (MAP). Nowadays only heat pumps which are installed in buildings that have been built before 2009 get a funding. To access the funding it is mandatory to verify a SPF (calculated value) of 3.5 for air to water heat pumps and 3.8 for ground source heat pumps. For a heat pump with 10 kW the funding amounts to 1300€ for an air to water heat pump and 2,800 € for a ground to water heat pump. A bonus funding of 500 € is given for systems which include a storage with a volume of at least 30l/kW_{th}. Further bonus subsidy is available for the combination with solar thermal systems and when it is installed in an efficient building.

Energy price conditions

In the past, a significant rise of the prices for natural gas and oil has encouraged the growth of the heat pump market. The development in recent years has been reversed. The current low gas prices might be expected for the next 5 to 10 years, while the electric prices might be expected to rise further.

A List of smart heat pump projects in Germany

A.1 Network load optimisation through the predictive control of CHP and heat pumps (Nevora)

Participating Entities	*Department of mechanical engineering at University of Applied Sciences and Arts in Hannover; ELENIA at Technical University of Braunschweig; University of Oldenburg; INGA mbH Hameln; Solar Computer GmbH; Energieservice Westfalen Weser; OFD Niedersachsen; Enercity Hannover*
Founding	Federal Ministry of Education and Research i.a. (project code number: 03FH020I2)
Time frame:	1.10.2012-30.9.2016
Objective:	Within this project, CHP systems and HPS will be controlled the way that electric load in the grid is optimized and however the heat supply is ensured. For this purpose an energy management system (EMS) will be developed which calculates the predicted thermal and electric load of the affiliated buildings and compare this predicted demand with the predicted conditions in the electric grid. This makes it possible to use the thermal capacity (building, buffer storage) in order to shift the operation time of the CHP or the HP into the time periods of high electric demand or high electric generation respectively. The EMS generates optimal timetables for the CHPs and HPs aiming an optimized operation of the total system (consisting of the building and the electric grid) in respect to energetic and economic aspects.
Description:	● Generating predictions for the thermal load profile ● Developing a thermal model ● Developing an energy management system, ● Testing the EMS in a lab ● Implementing the EMS for the control of some facilities ● Testing the EMS in the lab after being optimized
Further information; Source	http://www.hs-hannover.de/forschung/forschungsprojekte; http://doku.uba.de

A.2 Design and implementation of a smart grid with renewables-based storage components

Participating Entities	*Bosse Consulting GmbH; Bethke et al. GmbH; Steuerungsbau Hanswille GmbH*
Founding	German Federal Ministry of the Environment (BMUB) i.a. (project code number: 0325315)
Time frame:	1.12.2011-30.11.2014
Objective:	The project aims to link those SME and private households on the one hand who produce renewable fluctuating energy and those who consume electric energy and have a significant storage capacity on the other hand via an intelligent virtual network. As flexible users HPS will be considered in the beginning; later possibly electro mobiles will be considered as well. Within this pilot project a Smart Grid Connecting Users and Suppliers of Renewable Energies ('smartUSR') should be demonstrated.
Description:	Phase I: development of a basic concept Inquiry on market potential, on project related market parameters and on state-of-the-art elements of grid technologies. Development of a functional model of the smartUSR. Phase II: construction and realization of a virtual smart grid Further elaboration of the functional model; system optimization concerning the balance between theory and practice / feasibility and reasonability. Cooperation with industrial partners (HP operators) to consider their requirements. Phase III: realization and implementation Construction and operation of smartUSR in the first step as prototype system comprising about 3 HPs and in a second step as field trail comprising 10 to 20 HPs.
Further information; Source	http://www.smartusr.de; http://doku.uba.de

A.3 EnVisaGe Wüstenrot

Participating Entities	*Institute of combustion and power plant technology (ifk) at University of Stuttgart, Germany; Center for Solar Energy and Hydrogen Research, (ZSW), Germany; Institute of Building Energy Research at the Stuttgart University of Applied Sciences; Vattenfall Europe AG; et al.*
Founding	German Federal Ministry for Economic Affairs and Energy; i.a
Time frame:	ongoing
Objective:	The aim of the project is to develop a durable roadmap for the energy self-sufficient and energy-plus community of Wüstenrot. This shall be embodied in an energy usage plan for Wüstenrot and implemented by 2020.

Participating Entities	*Institute of combustion and power plant technology (ifk) at University of Stuttgart, Germany; Center for Solar Energy and Hydrogen Research, (ZSW), Germany; Institute of Building Energy Research at the Stuttgart University of Applied Sciences; Vattenfall Europe AG; et al.*
Description:	With the help of simulations, the durability of the community's own electricity network for the expansion scenarios is being analysed and weaknesses localized. Necessary grid expansion scenarios as well as the need for intelligent grid and consumption control are being determined. An energy-plus housing estate is being implemented as a model, which will have cold local heating provided via an agrothermal power plant and intelligent load management. The energy-plus model housing estate will combine PV systems for generating electricity with decentralized heat pumps and thermal storage systems for providing domestic hot water as well as with batteries for storing electricity. An intelligent load management system is also being realized and investigated during the course of the project, which, in addition to optimizing the self-consumption of PV electricity, also enables superordinate electricity grid-based load management via Vattenfall's virtual power plant.
Further information; Source	http://www.envisage-wuestenrot.de http://www.eneff-stadt.info/en/pilot-projects/project/details/the-community-of-wuestenrot-energy-independent-by-2020

A.4 Potential of heat pumps in terms of load management in the electric market and in order to support the grid integration of renewable energies

Participating Entities	*Prognos A.G.; Ecofys Germany GmbH*
Founding	German Federal Ministry for Economic Affairs and Energy (project code number PSUPDE101686); i.a
Time frame:	Finalized 2011
Objective:	Determining the contribution of the HP to a more flexible electricity demand and thereby considering aspects as electricity costs for the HP, electricity consumption, CO_2 emissions and curtailment of electricity from renewable energy sources. Deriving recommendations for actions.
Description:	Determination of basic assumptions concerning the energy scenario based on existing studies and adaption of the power plant model Determination of the different building types which will be considered and simulation of the HP using a dynamic building model. Implementation of the computed parameters of the HPS's flexibility for the respective scenarios into the power plant model. Simulation of the power plant utilization in the different scenarios. Merging the parameters concerning costs, energy efficiency and environmental aspects gained both in the building simulation and in the power plant simulation in an overall examination Summarizing regulatory barriers to the use of heat pumps for the purpose of load management
Further information; Source	Nabe, C.; Hasche, B. et al, Final Report: Potenziale der Wärmepumpe zum Lastmanagement im Strom und zur Netzintegration erneuerbarer Energien; 2011

A.5 Grid-interactive buildings

Participating Entities	*Fraunhofer ISE, Fraunhhofer IBP, RWTH Aachen (E.ON Energy Research Center)*
Founding	Federal Ministry for Economic Affairs and Energy

Participating Entities	*Fraunhofer ISE, Fraunhhofer IBP, RWTH Aachen (E.ON Energy Research Center)*
Time frame:	ongoing
Objective:	The aim of the joint research project "Netzreaktive Gebäude" (engl.: "grid-interactive buildings") is the holistic analysis of buildings as part of the energy system. The project seeks answers to the questions how individual buildings or larger groups of buildings should behave in a future, intelligent power grid, how they can reduce the stress on the energy grid in view of a rising share of renewable energies and how a "grid-interactive" operation can be achieved while retaining a good thermal comfort and efficiency.
Description:	All three project partners develop a joint simulation model of a city quarter and a consistent, dynamic methodology of evaluation for municipalities.
Further information; Source	http://www.netzreaktivegebaeude.de

A.6 E-Energy

Participating Entities	*several*
Founding	Federal Ministry of Economics and Energy, i.a.
Time frame:	Closed 2013
Objective:	Up to now, there has been little common ground between energy efficiency and information technology. The current objective is to create an "Internet of Energy". The project will ensure more effective utilization of the existing supply infrastructure and expand the use of renewable energy resources. It focused on the following three aspects: 1. Creation of an E-Energy marketplace that facilitates electronic legal transactions and business dealings between all market participants. 2. Digital interconnection and computerization of the technical systems and components, and the process control and maintenance activities based on these systems and components, such that the largely independent monitoring, analysis, control and regulation of the overall technical system are ensured. 3. Online linking of the electronic energy marketplace and overall technical system so that real-time digital interaction of business and technology operations is guaranteed.
Description:	"E-Energy: ICT-based Energy System of the Future" is a support and funding priority undertaken by the German government. In six model regions research and development activities has been carried out in respect to different smart grid aspects. They follow an integral systematic approach that spans all value adding segments. It includes all energy-specific business activities both at the market level and the technical operational level.
Further information; Source	http://www.e-energy.de

A.7 Smart operator

Participating Entities	*RWE Germany, Lechwerke, RWTH Aachen University*
Founding	n/s
Time frame:	2012 - 2015

Participating Entities	*RWE Germany, Lechwerke, RWTH Aachen University*
Objective:	The objective of the pilot project is to acquire experience regarding the development and operation of an intelligent electric grid which is guided by both the demand and the customer needs. It will be examined to what extent the “smart operator” could contribute to balance the fluctuation electric generation on one hand and the consumption load on the other hand by controlling single electric consumers. An important issue is the trial of intelligent electricity meters in households as well as the transmission of consumption data via a fibre-optic network having regard to the strict regulations of the German Federal Data Protection Law.
Description:	The Lechwerke (Group company of RWE) has built up an own fibre-optic network in the housing estate Wertachau (district of Schwabenmünchen, Germany) for the data transfer. 100 participating households, which have been equipped with intelligent electric meters, are connected to the fibre-optic network. RWTH Aachen University has developed the control model for the “Smart Operator”. In the second phase of the project the “Smart Operator” has been integrated into the electric grid. Energy storages, heat pumps and intelligent household appliance are part of the whole system. Since the official commissioning July 2014, the “Smart Operator” is in use: calculating – among others - the expected fed-in power as well as the load, the reception capacity and the available storage capacity based on the weather forecast. This pilot project bases on findings from the program “smart country” of RWE Germany which aimed the buildup of intelligent district girds. Besides the trial project in Wertachau two further are encouraged by RWE as well, but those projects will be commissioned later on: Kisselbach (Rhein-Nahe-Hunsrück) und Wincheringen (Mosel-Trier).
Further information; Source	www.lew.de/smartoperator

A.8 Further smart grid projects in Germany

The Smart Grids Projects Portal, a joint initiative by European electricity association EURELECTRIC and the European Commission's Joint Research Centre (EC JRC) provides information about the state-of-the-art of smart grids in Europe. An interactive map of smart grids projects provides an overview of the smart grids development in Europe. It contains continuously updated information on smart grids projects carried out by individual EU member states and by the EU.

There are projects listed which have been performed or are ongoing in Germany and which are not mentioned in the sections before.

https://portal.smartgridsprojects.eu; **http://ses.jrc.ec.europa.eu/**

www.heatpumpingtechnologies.org

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