HPT Annex 50

Heat Pumps in Multi-Family Buildings

Task 1: Market Overview

Country Report

AUSTRIA

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Summary

In order to determine the existing or expected future potential for the integration of heat pumps in multi-family houses (MFH), the development of the Austrian final energy consumption in total and per sector was determined. The housing sector accounts for approx. 24% of the total Austrian final energy consumption (as of 2015). This represents a significant theoretical potential for energy savings and associated emission savings through innovative heat supply technologies such as heat pumps. In order to determine the technical potential of heat pump use in MFHs, the development of the heat pump market and heat pump technology, the energy policy and legal framework conditions as well as the existing building stock and its expected future development were also examined. In addition, technical framework conditions, e.g. with regard to hygiene in hot water preparation and building requirements were elaborated.

Furthermore, the Task 1 report also deals with the most important political framework conditions including the rate of renovation. The collected information was used to assess the potential of heat pumps and to identify possible barriers of heat pumps in MFHs. The limitation of the heating flow temperature to 60 to 70 °C was identified as a barrier for the use of heat pumps in MFHs, which leads to the fact that only buildings with a maximum heating demand of 140 kWh/m² p.a. are eligible. The medium-term technical potential for the use of heat pumps in multi-family residential buildings (without the need for extensive renovation) was therefore identified as 60,000 MFHs. Assuming an annual refurbishment rate of 3 %, see Energiestrategie Österreich (2020), approximately 8,000 further MFBs per year may become suitable for the implementation of heat pumps for heating and DHW preparation.

Key Facts in Austria

Heat pump benefits

	2015	Potential*
Sales	23k	113k
Stock	239k	1.3m
Renewable energy produced	3.1 TWh	17.5 TWh
CO2 emissions saved	0.82 Mt	4.6 Mt
Final energy saved	4 TWh	22 TWh
Full time jobs provided	1 620 Jobs	8 986 Jobs

Key facts

Capital	Vienna	
GDP per capita	36 400 €	rank

Housing

Dwelling stock by category		
Total	4 441 408	% of tot:
One	1 442 066	32.5%
Two	570 126	12.8%
Multi	2 287 857	51.5%
Non residential	141 359	3.2%

Average energy consumption per m²	231 kWh/m²	
Space heating	149 kWh/m²	64.6%
Water heating	24.3 kWh/m²	10.5%
Other	57.4 kWh/m²	24.9%

Growth of new building permits	5.2%

Renewable energy

Share of renewable energy of total consumption	-
EU 2020 target for the share of renewable energy	34%
National emission factor of electricity	215 g/kWh

Energy consumption

Dwellings by energy source used for space heating		
Gas	1 104 250	31%
Oil	959 780	26.9%
Biomass	605 650	17%
District heating	659 380	18.5%
Electricity	211 750	5.9%
Coal	21 670	0.61%

Energy prices	
Electricity	0.2 €/kWh
Gas	0.08 €/kWh
Heating oil	0.1 €/kWh
District heating	0.09 €/kWh
Pellets	0.08 €/kWh

Figure 1: Factsheet Austria, part 1 (EHPA, 2016)

Market trends

Heat pump type	2010	2011	2012	2013	2014	2015	2015 vs 2014
H-ground/water	6 482	6 590	6 412	5 942	5 126	5 897	15%
H-air/water	4 412	5 399	7 083	8 506	8 953	11 554	29.1%
Exhaust air	578	450	115	149	188	49	-73.9%
Sanitary hot water	5 490	4 247	3 884	3 847	5 085	5 482	7.8%
Total	16 962	16 686	17 494	18 444	19 352	22 982	18.8 %

Figure 2: Factsheet Austria, part 2 (EHPA, 2016)

1. Austrian Energy Demand

Figure 3 shows the development of Austria's Inland Production of Primary Energy, Imports of Primary and Secondary Energy and Gross Inland Consumption between 1970 and 2015. Until 2005 the energy imports have been creasing steadily from approximately 500 PJ to approximately 1200 PJ, keeping stable since then. During this period, the value of the Inland Production of Primary Energy only increased slightly from little less than 400 EJ to little more than 500 EJ. As expected, also the Gross Inland Consumption increased significantly from 800 EJ in 1970 to its historic maximum of more than 1.400 EJ in 2010. Since then, this value has been decreasing slightly.

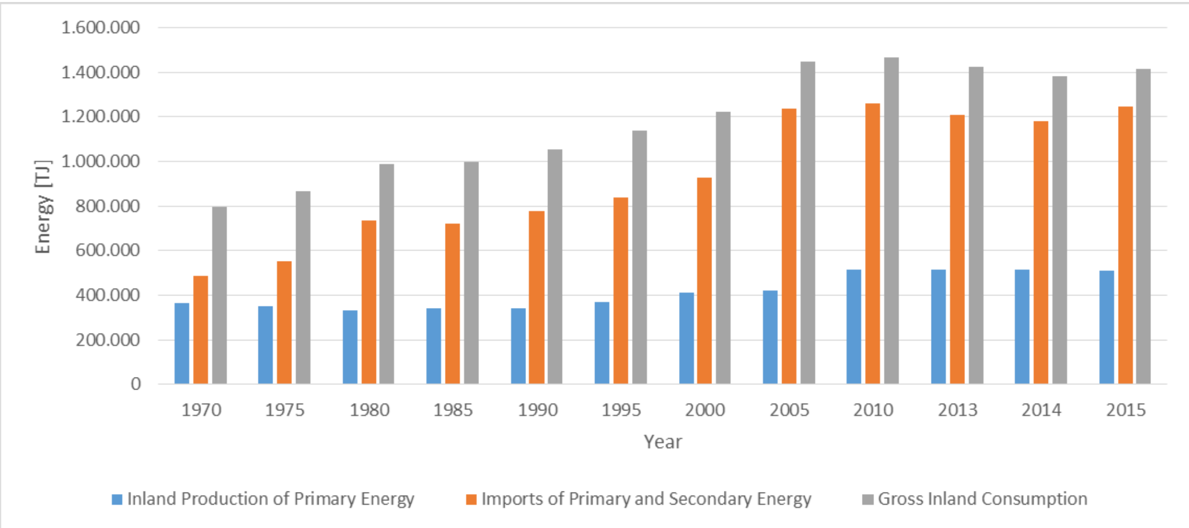


Figure 3: Austria's Inland Production of Primary Energy, Imports of Primary and Secondary Energy and Gross Inland Consumption between 1970 and 2015, diagram based on (Statistic Austria, 2015)

Figure 4 shows the development of Austria's Total Final Energy Consumption (TFE) in Mtoe between 2000 and 2015. The TFE is separately shown for the sectors Heavy Industry, Other Industry, Residential, Tertiary and Transport. Between 2000 and 2005 the TFE rose from 24 Mtoe to 26 Mtoe. Between 2005 and 2015 the TFE increased by 2 Mtoe to its historic maximum of 28 Mtoe. The graph shows that also the final energy consumption per sector has been remaining stable.

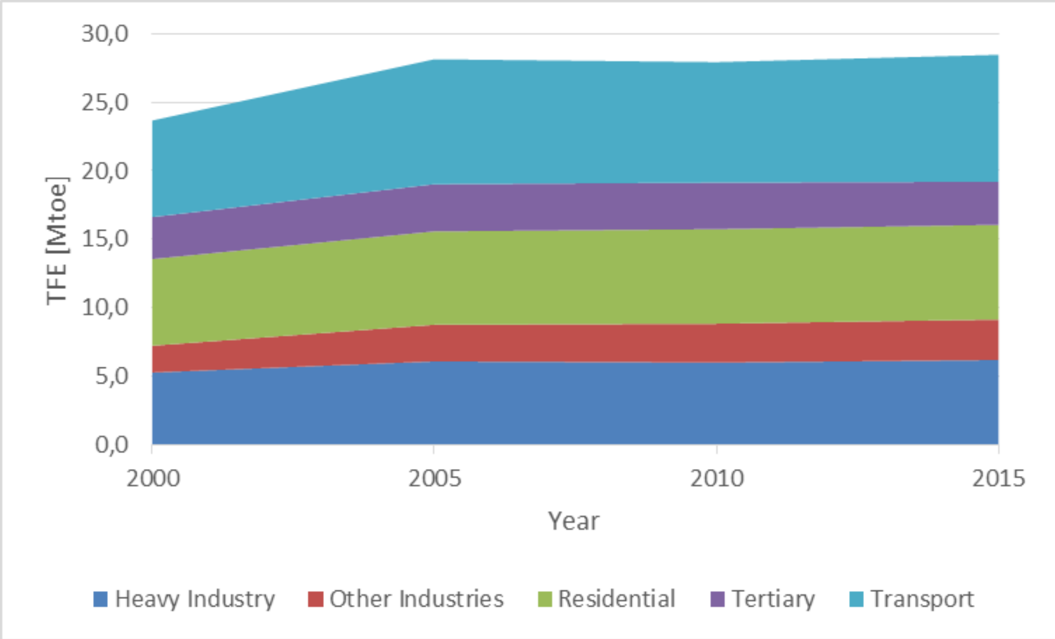


Figure 4: Austria's TFE per sector from 2000 to 2015, diagram based on (BMWFW, 2013)

Figure 5 shows the TFE per sector in % (2015). After the Transport sector, the Residential sector is the second largest sector in final energy consumption. Approximately 52 % of Austria's dwellings are located in multi-family buildings (see Figure 14).

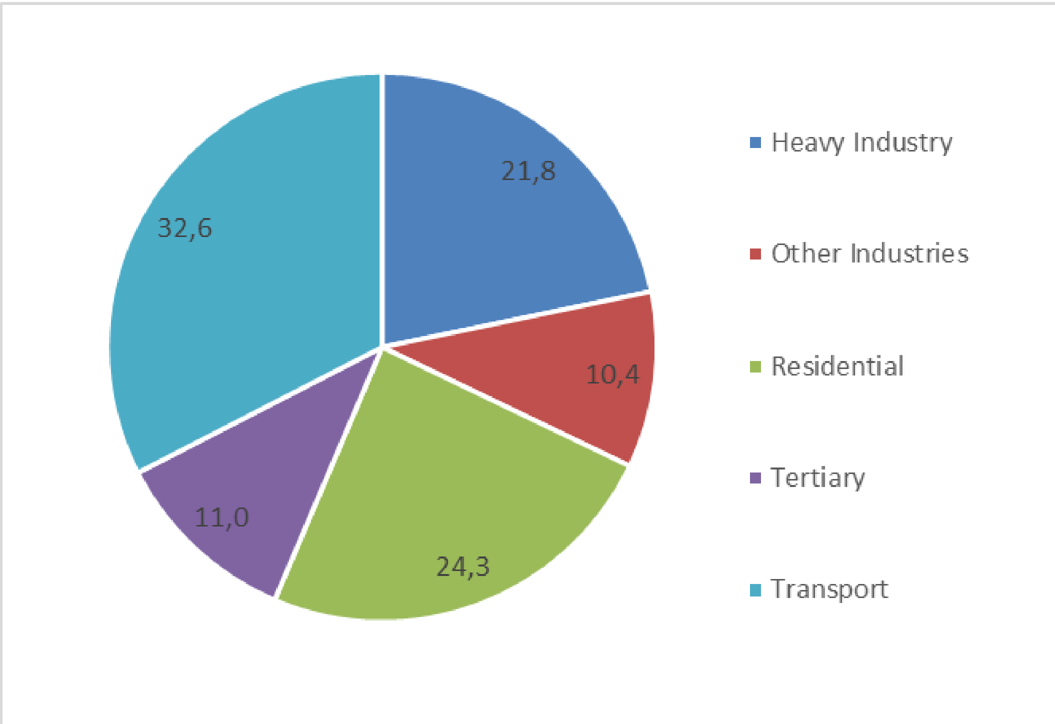


Figure 5: TFE by sector in % (2015), diagram based on (BMWFW, 2013)

2. Policy framework

2.1. General

Austria's policy framework concerning energy use and energy efficiency depends highly on the decision making process at EU level, e.g. the 20-20-20 targets, enacted in legislation by the EU in 2009 demanding a reduction of greenhouse gases by 20 % (from 1990 levels), a share of 20 % for renewables in the energy supply and an improvement in energy efficiency of 20 % until the year 2020. The 2030 climate and energy framework, adopted by the EU in October 2014, updates these key targets for the year 2030 enforcing a reduction of greenhouse gases by 40 % (from 1990 levels), a share of 27 % for renewables in the energy supply and an improvement in energy efficiency of 27 % (EC, 2016). The EU's long-term goal is reducing greenhouse gas emissions by 80-95 % compared to 1990 levels by 2050 (EC, 2016).

In 2013, the Ministry of Environment has published a program of measures for the achievement of the national climate target between 2013 and 2020. These measures concern the sectors energy and industry, fluorinated gases, agriculture, buildings, transport and waste management. The program required among others advisory programs, new subsidies, the continuance of existing ones and measures for better energy efficiency with reduced greenhouse gas emissions. It has already been achieved that every building needs an energy certificate that includes important characteristic values like the heating energy consumption that has to be expected. The certificate has to be shown to the tenant or buyer before the conclusion of the contract and is at most 10 years valid (BMLFUW, 2013).

In 2015, a further program of measures has been published by the Ministry of Environment, including an energy strategy for the years from 2015 to 2018 in order to demand more enhanced measures, e.g. in the transport sector and the field of thermal rehabilitations of buildings (BMLFUW, 2015).

Moreover, the Ministry for Environment offers a climate initiative, called "klimaaktiv". This initiative is intended as a consulting network and seeks for the progressive implementation of Austria`s climate targets. It offers advices in issues like energy efficiency, renewable energies and reduction of greenhouse gases, in private and public. The initiative collaborates with many Austrian municipalities and several companies (Klimaaktiv, s.a.).

The following two policies have especially encouraged the further use of renewable energies and a better energy efficiency in Austria:

2.1.1. Energy Efficiency Act

The energy efficiency directive 2012 (EP 2012) demands an energy efficiency obligation system including monitoring of the improvements. In Austrian legislation, this directive was ratified by the federal Energy Efficiency act (Bundes-Energieeffizienzgesetz; EEffG) in 2014 and sets a number of energy efficiency targets that have to be achieved until 2020. These include a maximum final energy consumption of 1050 PJ in the year 2020 and energy savings via energy efficiency measures of 310 PJ (159 PJ by energy suppliers, 151 PJ by strategic measures) between 2014 and 2020.

In order to achieve those targets, several concrete measures were stated, e.g. obligatory energy efficiency audits for large companies and the obligation for Austria's federal administration to act as a role model. The latter includes an obligatory annual refurbishment rate of 3 % of buildings owned by the federal administration (there are some exceptions).

2.1.2. Green Electricity Act

This federal law provides among others the expansion of renewable energies, more subsidies, climate and environment protection and the independence of Austria from nuclear power imports within the next years (Nationalrat, 2012).

The technical and legal boundary conditions for the application of heat pumps in multi-family buildings are set by building regulations and regulations concerning the preparation of domestic hot water (DHW).

2.2. Building Regulations

In Austria, the federal states are responsible for the legislation in the building area, e.g. building codes. In order to harmonise the regulations concerning construction engineering, the Austrian Institute of Construction Engineering (OiB) provides the OIB Guidelines (OiB, 2015). The federal states may declare OIB Guidelines as binding in their building codes, which is already the case in all federal state. The OIB Guidelines follow the concept of performance-oriented building requirements and cover the fields of statics, fire safety, hygiene, health, preservation of the environment, noise protection, energy saving and heat insulation.

OIB Guideline 6 states the maximum allowed heating energy demand for new and comprehensively refurbished residential buildings depending on the buildings' compactness. This value never may exceed 54.4 kWh of final energy per m² and year. Consequently, all new constructed and all comprehensively refurbished multi-family buildings are suitable for heat pump application.

2.3. Regulations concerning DHC Preparation in Multi-Family Buildings

Apart from space heating (SH), which usually accounts for the major part of heat demand of residential buildings, a substantial heat demand is requried for DHW. The temperature for DHW is in principle determined by the requirements of the residents. DHW is defined as tap water with a temperature above 40°C. As temperatures beyond 45°C are often considered as "too hot" by the user, hot water is usually mixed with cold water. To avoid the growth of microbes like legionella in warm water, certain measures have to be taken into account (Green Heat Pump, 2014)

2.3.1. Legionella

The growth of legionella is high at temperatures around 40 °C, while legionella is killed at temperatures above 60 °C. Therefore, in most countries there is national legislation concerning the design of DHW preparation systems in residential and commercial buildings. There are no EN Standards or EC-regulations dealing with temperature levels for DHW preparation concerning legionella treatment, but there is a WHO recommendation (see WHO 2007) stating that a minimum flow temperature of 60 °C should be maintained in water leaving the heating unit, and of 50 °C at the tap (1 minute after leaving the heating device).

The valid standard in Austria concerning the planning, installing, operation, control and restoration of centralized DHW systems is the ÖNORM B 5019:2017. Its aim is the prevention of infections caused by contaminated DHW . Beside other building types, this standard applies for multi-family buildings, but not for single-family houses and semi-detached houses. The ÖNORM B 5019:2017 refers to centralized DHW preparationsystems that contain several taps where the water volume between the heater and the remotest tap of are more than 3 Liters.

These centralized DHW systems have to constantly maintain a water temperature of 60 °C or above after the heating facility and of 55 °C or above in all pipes.

One way to avoid these restrictions is to use so called "fresh water stations" in each dwelling. This way, the individual systems have no DHW storage and the volume of water between the heater (fresh water station) and the remotest tap usually can be maintained below 3 Litres. The DHW tubing inside a dwelling is usually smaller, therefore the usage of fresh water stations avoids the restrictions imposed by the ÖNORM B 5019:2017.

In order to maintain the piping's required minimum temperature of 55 °C at all times, centralized DHW systems must contain

- circulation piping with constantly working circulation pump
- electrical trace heating (required temperature: 60 °C)

The standard defines 4 risk groups. Risk group 1 refers to public buildings (1a) and multi-family buildings (1b), risk group 4 refers to hospitals or areas of hospitals where persons with suppressed immune system reside. The strictness of the required safety measures depend on the risk group of the persons that may reside in the building. Safety measures concerning water temperature measurement and water quality examination apply in the commissioning phase (initial examination) and during the operations phase of the building (continous examination). In multi-family buildings (risk group 1b), the temperatures in the circulation systen and the total DHW consumption must be monitored at least annually, if necessary, the taps' frequency of use may be monitored aswell.

If the Legionella concentration, measured during the initial or any continous examination, exceeds the value of 100 colony-forming units, restoration is required, the measures are categorized in (Austrian Standards 2017):

1. Installation-related mearures: maintaining required operation temperatures, replacement of shower heads, removing dead pipes, using dezentralized DHW heaters
2. Process-related measures: thermal desinfection at 70°C (preferred), chemical desinfection e.g. with chlorine dioxide (only if other measures are not possible), UV desinfection (not recommended), filters in taps (only temporarely)

2.3.2. Potential solutions for DHW preperation by heat pumps in MFBs

Heat pump systems for SH and DHW are usually designed with two supply temperature levels, one for DHW and a lower temperature level for SH. In low temperature heating systems (for which most heat pumps in the market are designed), this design leads to substantially higher performance factors compared to a system with only one supply temperature at the highest temperature level. The reason is that SH, which accounts for the highest share of the heat demand, is supplied at the lower temperature level leading to a higer Coefficient of Performance (COP) of the heat pump. This advantage compensates the additional thermal losses arising from additional tubing and storage. In a stratified storage tank, water at these two temperature levels is stored at different heights (Green Heat Pump, 2014).

The research project Green Heat Pump proposes two main solutions for the DHW preparation by heat pumps in mulit-family buildings:

i. Decentralized DHW preparation:

Fresh water stations in each dwelling (see Figure 6) heat the DHW to a supply temperature of approxmately 50 °C. The heating supply temperature may rise to 55 °C in design conditions (low outdoor temperature), but fall below 50 °C at higher outdoor temperatures. In some cases, e.g. at low outdoor temperatures, the middle part of the storage will be charged with higher temperature than the design temperature in the upper part and consequently both parts will be maintained at the design heating supply temperature. The fresh water stations will then receive supply at higher temperature then necessary. Energetically it is not optimal (DHW could be prepared at a lower temperature than it actually is) but as it only applies to a limited number of days during the year, an alternative layout with two separate storage tanks is not justified.

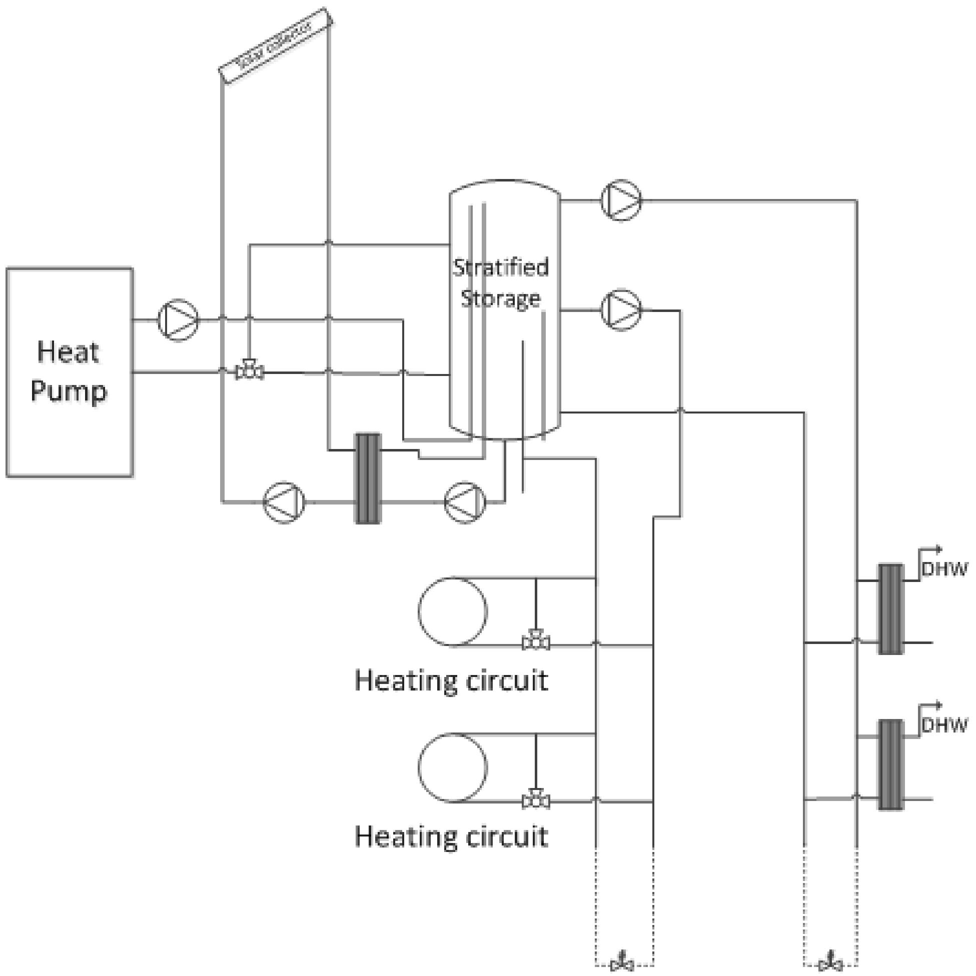


Figure 6: Simplified scheme of the hydraulic layout with a fresh water module in each dwelling (Green Heat Pump, 2014)

ii. Centralized DHW preparation:

The second solution is a system layout with a central DHW heat exchanger (see Figure 7), According to ÖNORM B 5019:2017, DHW has to be maintained at 60 °C at all times. Therefore, the DHW temperature must be always higher than the heating supply temperature. The upper part of the storage tank is thus maintained at above 60 °C, while the medium part is maintained at the heating supply temperature determined by the heating curve. This is achieved by two set points for the heat pump. For maintaining DHW temperature, the heat pump draws its return water from the middle part of the tank, while for maintaining the heating temperature in the central part the return comes from the lower part of the storage (Green Heat Pump, 2014).

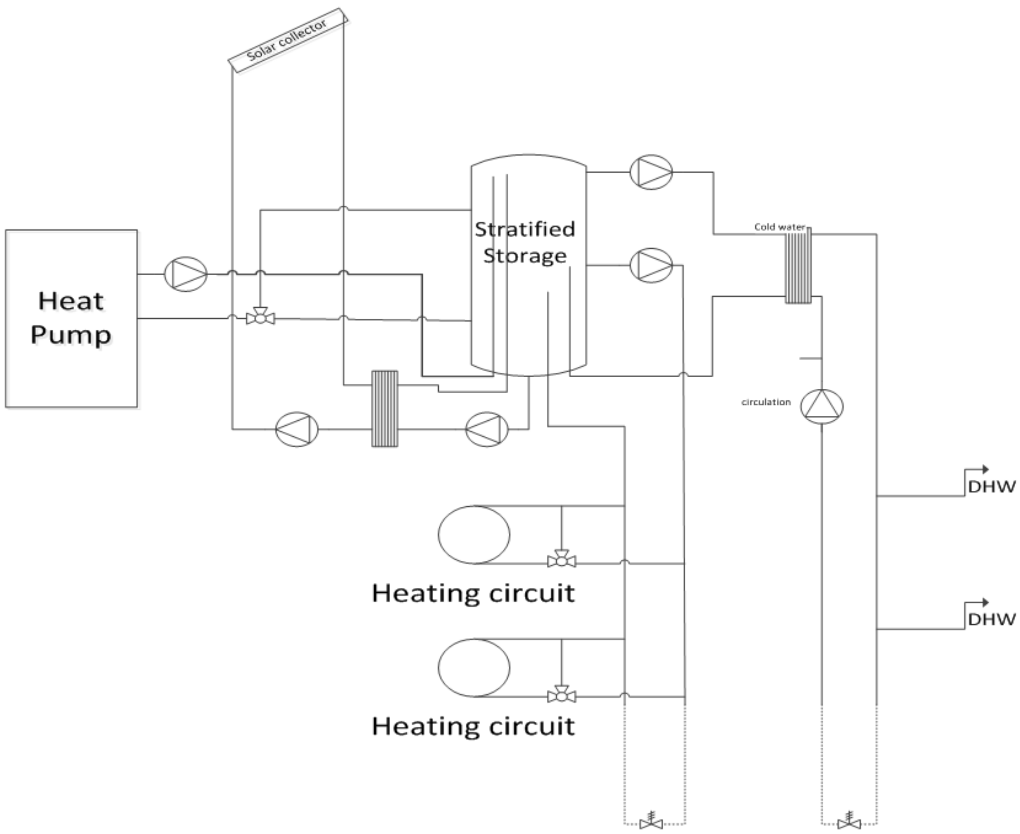


Figure 7: Simplified scheme of the hydraulic layout with centralized DHW generation (Green Heat Pump, 2014)

3. Building stock Characteristics

3.1. Austrian Building Stock

According to the micro census of Statistik Austria, in 2015 around 3.8 Mio. main residences are registered. The micro census is an extrapolation based on an elicitation of 20 000 residences. It permitts the subdivision in home ownership (1462 tsd), dwelling ownership (413 tsd), community housing (293 tsd), cooperativee housing (621 tsd), other rental housing (654.1 tsd) and others (371 tsd), as shown in Figure 8. Home ownership means, that one or more members of the household are owners of the building, while dwelling ownership has to be understood in that way, that one or more members of the household are owners of a dwelling in a building. It is not defined which kind of building this is, but it can be presumed, that the most home owners owns are single/two family house, while the major part of dwelling ownership, community housing, cooperative housing and other rental housings can be seen as dwellings in multi family buildings. (Statistik Austria, 2016)

The second homes are counted the last time in 2011 and amounted in a number of 796 tsd. A closer subdivision has not been made for this type of homes. (Statistik Austria, 2013)

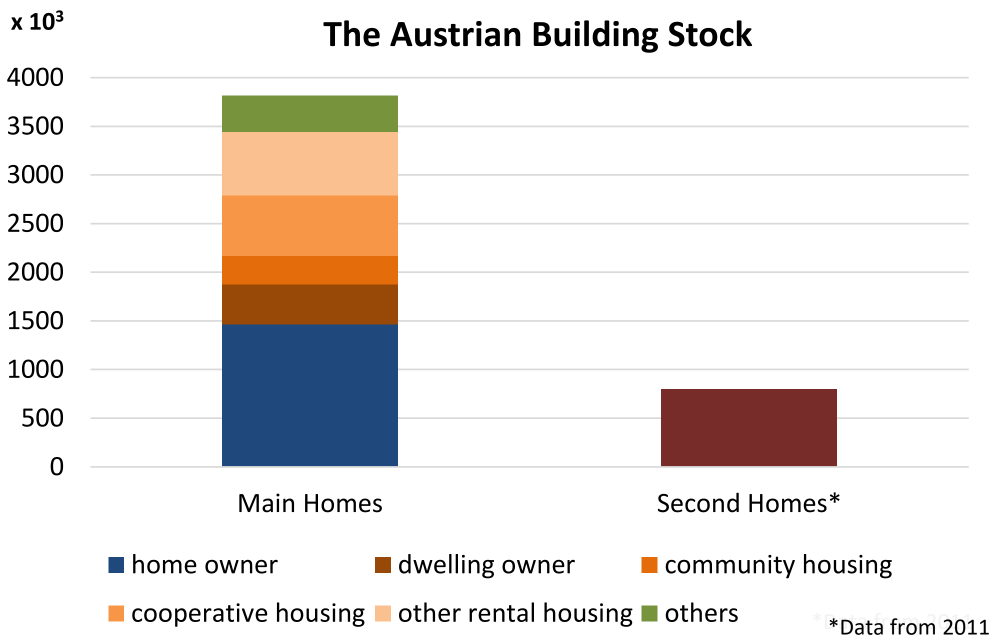


Figure 8: Austrian building stock 2015 (2011); data according to Statistik Austria (2016) & Statistik Austria (2013)

Figure 9 shows the Austrian building stock divided in construction periods. On the one hand all buildings are counted (in blue) and on the other hand the number of dwellings (in red) are counted and allocated according to the age of the building. It is shown that there is a heterogeneous mix of building in Austria according to their age. Counted according to the number of dwellings there is still a large number located in old buildings which are built before 1919.

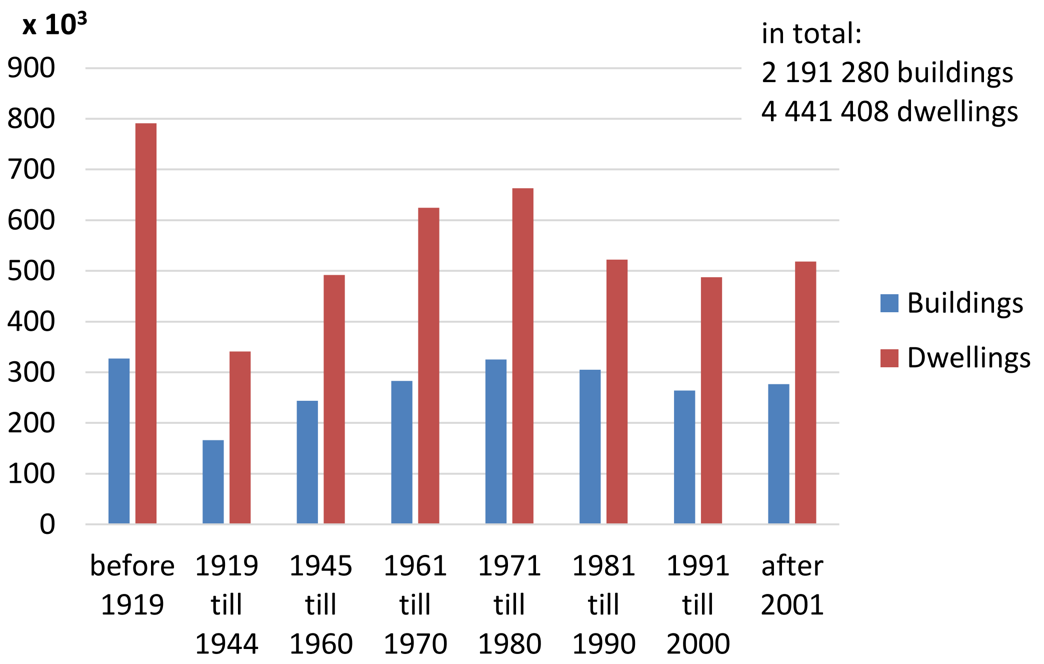


Figure 9: Building and dwelling stock 2011 divided in construction periods; data according to Statistik Austria (2013)

Moreover Figure 10 shows the buildings separated in legal relationships and construction periods. The owners are moreover separated in house ownerships (mainly single family buildings) and dwelling ownerships (mainly multifamily buildings). It is seen that there is no significant difference between them according to the construction period. The house ownerships as well as the dwelling ownerships are more or less evenly distributed over the selected construction periods, with a bit more older buildings in the house ownership section.

In the section private rental the buildings which are built before 1919 are with about 40 % the major part, while it is different the opposite for social housing (community housing). There more than 80 % are built between 1919 and 1980 and the share of the buildings which are built before 1919 is negligible small.

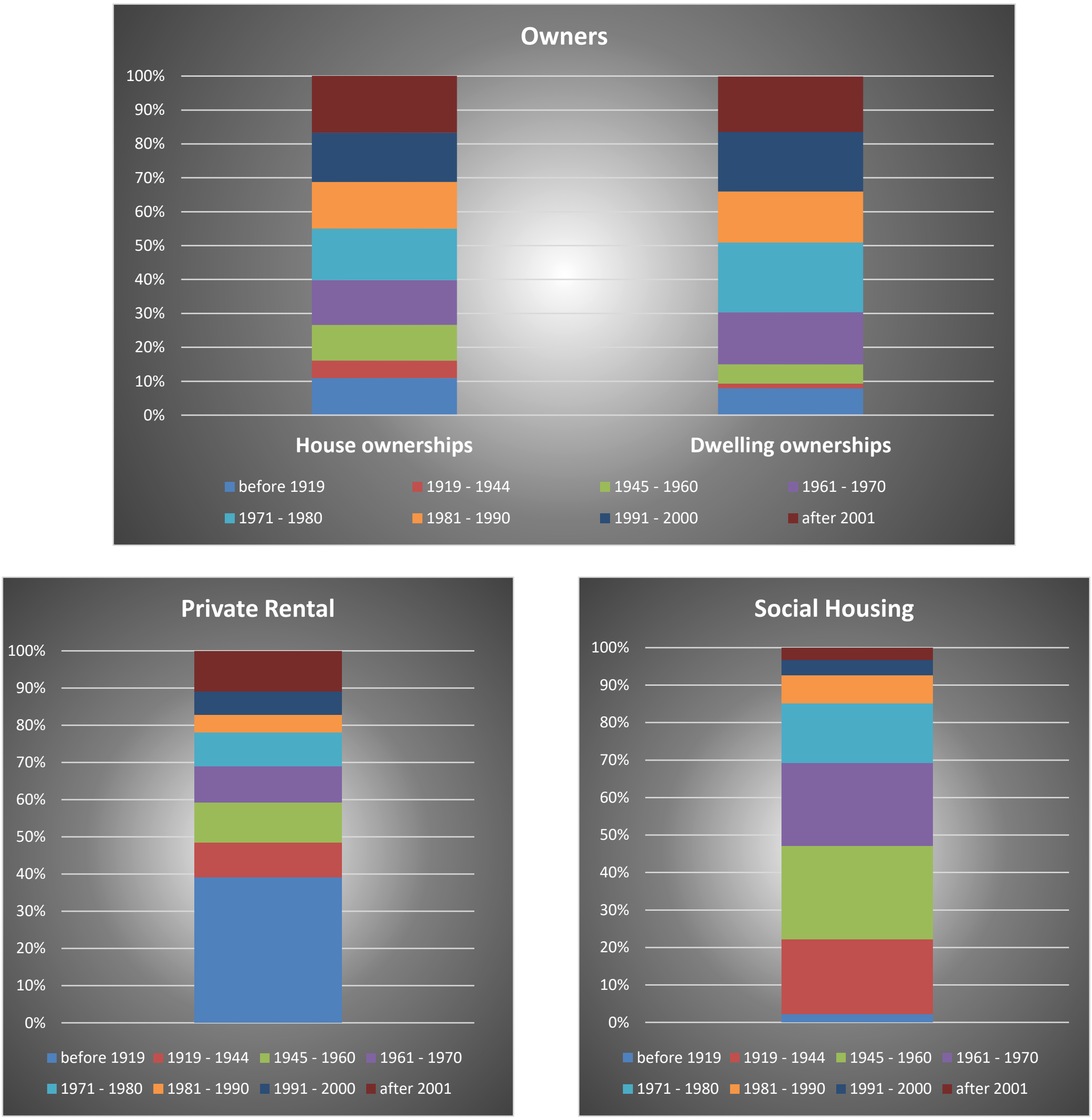


Figure 10: Legal relationships of main homes divided in construction periods; data according to Statistik Austria (2016)

In Austria, the dominant fraction of dwellings is privately owned with a share of 73 %, which results in an absolute number of 3.25 million (see Figure 11). The second largest group of owners are the non-profit housing associations with a fraction of 13 % followed by local authorities with 8%. Other companies make up 5 % of the total amount of dwellings in Austria. (Moisi et al., 2015)

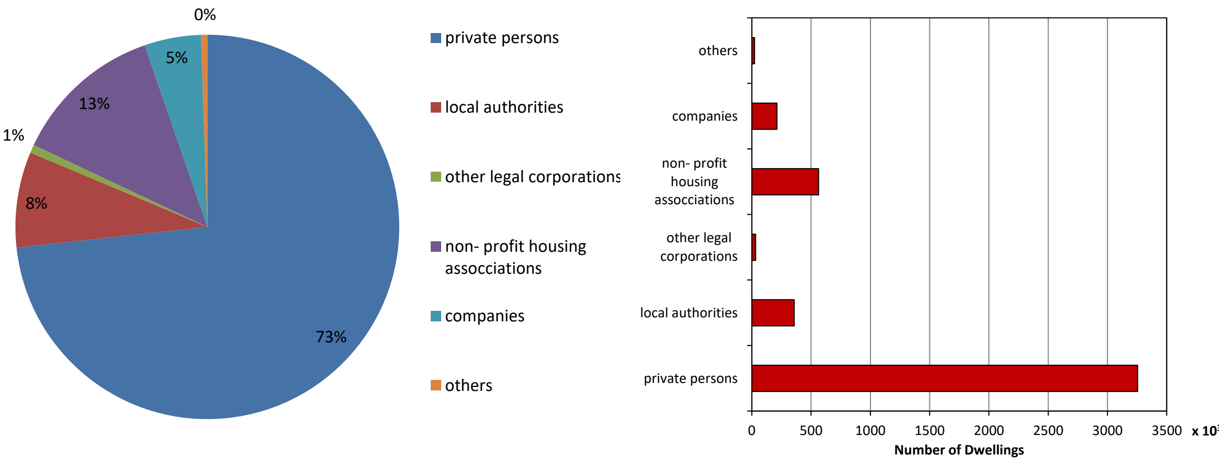


Figure 11: Ownership relations of dwellings in Austria in 2011 according to Statistik Austria (2013)

If the counting method is changed to the number of buildings instead of dwellings, the fraction privately owned is with 89 % even more dominant, as Figure 12 shows.

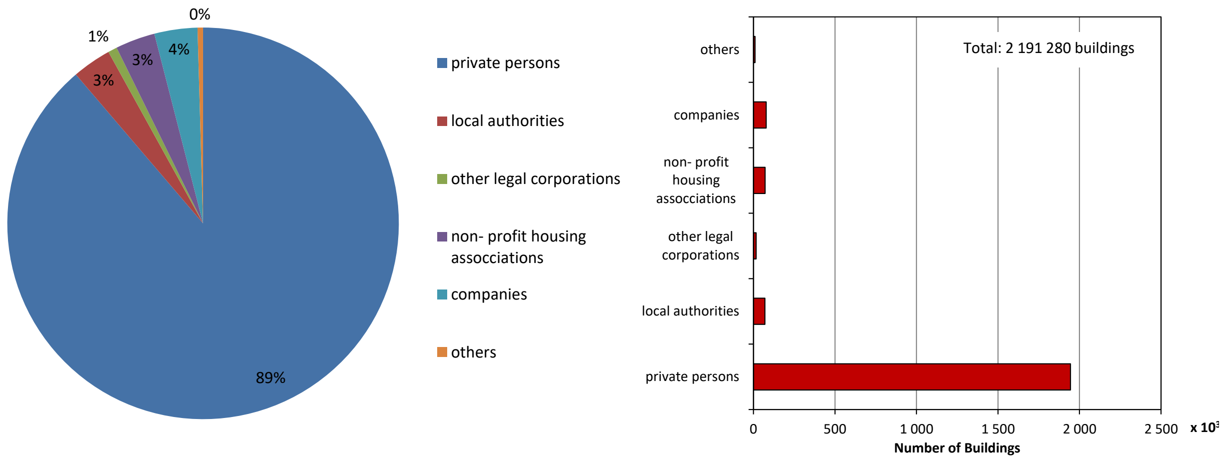


Figure 12: Ownership relations of buildings in Austria in 2011 according to Statistik Austria (2013)

By far the majority of Austrian buildings in the year 2011 are buildings with one or two dwellings. The number is approximately 1.7 million which is illustrated in Figure 13. Buildings with 3 to 10 dwellings only make up 176 000 and buildings with 11 or more make up 76 000 of the total housing stock. (Moisi et al., 2015)

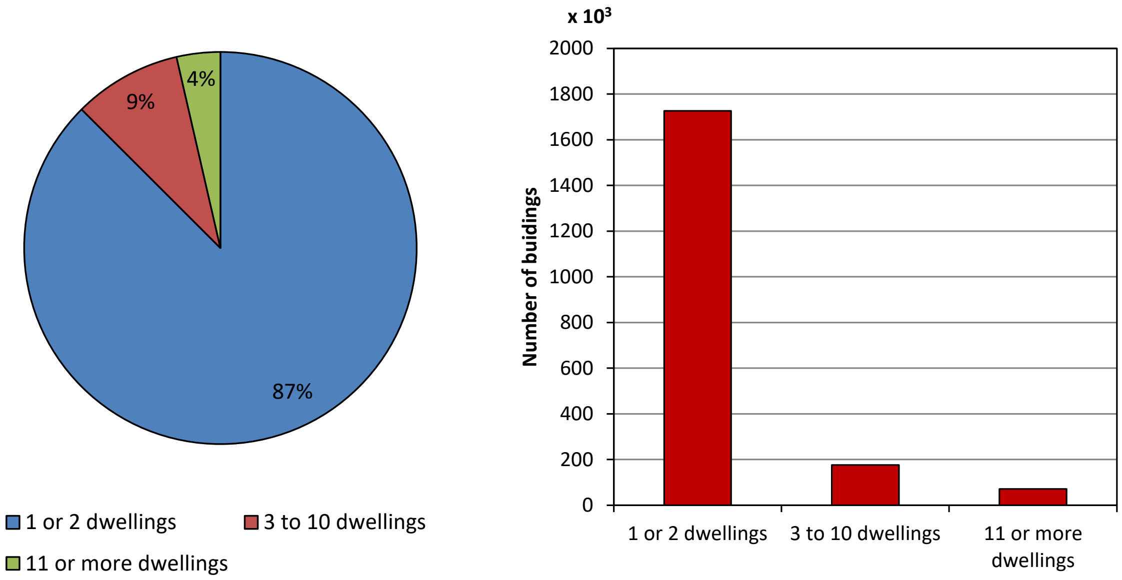


Figure 13: Building Stock in Austria by number of buildings, relative (left) and absolute in thousand (right) (Moisi et al., 2015)

If it is counted according to the registered main residences in the year 2015 (micro census) the half of them are located in buildings with one or two dwellings. In total that are about 1.8 million which is illustrated in Figure 14. Main residences in buildings with 3 to 10 dwellings make up only 19.1 %, while those in buildings with more than 10 dwellings are with about 33 % the second largest group. This fraction can be further divided in 18.1 % of main residences in buildings with 10 to 19 dwellings and in 15.1 % of those in buildings which have more.

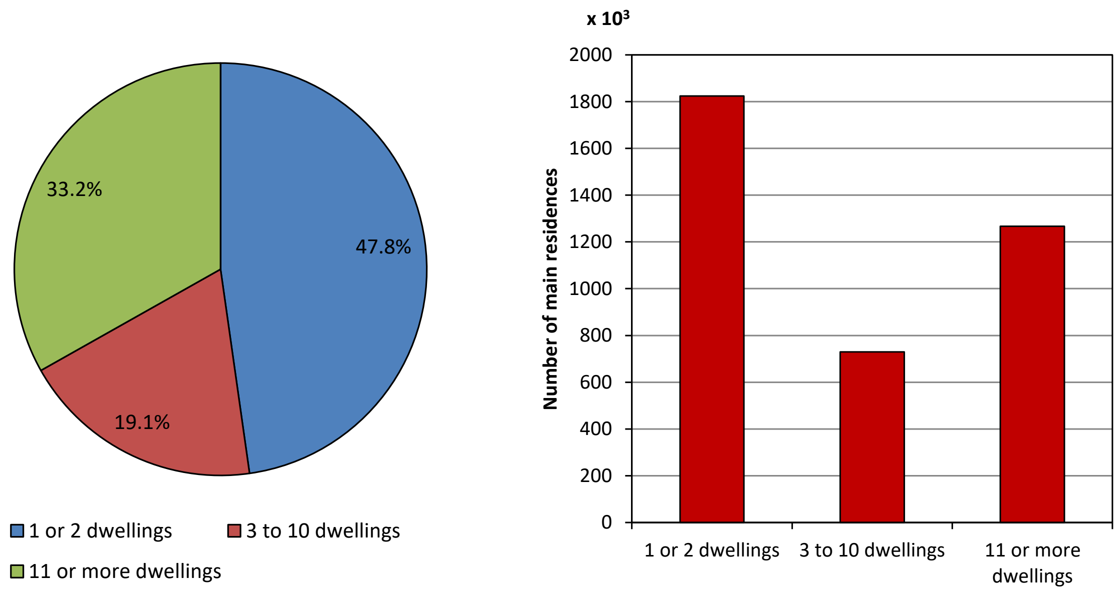


Figure 14: Building Stock in Austria by number of dwellings (only main residences), relative (left) and absolute (right); data according to Statistik Austria (2016)

The average living area in Austrian dwellings was about 100 m^2 in 2015. The average living space separated for different dwelling types and building age is illustrated in Figure 15. (Statistik Austria, 2016)

Home ownerships have in average the largest living area with 138.9 m^2. By contrast dwellings have only an average living space of 83.5 m^2. Moreover new buildings which are constructed after 2001 show with 109.1 m^2 the highest average living space per dwelling. (Statistik Austria, 2016)

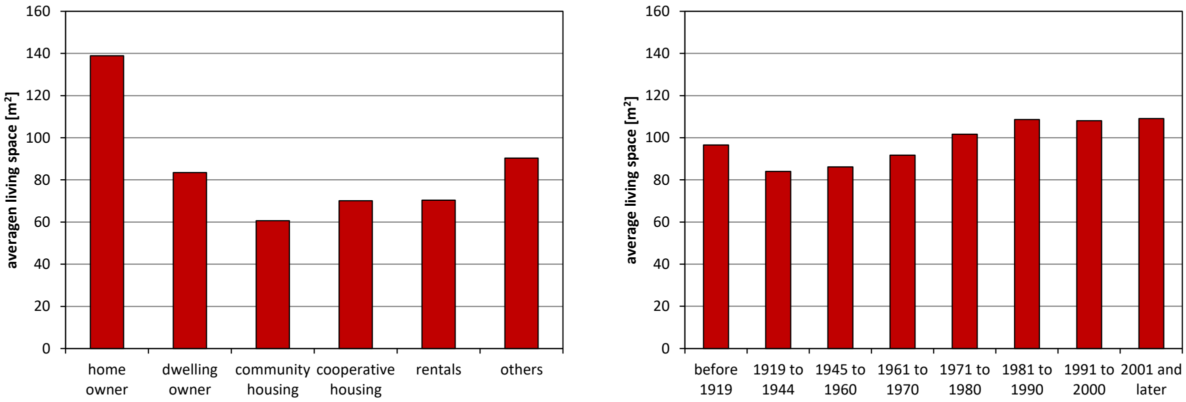


Figure 15: Average living space by ownership (Left) and construction period (right) in 2015 (Moisi et al., 2015) updated with data according to Statistik Austria (2016)

In addition to the data shown in Figure 15, Table 1 provides a distribution according to the population. It is shown, that the total living area as well as the average living area per person have increased much stronger, than the average living area per residential unit. In the last forty years the living area per person has nearly doubled. While in 1970 one person had in average about 22 m^2 for living, this area has been increased up to 43 m^2 till 2010.

Table 1: Development of the housing stock in Austria (Rieberer, 2017)

		1970	1980	1990	2000	2010
a) Population	10^6 Pers.	7,5	7,5	7,7	8,0	8,4
b) Residential units (RU)	10^6 RU	2,67	3,05	3,39	3,86	4,21
per inhabitant	RU / Pers.	0,36	0,40	0,44	0,48	0,50
c) Living area						
Total living area	10^6 m^2	164	211	253	304	360
Average living area per residential unit	m^2 / RU	61,6	69,3	74,7	78,8	85,4
Living area per person	m^2 / Pers.	22,0	28,0	33,0	38,0	43,0
d) Heated living area						
90% of the total living area (estimated!)	10^6 m^2	148	190	228	274	324

3.2. Energy Consumption in Austrian Buildings

The final energy demand in the Austrian building stock is illustrated in relative in Figure 16 to Figure 18 and in absolute numbers in Figure 19. It is shown, that since 2003/2004 the specific heating demand per cubic metre decreased in the last years. In contrast the specific hot water demand per person has been increased till 2011/2012 before it started to decrease again in 2013/2014. The energy for cooking approximately remained the same in the considered period.

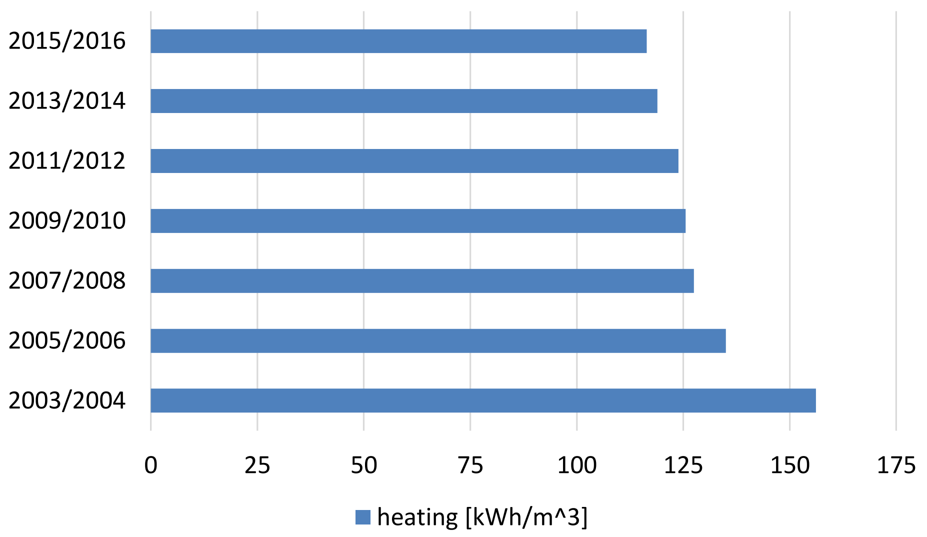


Figure 16: Final energy demand for heating in buildings per m3; data according to Statistik Austria (2017)

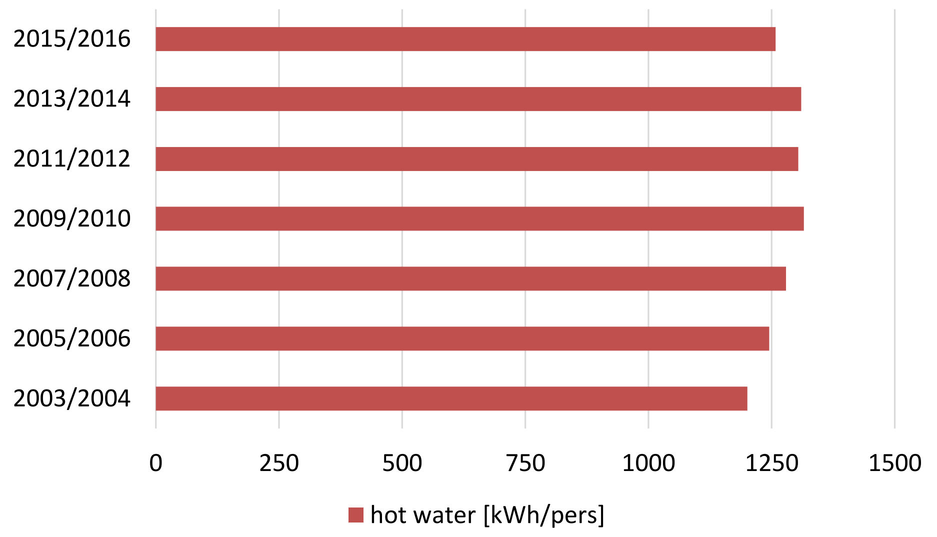


Figure 17: Final energy demand for hot water preperation in buildings per person; data according to Statistik Austria (2017)

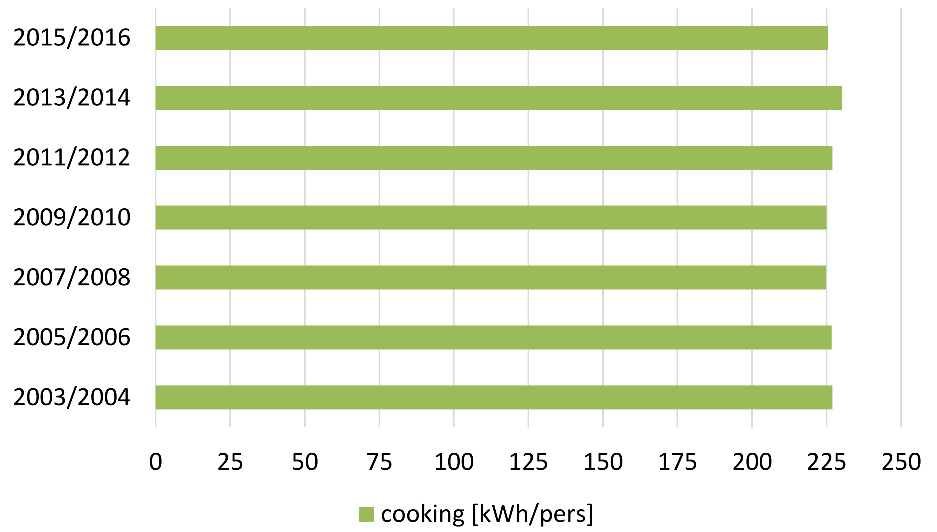


Figure 18: Final energy demand for cooking in buildings per person; data according to Statistik Austria (2017)

In total numbers the energy for heating amounted to 45.45 TWh, the DHW demand to 10.84 TWH, the energy for cooking to 1.94 TWh and other usages to 9.74 TWh. The heating demand is with about 67 % by far the largest energy demand in the building sector. It is shown, that in total numbers too, the heating demand decreased from 2003/2004 till 2007/2008 before it remained approximately the same since 2007/2008. The hot water demand, the energy for cooking as well as the energy for other usages does not significantly change in the considered period.

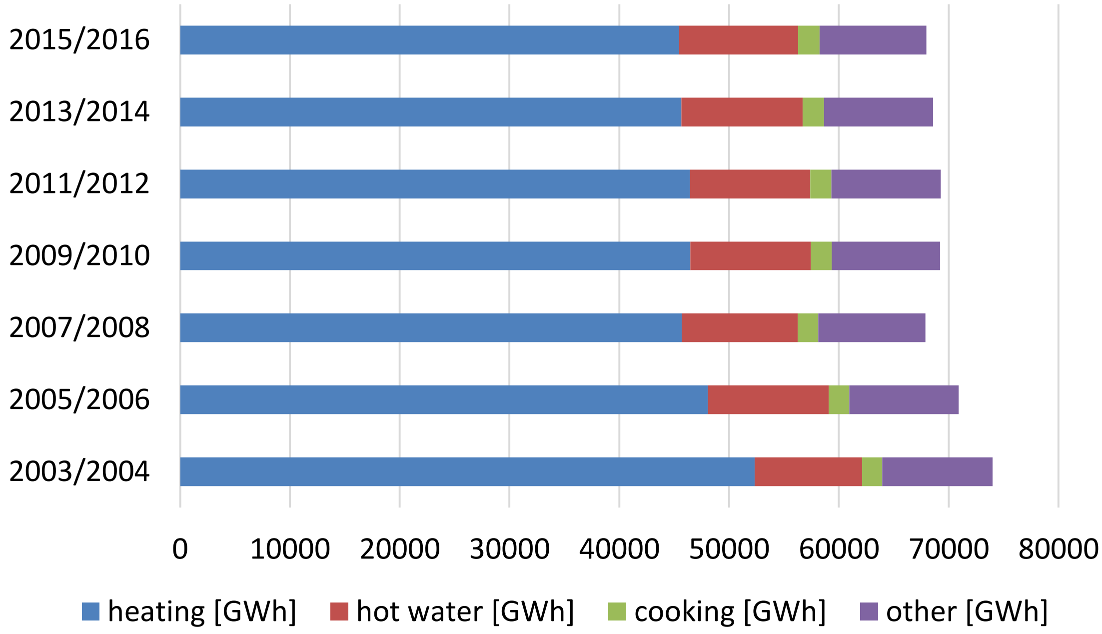
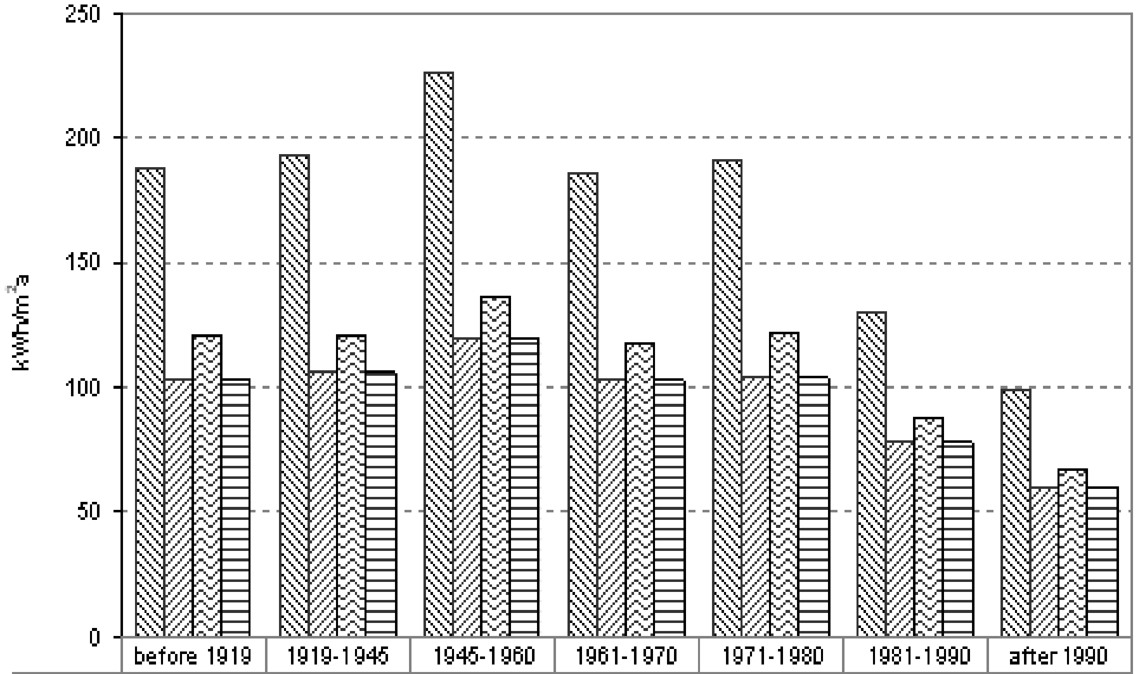


Figure 19: Final energy demand for buildings in total numbers; data according to Statistik Austria (2017)

The heat demand strongly depends on the year of construction and possible thermal refurbishment of the building envelope. As shown in Figure 20, buildings with one dwelling built in Austria before 1945 have a specific useful energy demand for SH of about 190 kWh/(m²a). For dwellings built between 1945 and 1960 this value rises to 230 kWh/(m²a). This period was the time of fast and cheap production of living space after the Second World War. Since then the specific energy demand of buildings steadily decreased, partly due to the first oil price shock in the end of the 1970s. This development was enabled by the availability of more effective insulation materials and advanced window technology, supported by a growing environmental concern. For single dwelling buildings built after 1991 the useful heating demand is in the range of 100 kWh/(m²a), which is already less than half of the values of the period from 1945 to 1960. (Moisi et al., 2015)



	before 1919	1919-1945	1945-1960	1961-1970	1971-1980	1981-1990	after 1990
SDB	188	193	226	186	191	130	99
MDB - B	103	106	120	103	104	78	60
MDB - S	121	121	136	118	122	88	67
NRB	103	106	120	103	104	78	60

*Figure 20: Specific annual energy use for heating in kWh/(m2*a) of single (SDB) and multi-dwellings (MDB; -B = Large, -S = Small) buildings, as well as non-residential buildings (NRB) by the construction period (Moisi et al., 2015)*

For multifamily buildings the value was already 60 – 70 kWh/(m²*a) in 1991. The trend is in the direction of values even far lower. With building codes and subsidy schemes values of about 50-60 kWh/(m²a) for single (and two) dwelling buildings and 40-50 kWh/(m²*a) for multi dwelling buildings are achieved. Houses built according to the passive house concept show that the SH demand can be decreased to 15 kWh/(m²a). The requirements to reach such small heating demands are an optimal thermal insulation of the building envelope and effective mechanical ventilation using air heat recovery. Thus, the energy demand of new buildings decreased drastically in the last 50 years. However, the average living space per person has increased from 38 m^2 in 2001 to 44.3 m^2 in 2013 according to Statistik Austria. Although the heat demand of buildings is decreasing, the opposite trend of living space compensates the decrease of the total energy consumption, to a certain extend. (Moisi et al., 2015)

3.3. Heating systems in Austrian buildings

Figure 21 shows the heating systems used in the Austrian building stock according to the construction periods. It is shown, that in modern buildings the central hydronic heating and the district heating are with more than 90 % the dominant heating system. The older the buildings are, the more other heating systems are installed too. For example in buildings which are built before 1919 the floor/dwelling central heating systems are with a share of about 35 % still the most installed system. As shown in Figure 9, with about 800 000 dwellings which are built before 1919 this segment is still important to consider. The direct electric heating systems and the gas convectors have been around 10 % (both together) till they finally started to loos popularity in the 1990s. That was partly because of security reasons (gas convector), bad economy (electric heating) and especially because of the more efficient central heating system or connecting the building to the district heating system, if available.

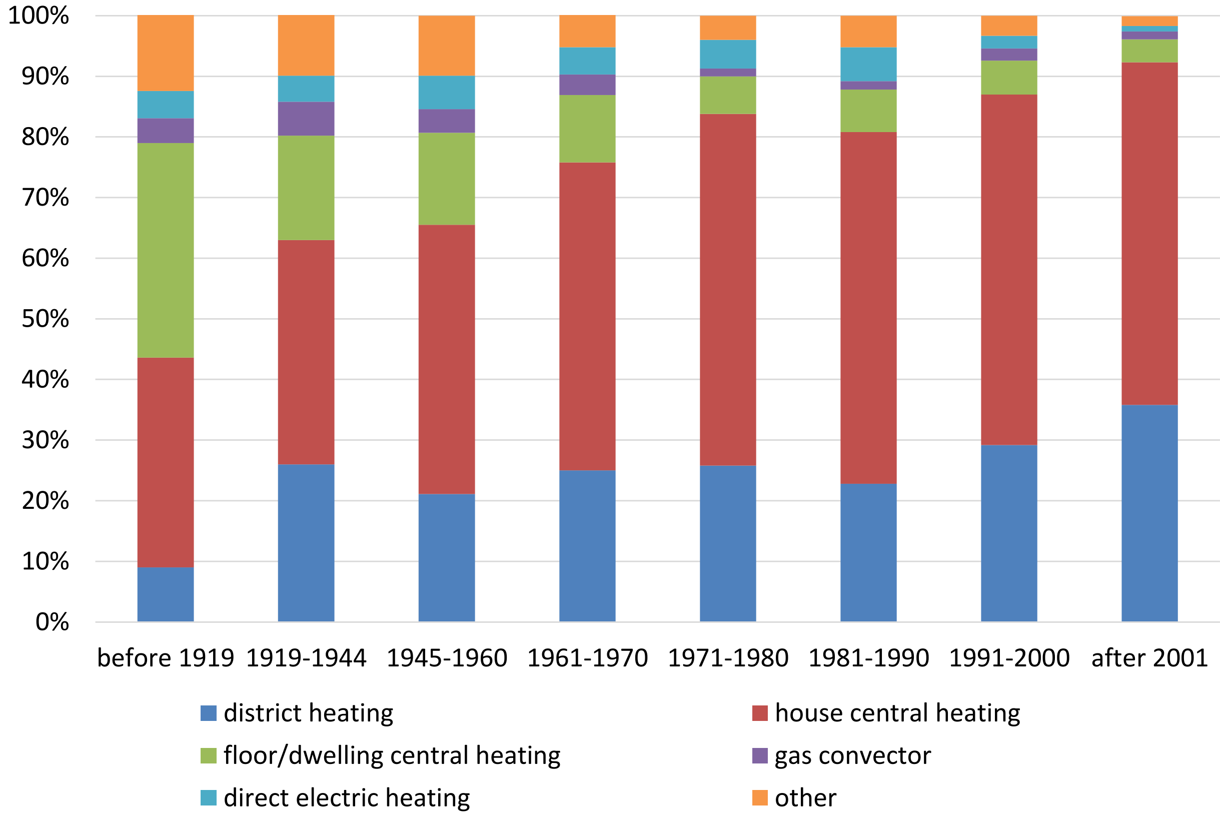


Figure 21: Heating systems in the building stock according to the construction period; data according to Statistik Austria (2016)

Figure 22 shows the distribution of the heating systems for the whole building stock and divided to the legal matters. In total 24 % of the buildings are connected to the district heating system, 50 % are heated with a house central heating system and 13 % are heated with a floor/dwelling central heater. The remaining 13 % are distributed as follows: 3 % gas convector, 4 % direct electric heating and 6 % other or no heating systems.

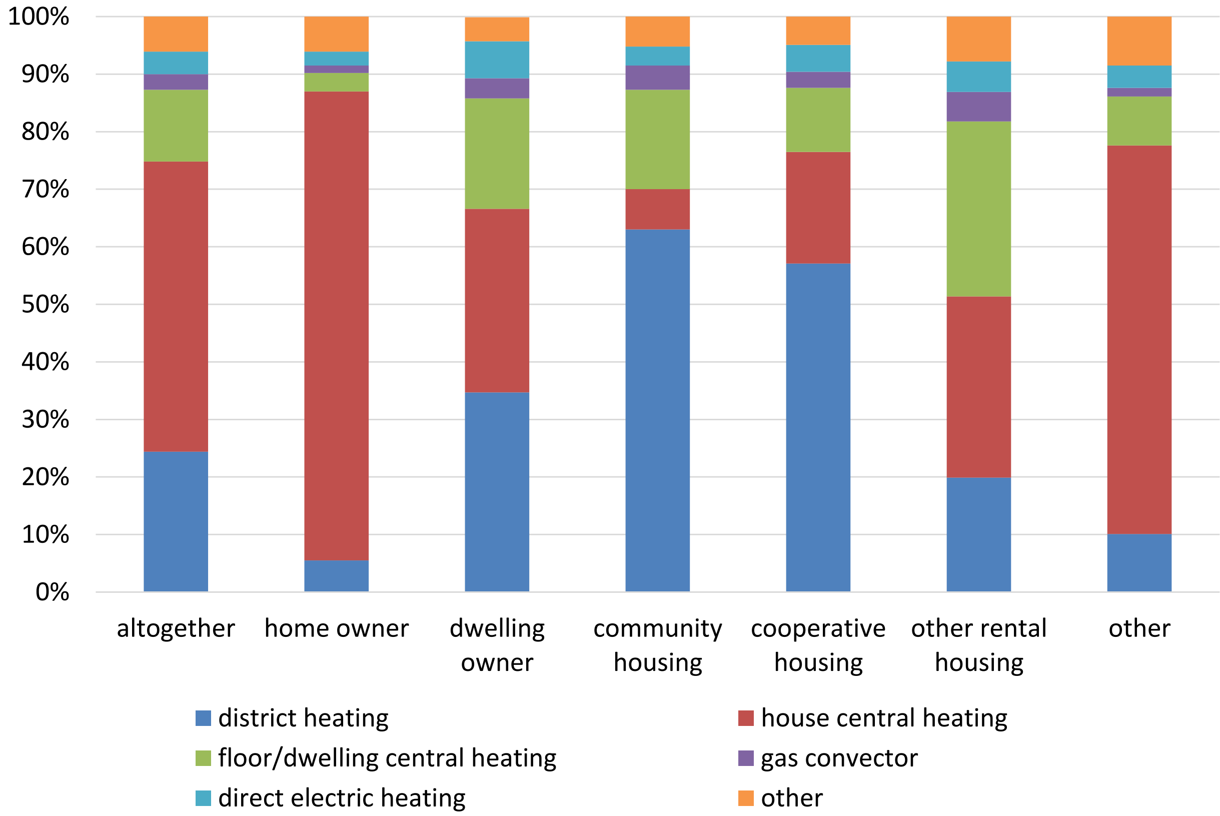


Figure 22: Heating systems in the building stock according to the type of ownership; data according to Statistik Austria (2016)

Furthermore, there are big differences in the installed heating system according to the legal matters. While the house central heating is by far the most popular heating system in the home ownership segment, the district heating is much more dominant in dwellings, especially in community and cooperative ones. This is mainly a matter of the availability of a district heating connection. While community and cooperative dwellings are often located in a city, private owned homes are typical for the countryside where often no district heating is available.

3.4. Energy carrier for heating & DHW in the building stock

In the following figures (Figure 23 to Figure 27) the used fuel types for heating in the Austrian building stock are illustrated. The used data is provided from the Invert/EE-Lab database (Invert/EE-Lab Database, 2017) and from Müller (2015) which uses this data to calculate forecast scenarios up to 2030, 2050 and 2080. Therefore the shown numbers have to be understood as an estimation which are furthermore not especially determined regarding to the heat pump situation in Austria. It is assumed, that the amount of the actual heated gross floor area, particularly in MFHs, is lower than it is shown in this figures.

In Figure 23 the share of the used fuel types divided in SFHs (including two family houses) and MFHs is shown. Data was available till the year 2014 (no forecast considered) and the shares are calculated relating to the heated gross floor areas. There is a big difference in the distribution in the SFHs and in the MFHs. While wood, and especially wood log (32 %), plays an important role in the SFHs, their share in the MFHs (1 %) is negligible small. In contrast, gas and district heating are the dominant energy sources in the MFHs.

While heat pumps with a share of 11.9 % have already been well established in the SFH section, they are with 4.0 % still the exception in MFHs.

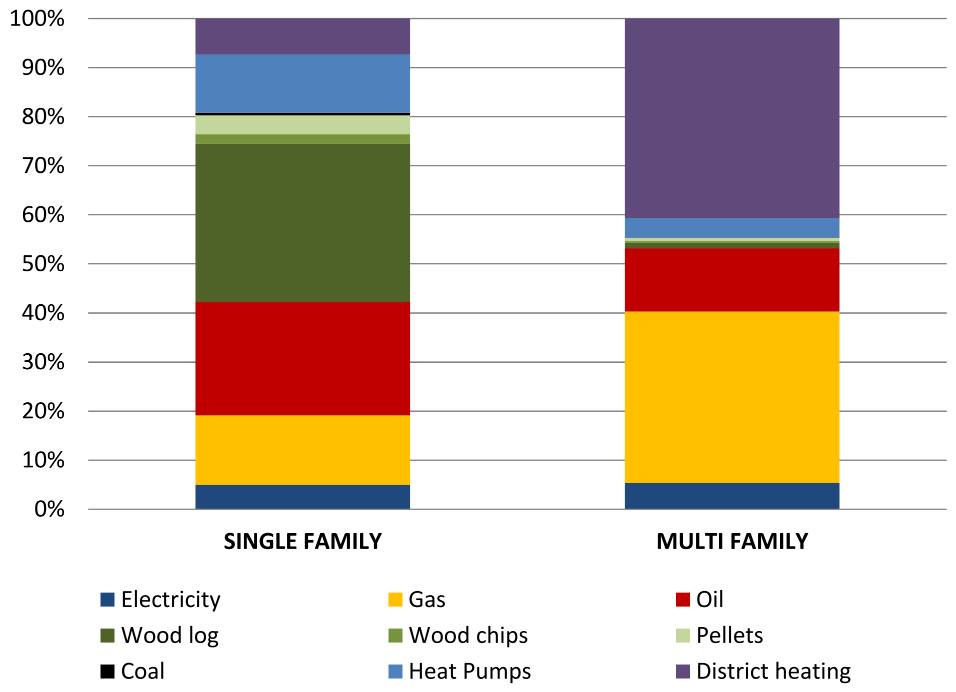


Figure 23: Share of used fuel types for heating in SFHs and MFHs related to the heated gross floor area; data according to Invert/EE-Lab Database (2017)

Figure 24 shows the share of used fuel types for heating in SFHs for different construction periods and related to the heated gross floor area. It is shown, that the share of wood log has continually been decreased in the considered period, while the amount of the heated area which is heated with district heating connections and heat pump systems has been increased. In new buildings (2009 – 2014) heat pump systems already heats around 30 % of the gross floor area and according to the calculations from Invert/EE-Lab this share will further be increased in the next years. In contrast, electricity, coal and wood chips have nearly disappeared in new SFHs. Oil heating systems have been popular after the Second World War till to the 1990s before they also started to decrease more and more.

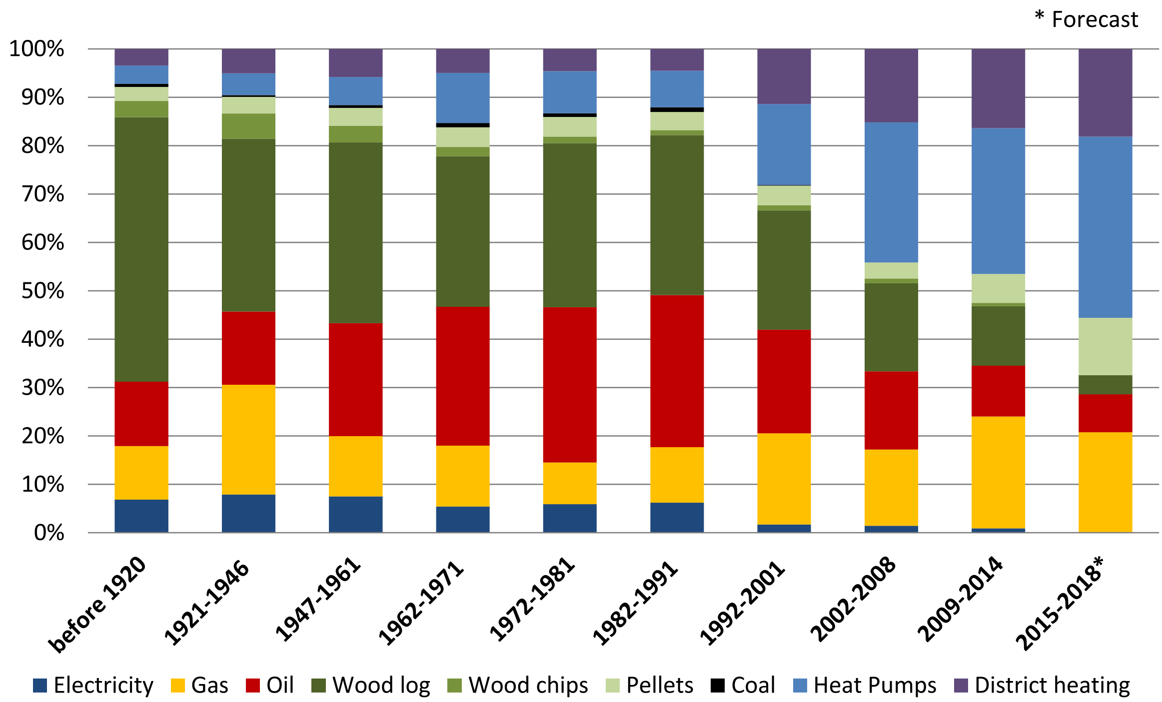


Figure 24: Share of used fuel types for heating in SFHs related to the heated gross floor area; data according to Invert/EE-Lab Database (2017)

Moreover, Figure 25 shows the same data as used in Figure 24 in absolute numbers, to give an overview of how many square metres are heated with which kind of energy source.

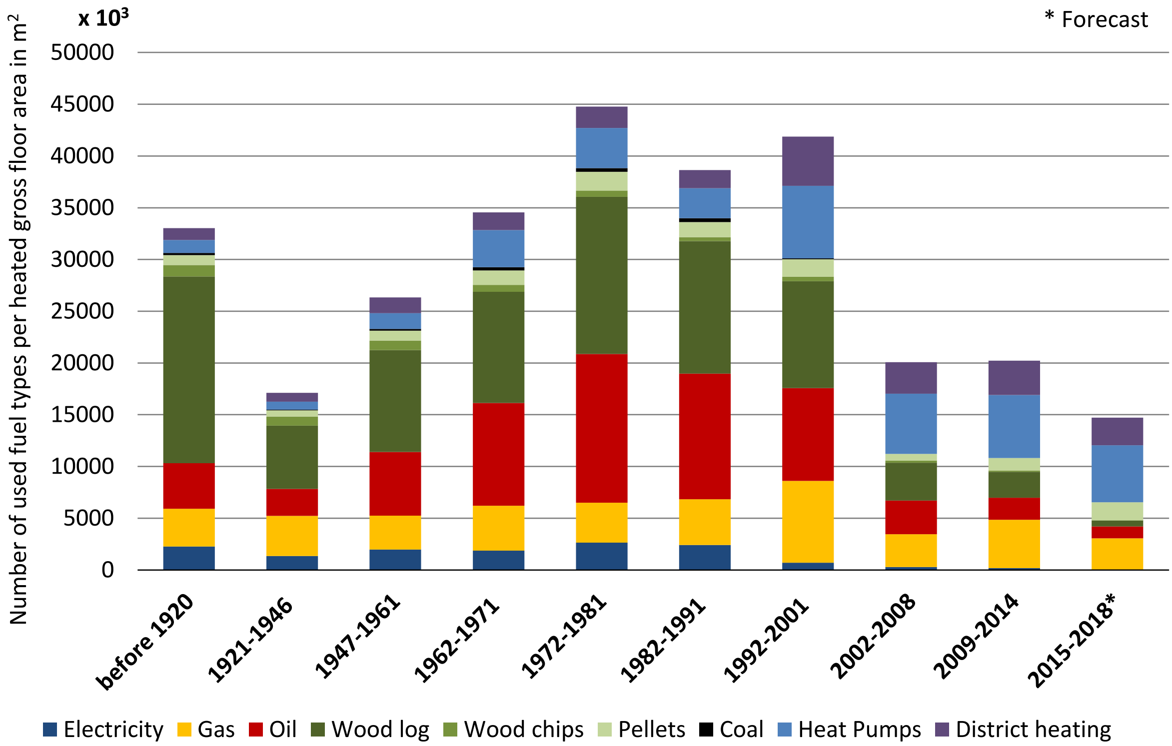


Figure 25: Number of used fuel types for heating per heated gross floor area in SFHs; data according to Invert/EE-Lab Database (2017)

In the MFHs gas is the dominant fuel type in buildings which are built before 1960. In the 1970s the share of gas heating systems have been decreased for the benefit of district heating and oil heating systems. While the share of new oil heating systems also started to decrease in the last years, the district heating is with about 55 % still the dominant system. Wood, coal and electricity does not play an important role anymore, while in contrast, the heat pump section started to take root in the MFH section too. In the new built buildings (2009 – 2014) already 11 % of the heated gross floor areas are heated with heat pumps and according to the Invert/EE-Lab calculation this share will double for the construction period 2015 – 2018.

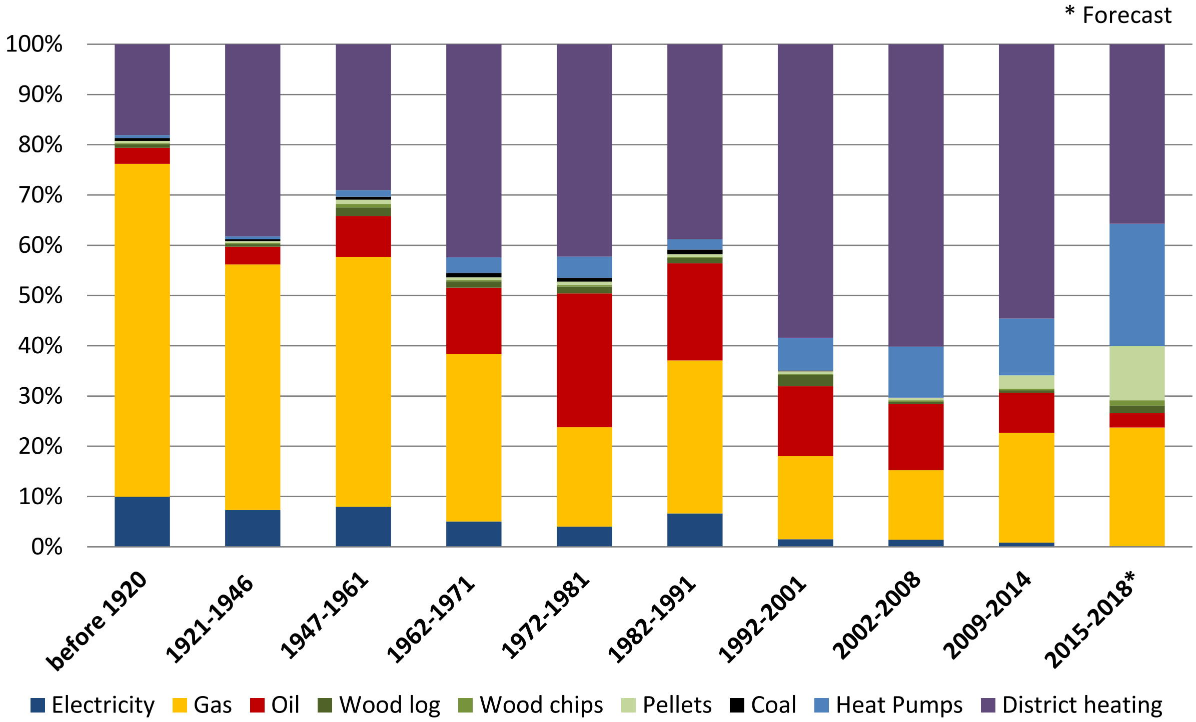


Figure 26: Share of used fuel types for heating in MFHs related to the heated gross floor area; data according to (Invert/EE-Lab Database, 2017)

Figure 27 shows again the same data as used in Figure 26 in absolute numbers, to give an overview, of how many square metres are heated with which kind of energy source.

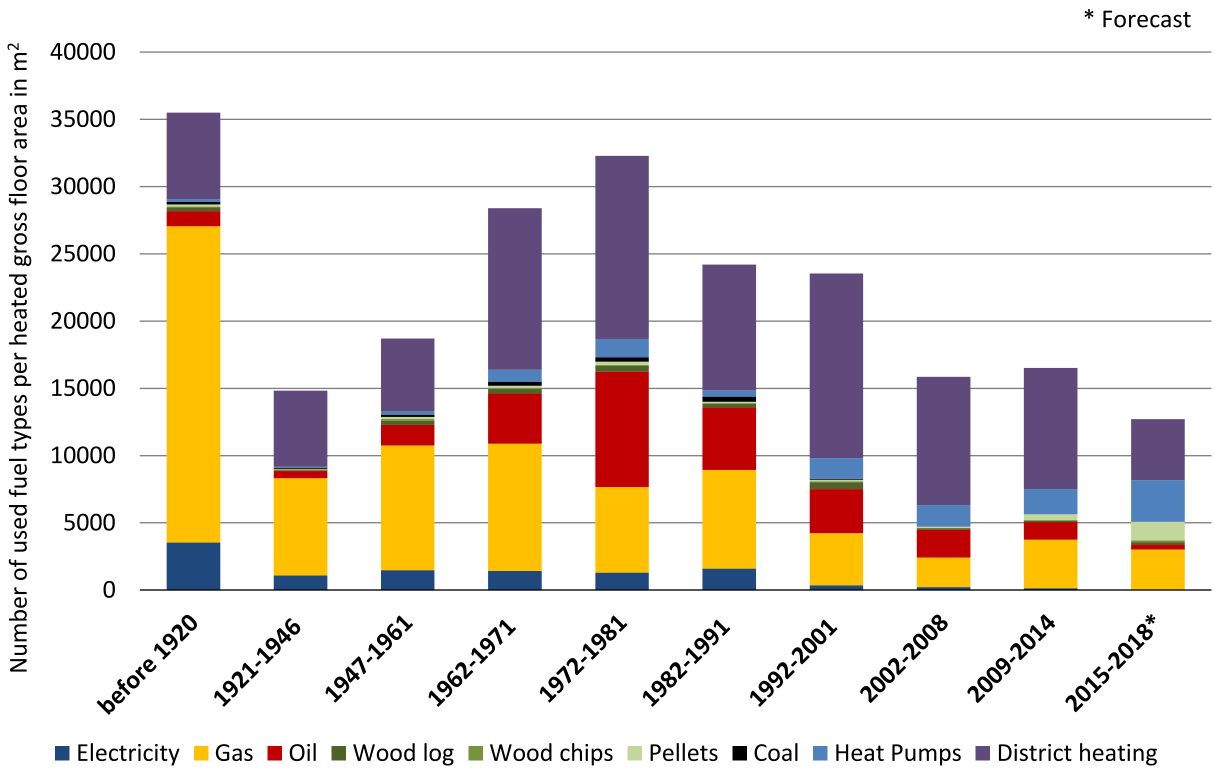


Figure 27: Number of used fuel types for heating per heated gross floor area; data according to (Invert/EE-Lab Database, 2017)

Furthermore Statistik Austria (2017) published a distribution of the usage of the different fuel types in GJ per energy source. This data is illustrated in from 2003/2004 till now. However no distinction between SFHs and MFHs has been made in the data collection. It is shown, that in this consideration the dominant energy source is wood/biomass (33 % for 2015/16) followed by gas and oil (both 21 %) and district heating (15 %). The share of heat pumps is with 2.77 % much lower than it is in Figure 23 (4 % MFH; 11.9 % SFH) where the share is calculated according to the heated gross floor area.

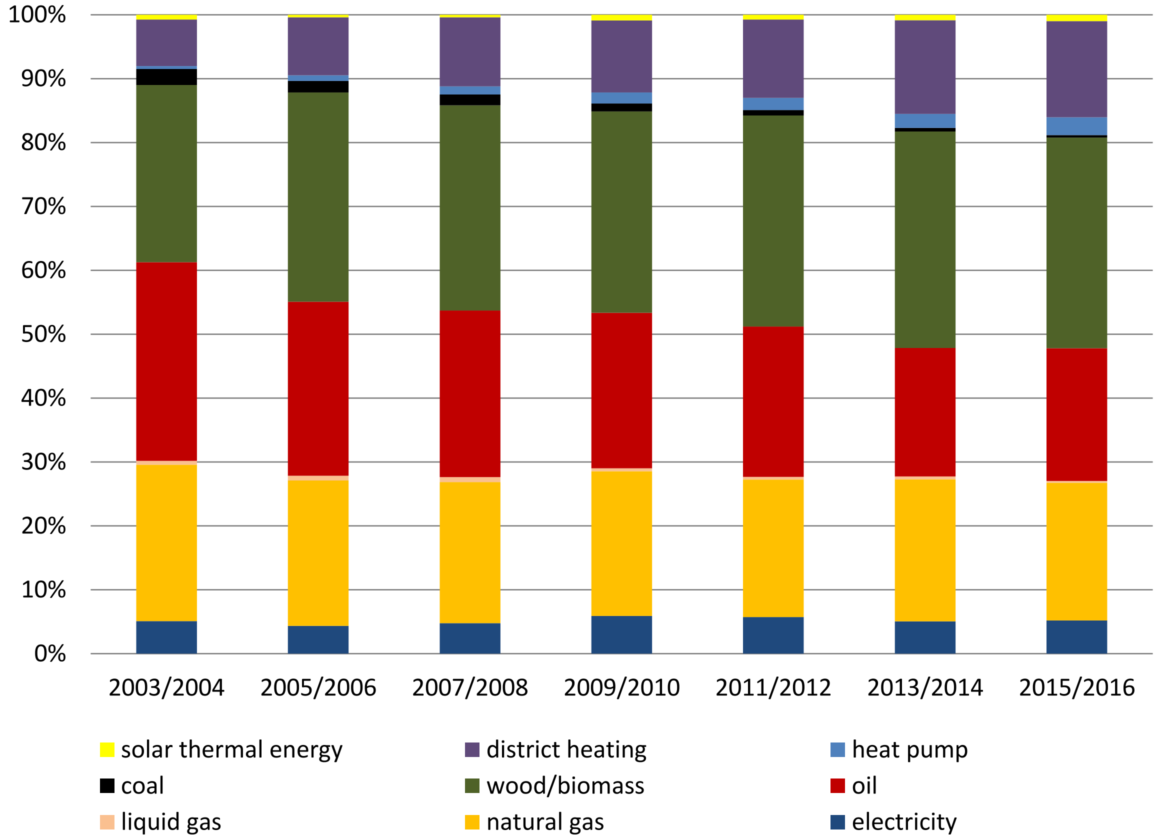


Figure 28: Relative use of energy sources for SH in all buildings; data according to Statistik Austria (2017)

The same data as shown in for SH is also available for the DHW preparation. The distribution of the used energy sources for this application is illustrated in Figure 29. It is shown that electricity (27 % in 2015/16) is still the most common way for DHW heating followed by gas (17 %), wood/biomass (16 %) and oil (12 %). Furthermore the solar water heating make up about 10 % of the whole energy used for DHW heating and heat pumps as well came to a share of approximately 3.6 %. One sees, that the share of energy from heat pumps is bigger for DHW preparation than for SH, despite there is normally a much higher temperature level needed in that case. More detailed data for DHW heating in the building stock in Austria is not available until the present time.

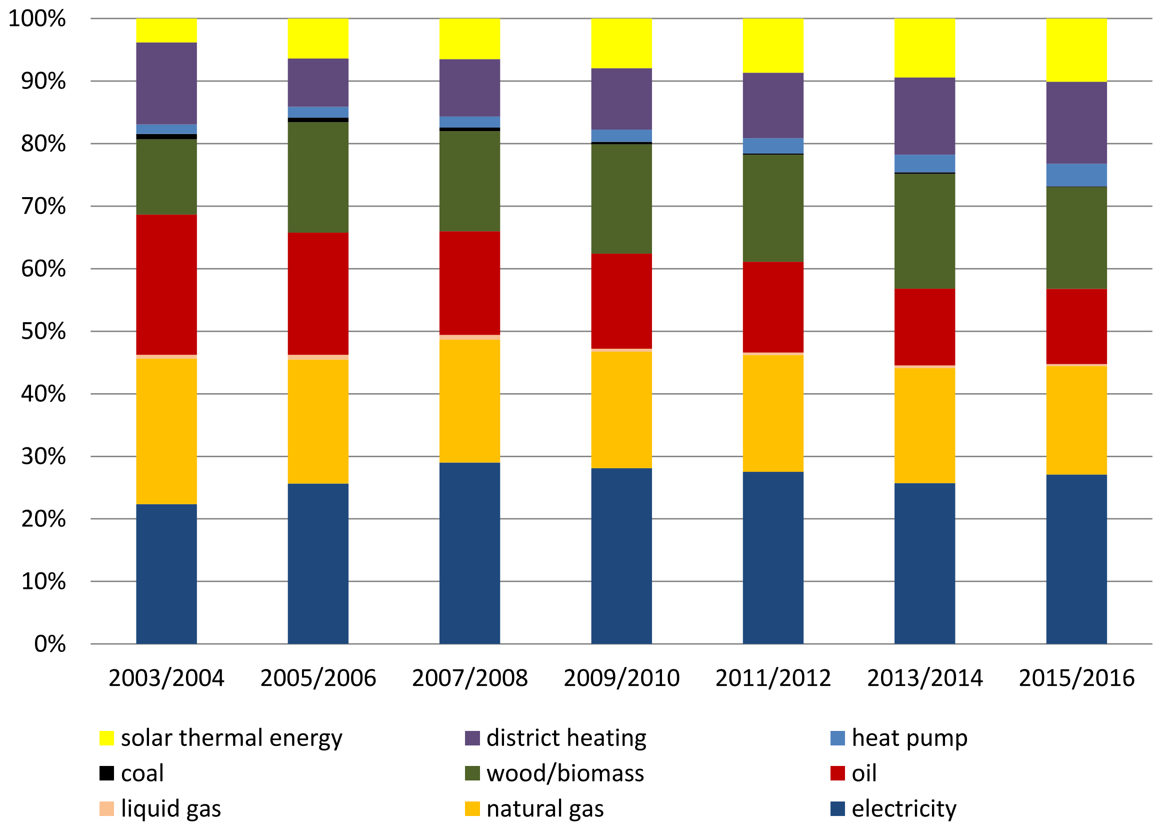


Figure 29: Relative usage of all energy sources for DHW heating; data according to Statistik Austria (2017)

Figure 30 shows a forecast of the development of the energy demand for SH and DHW preperation in the Austrian building stock distributed in energy sources. According to the so called "WEM 2017 Szenario" the total energy demand decreases from currently about 86 TWh to about 57 TWh in 2050. A detailed description of this scenario can be found in Müller et al. (2017). Fossil energies, electrical energy and log wood as well as district heating after 2030 will decrease, while renewable energy sources like pellets, wood chips, solar thermal energy and ambient heat will increase in total numbers. The greatest reduction will occur in the use of oil. (Müller et al., 2017)

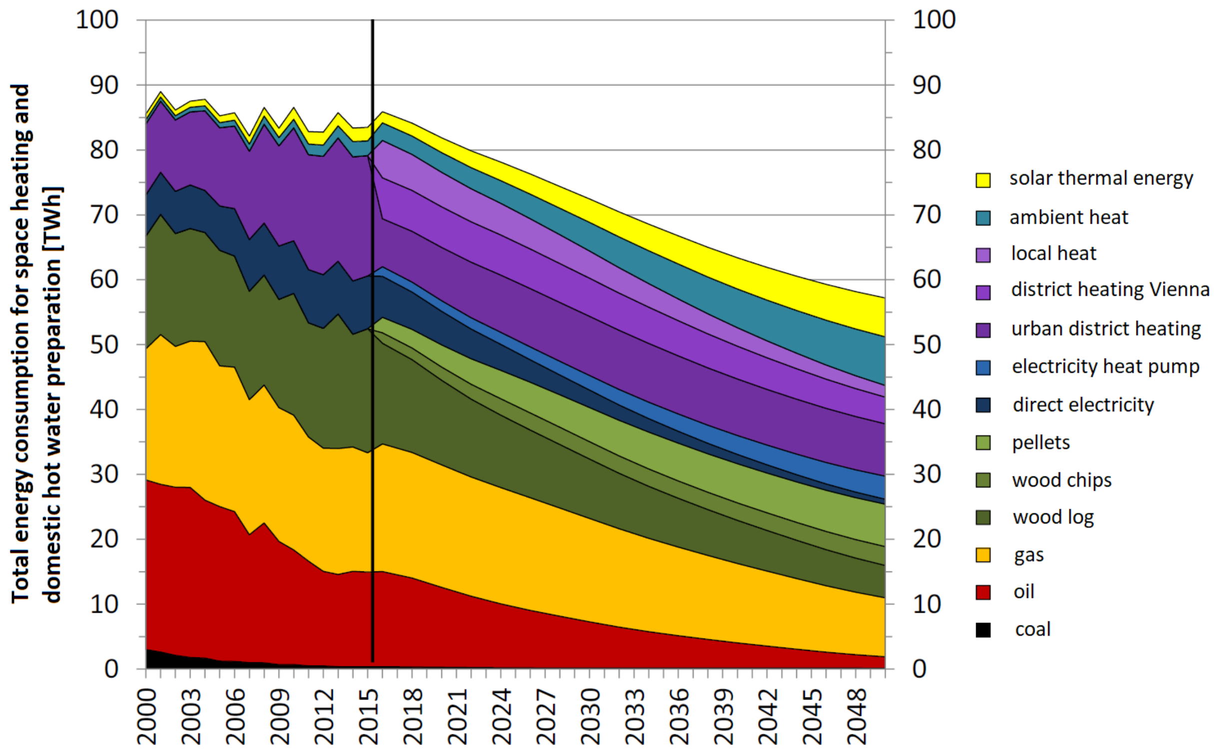


Figure 30: Forecast of the development of the energy demand till 2050 Müller et al. (2017) – translated

4. Market overview of heat pumps

Figure 31 shows the situation of the installed heat pumps in Austria per year since 1975. The market launch in the late 1970s was motivated by the rising prices of fossil fuels. It is shown that in the early 1980s the number of sold heat pumps rose every year and that they have been used mainly for DHW heating. Because of the falling fossil fuel prices and problems with the quality management the number of sold heat pumps dropped down significantly during the 1990s. After this period it took till the year 2000 until the sales number started to rise again. From this time on especially the heat pumps for SH have been proven more and more popularity. A main reason for this trend was the better energy efficiency of new buildings which are good suited for the use of heat pumps because of lower heat demands and lower flow temperatures in the heating system. Moreover the quality has been improved too and some subsidies have been established. During the financial crisis the sales numbers went back a little bit but after that period the number of sold heat pumps especially for SH heating was again growing year by year. After some years with increasing sales numbers they have been remained nearly constant between 2015 and 2016, but this is a stagnation at a high level. (Biermayer et al., 2017)

The numbers of heat pumps used for ventilation systems (since 2000) and the ones which are installed in industrial companies (since 2012) are also shown in Figure 31, but compared to the ones for DHW and SH heating this is a small amount. (Biermayer et al., 2017)

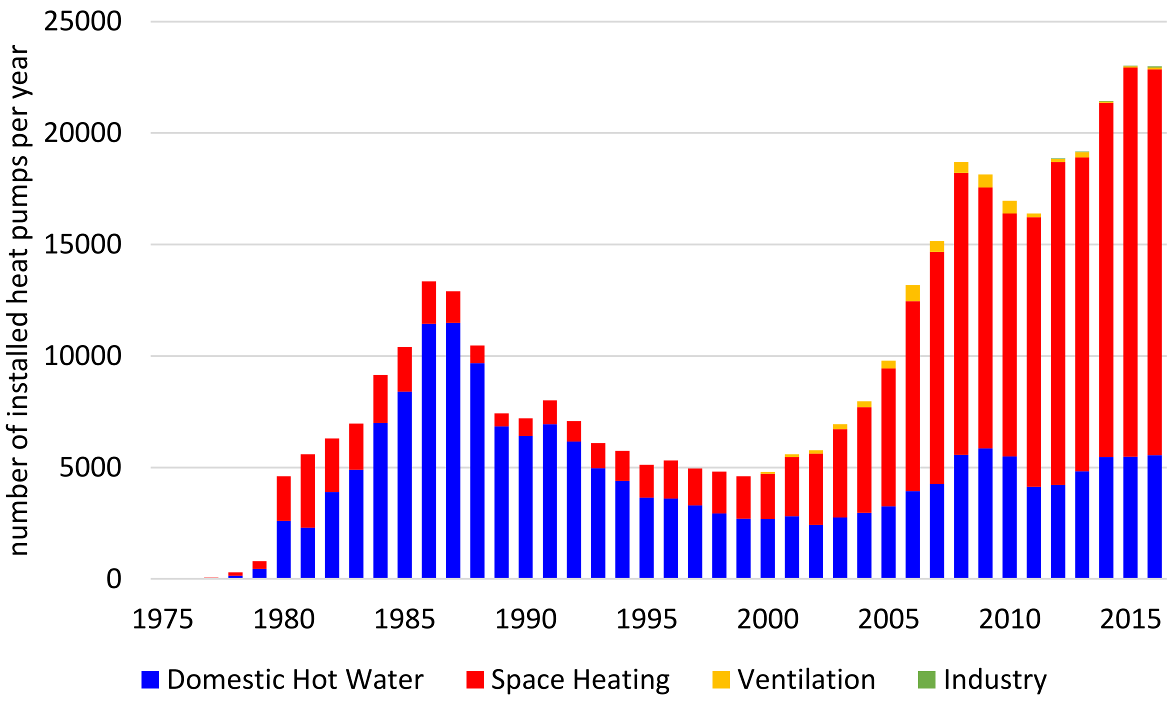


Figure 31: Number of installed heat pumps in Austria per year; data according to Biermayer et al. (2017)

Based on the data shown in Figure 31, Figure 32 shows the number of heat pumps which are currently in operation in Austria. For the calculation a technical life time of 20 years was assumed. Because of the historical trend of the sales numbers of DHW heat pumps with a first maximum in the year 1986 the number of DHW heat pumps in operation started to decrease in 2000, despite the number of sold DHW heat pumps started to rise again in the same time. Because of the strong increase of the SH heat pumps, the overall number of the heat pumps in operation is rising since 2007 after a few years of stagnation. According to this approach there have been 80 656 DHW, 178 455 SH, 4781 ventilation and 154 industrial heat pumps in operation in 2016. It is assumed that this trend will hold on the next years. (Biermayer et al., 2017)

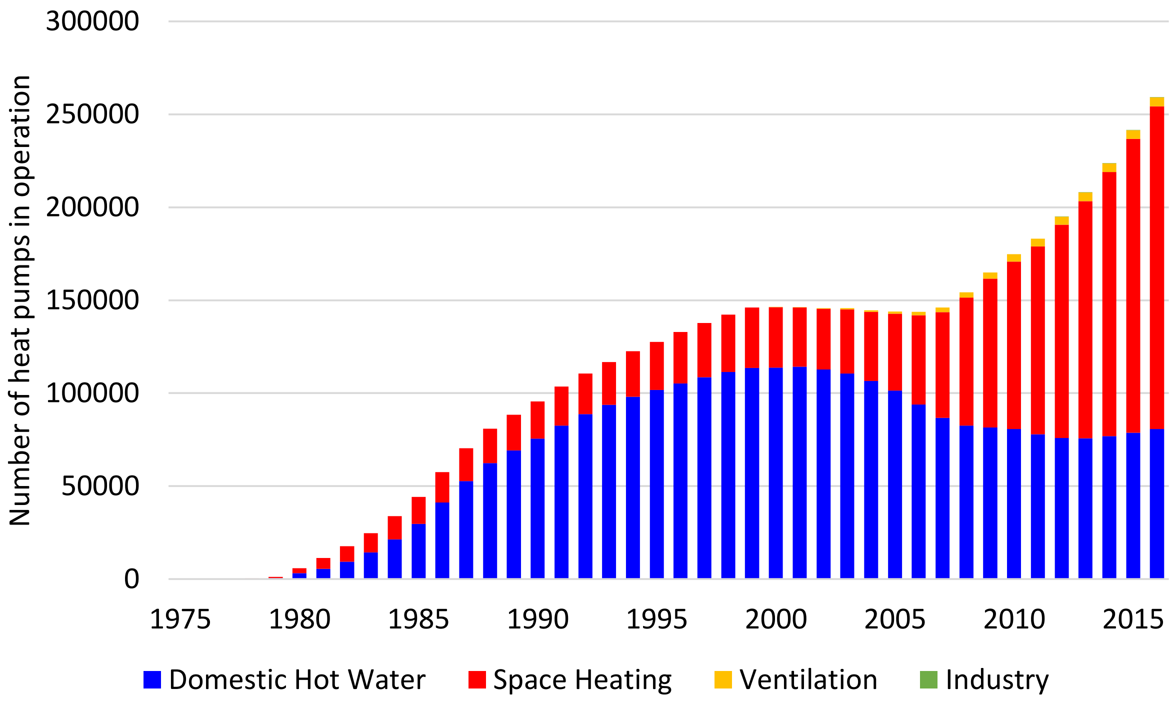


Figure 32: Number of heat pumps in operation in Austria; data according to Biermayer et al. (2017)

In addition to that, there is a more detailed classification of the SH heat pumps shown in Biermayer et al. (2017). A distinction between the capacity and a further distinction between the different heat source systems is made. The percentage distribution of the capacity for the year 2016 is shown in Figure 33. In total there have been 17 304 SH heat pumps installed in this year.

The biggest group are with 47 % the heat pumps with a capacity under 10 kW. This heat pumps are typically installed in new single family houses (low energy houses), because the energy demand of such buildings can normally be provided from this kind of heat pumps. The second biggest group are the heat pumps with a capacity between 10 kW and 20 kW. These heat pumps are primarily used in (renovated) existing single family buildings. Moreover they could also be installed in new one or two family houses, which have a higher energy demand because of their size. It is seen that more than 90 % of all sold heat pumps have a capacity below 20 kW. Larger heat pumps are the minority. Six percent are in a range between 20 kW and 50 kW and only 2 % are even bigger. Since the heat pumps which are installed in industrial companies are considered separately, it can be assumed that the ones which are larger than 20 kW are mainly used for MFH heating and for service companies. Heat pumps with a capacity of more than 50 kW are moreover also used in thermal grid connected heat supplies. (Hartl et al., 2016)

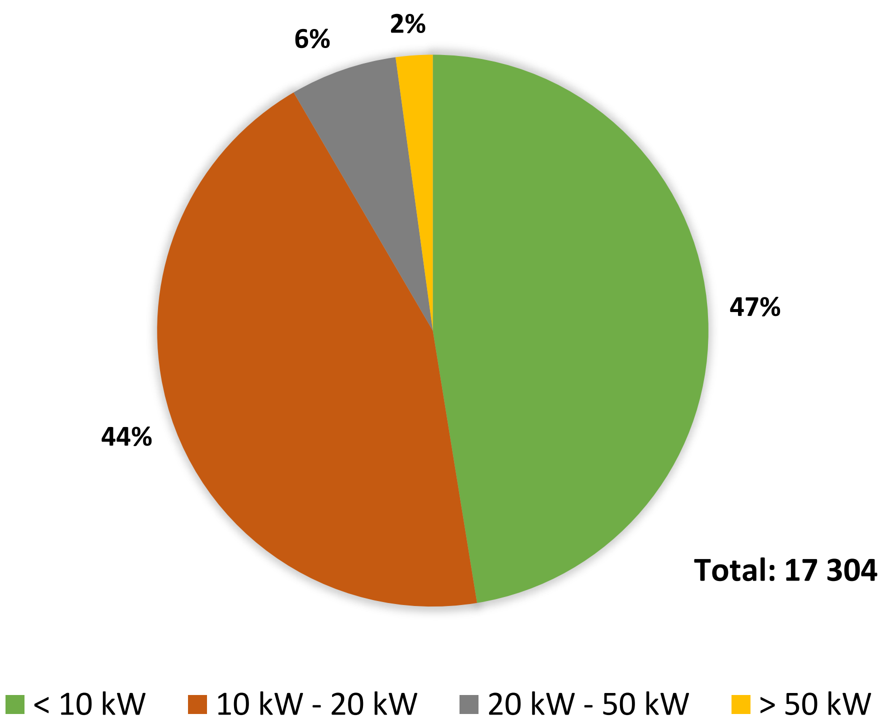


Figure 33: Share of different capacity classes sold in 2016; data according to Biermayer et al. (2017)

A personal assessment from Dr. Peter Biermayr who is an expert in the field of heat pump statistics concretizes the already gained information from Hartl et al. (2016) as follows:

The installation of heat pumps with a capacity up to 10 kW should be the exception in MFH, although he noticed in the last time an increased number of small split devices for heating and cooling which belong to this capacity class. From his view there is a large market potential for this systems in Austria because of the possibility of active cooling. Moreover the systems are already available in construction markets for a very cheap price. Because of the reason, that this construction markets normally place direct imports, the number of sold split devices is hard to record. (Biermayer, Personal assessment, 2017)

In the capacity class between 10 and 20 kW he assumes a small amount (about 10 %) in two family buildings/semi-detached houses, but not in MFH. The two family buildings are normally not counted as MFH. (Biermayer, Personal assessment, 2017)

Heat pumps with a higher capacity class (>20 kW) are often used in thermal grids, with the effect that they indirectly also supply MFH with heat. Moreover they are installed in service companies and directly in MFH. However a more detailed information about the distribution depending on the building type is not known. (Biermayer, Personal assessment, 2017)

Figure 34 shows the percentage distribution according to the different heat source systems. It is shown that by far the biggest part are the Air/Water heat pumps. In the last ten years the sales number of this kind of heat pumps started to grow more and more. Since 2010 they are the most sold ones in Austria and the share increases nearly every year. The low investment costs and the good availability are two reasons for their success. In addition it is sometimes the only available heat source. In contrast to the advantages, the noise impact is a disadvantage with which this kind of heat pump has to deal with. (Biermayer et al., 2017)

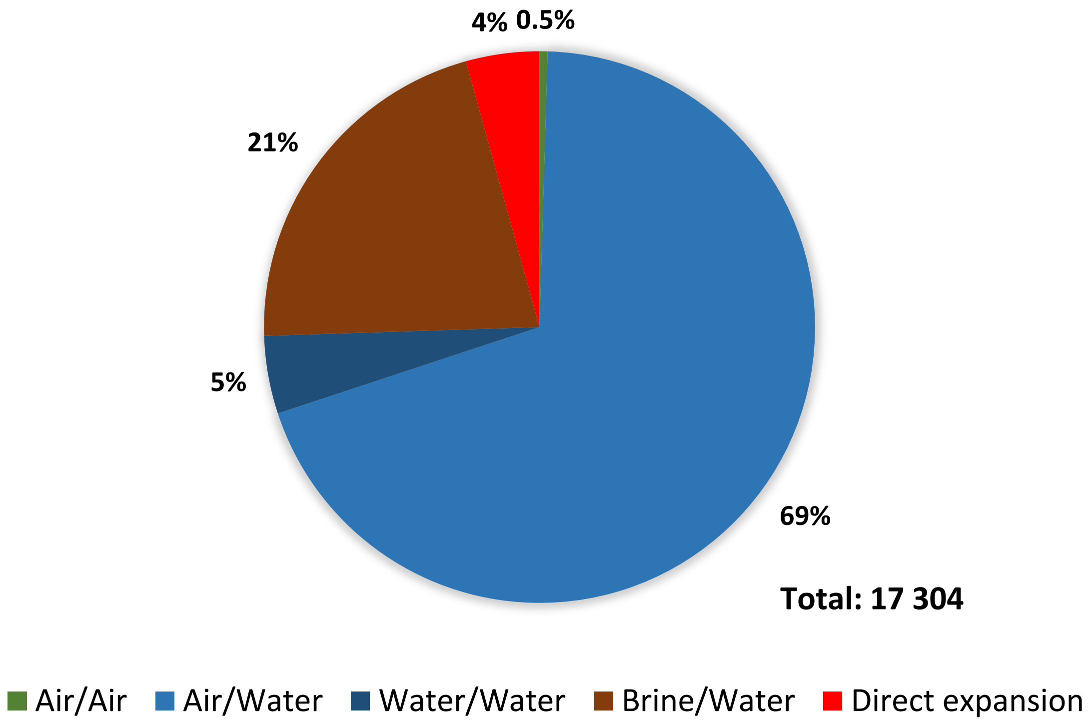


Figure 34: Share of different heat source systems sold in 2016; data according to Biermayer et al. (2017)

The second biggest group are the Brine/Water heat pumps which have been the biggest one till 2010. The market share of the other types are with 5 % Water/Water, 4 % direct expansion and 0.5 % Air/Air already quite small. (Biermayer et al., 2017)

The trend over the last years is shown in Figure 35 and Figure 36. It is assumed that this development will continue in the next years, so that the share of Air/Water heat pumps will increase at the expense of the Brine/Water heat pumps since the sale numbers of the other ones are already quite low (Biermayer, et al. 2017).

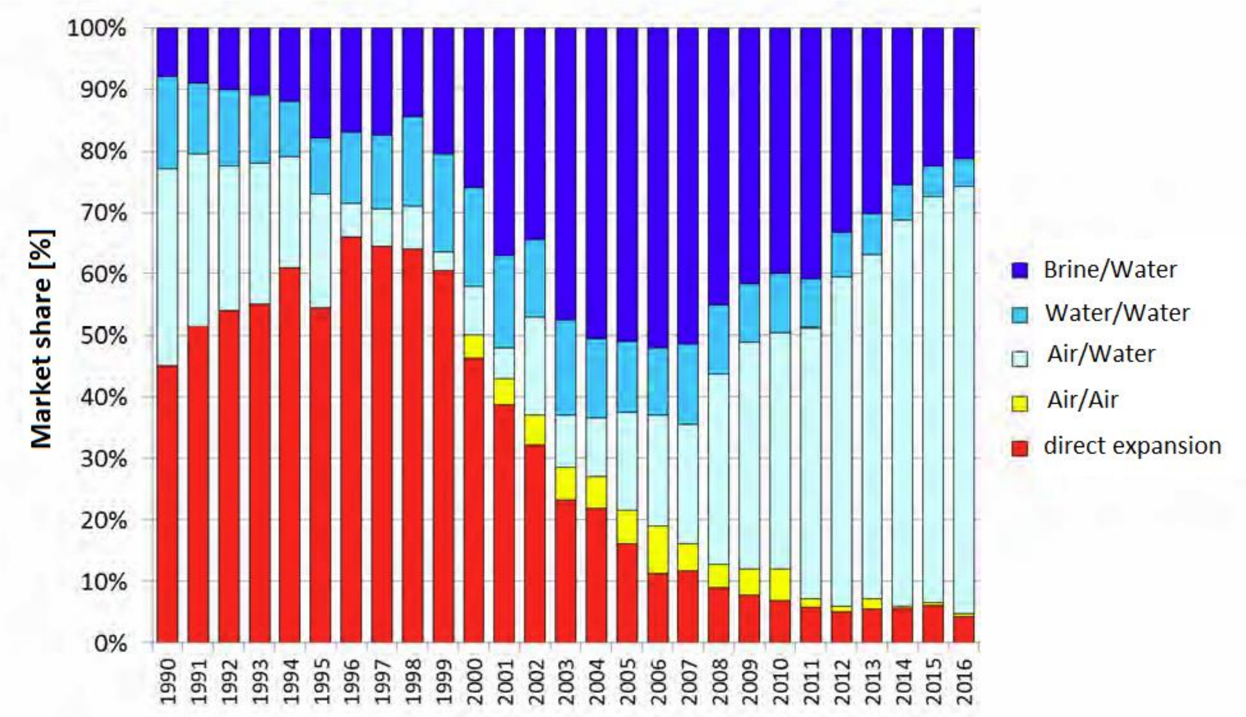


Figure 35: Trend of the market share of the different source system of SH and ventilation heat pumps in Austria (Biermayer et al., 2017) – translated

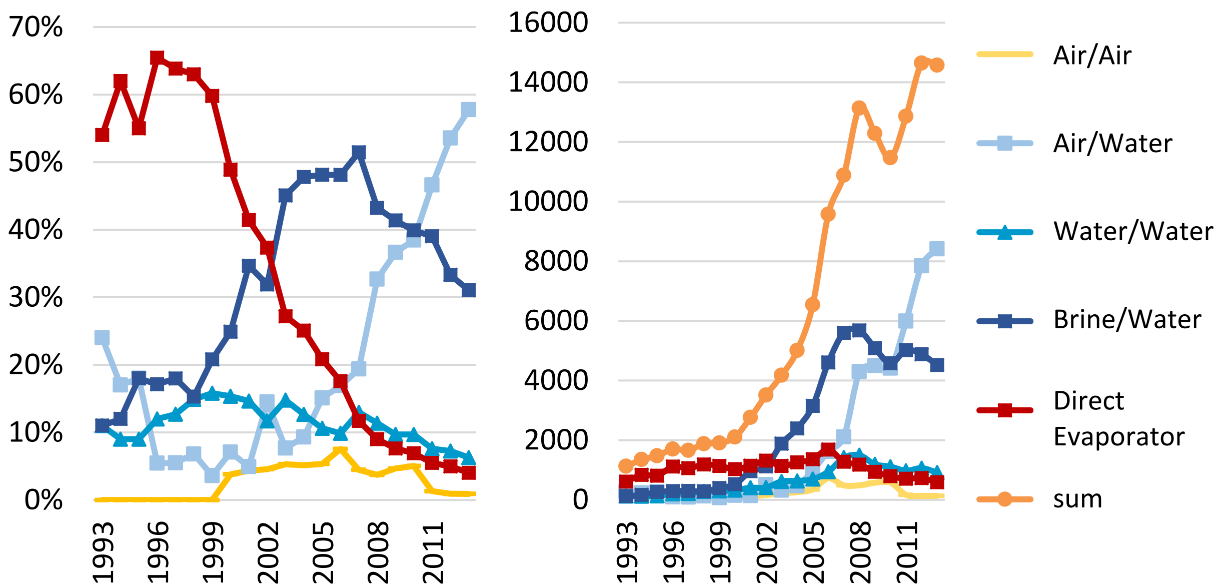


Figure 36: Sold heat pumps per year divided in the kind of source/sink systems in relative (left) and absolute numbers (right) (Rieberer, 2017)

A further look on the sales number of the heat pumps distributed in capacity classes shows, that compared to the year 2015 the sales numbers of the heat pumps till 50 kW slightly decreased, while the sale numbers of the heat pumps larger than 50 kW are doubled. This trend, which is shown in Table 2, differs clearly from the last years where the segment of the smaller heat pumps under

10 kW registered the biggest increase. During these years the most heat pumps have been installed in new relatively energy efficient single family buildings. It is assumed that in this segment now a saturation effect has been occurred. (Biermayer et al., 2017)

Table 2: Comparison of the sales number in the domestic market in 2015 and 2016

rated capacity	type	domestic market 2015 (units)	domestic market 2016 (units)	relative change 2015/2016 (%)
up to 10kW	Air/Air	63	82	+30.2 %
	Air/Water	6192	6198	+0.1 %
	Water/Water	255	236	-7.5 %
	Brine/Water	1574	1495	-5.0 %
	direct evaporation	364	279	-23.4 %
	total	**8448**	**8290**	**-1.9 %**
10 kW to 20 kW	Air/Air	0	0	0.0
	Air/Water	4892	5301	+8.4 %
	Water/Water	439	374	-14.8 %
	Brine/Water	1839	1611	-12.4 %
	direct evaporation	515	353	-31.5 %
	total	**7685**	**7639**	**-0.6 %**
20 kW to 50 kW	Air/Air	0	0	0.0
	Air/Water	437	434	-0.7 %
	Water/Water	148	124	-16.2 %
	Brine/Water	443	409	-7.7 %
	direct evaporation	173	117	-32.4 %
	total	**1201**	**1084**	**-9.7 %**
50 kW and up	Air/Air	0	0	0.0
	Air/Water	33	143	+333.3 %
	Water/Water	40	59	+47.5 %
	Brine/Water	87	171	+96.6 %
	direct evaporation	20	0	-100.0 %
	total	**180**	**373**	**+107.2 %**
total amount of heat pumps	Air/Air	63	82	+30.2 %
	Air/Water	11554	12076	+4.5 %
	Water/Water	882	793	-10.1 %
	Brine/Water	3943	3686	- 6.5 %
	direct evaporation	1072	749	-30.1 %
	total	**17514**	**17386**	**-0.7 %**

5. Building Refurbishment

The building sector plays an important role for reaching the energy and climate policy goals. More than a third of the final energy consumption in Austria is used for SH, DHW preparation or cooling in residential or service buildings. With a share of new buildings of only 1-2 % per year, the main energy reduction potential can be found in existing buildings with a need of refurbishment. According to the Energiestrategie Österreich (2020) the refurbishment rate should be increased from about 1 % to 3 % per year until 2020.

Furthermore the Austrian building refurbishment strategy is orientated on the given guidelines from the European Union. As for example on the “20/20/20 climate target” with the aim to reduce the emission of greenhouse gases by 20 %, to rise the share of renewable energy by 20 % and to increase the energy efficiency by 20 %. This goal should be reached till the year 2020. Moreover another long-term objective has been defined with the aim to reduce the emissions of buildings by 80 % to 90 %

till 2050. Beyond that, the Austrian building refurbishment strategy is not only focused on the environmental aspect but also on economic and social targets. (IIBW, 2013)

The national realization of the European targets is governed in a variety of laws and other government documents as for example the “Klimastrategie 2002” (climate strategy) the “Energiestrategie 2020” (energy strategy) the “Bundesklimaschutzgesetz 2011” (national climate protection law) or the “Energieausweisvorlagegesetz 2012” (energy certificate template law). As a result every few years some changes or supplements have been made to the Austrian building refurbishment strategy. However, one central goal over the last years was to increase the yearly building refurbishment rate up to 3 %. For the evaluation of this goal the terms “refurbishment rate” (german: “Sanierungsrate”) and “comprehensive refurbishment” (german: “umfassende Sanierung”) has to be defined first. (IIBW, 2013)

The most widely read definition of the refurbishment rate is, that it is the ratio of the in the considered year renovated buildings referred to the whole building stock. However, as often as this definition is used, as unclear it is. On the one hand it makes a big difference, if every refurbishment is counted, which would also include single component refurbishments, or if only comprehensive refurbishments are counted. In the public communication it is often but not always referred to comprehensive thermal refurbishments. On the other hand the term “whole building stock” has to be defined too, to determine, if for example every main residence, every dwelling or every not refurbished dwelling is meant. As a result care has to be taken under which assumptions the considered refurbishment rate was calculated. (IIBW, 2013)

The term comprehensive refurbishment is also not so easy to define. In 2007 a guideline (OIB-Richtlinie) was published which defines the comprehensive refurbishment as the summery of at least three thermal relevant individual measures (e.g. windows, upper ceiling, facade, cellar ceiling, building services). This definition was confirmed in the “Art. 15a B-VG-Vereinbarung” (“Vereinbarung” = agreement) in 2009. But the next version of the OIB guideline in 2011 changed this term to “bigger refurbishment” and defined it as follows: The in the refurbishment involved share of the building envelope and the increase of the value of the building have to exceed 25 %. In the following years it was considered to define the term more widely to increase the refurbishment rate. (IIBW, 2013) However in the newest Art. 15a B-VG-Vereinbarung of the year 2017 the comprehensive refurbishment is again defined as it was primary in 2007 (2009). (Rechtsinformationssystem (RIS), 2017)

In the last years some different studies based on different data have been published to determine the refurbishment rate in Austria. For comprehensive refurbishment the results are around 1 % for the years 2000-2010. That means that the original goal of a rate of 3 % was clearly not reached in this period. (IIBW, 2013) The latest data was published from the Federal Ministry of Agriculture, Forestry, Environment and Water Management and is shown in Figure 37 for the federal states as well as for the whole country. The shown refurbishment rate was calculated as the ratio of the actual refurbished gross floor area per inhabitant referred to the total gross floor area per inhabitant. It can be seen that the resulting rate for the whole country decreased from about 1.2 % in 2010 to about 0.5 % in 2015. The numbers in single federal states deviate partly depending on the current subsidy programme, but the overall trend is the same. (BMLFUW, 2016)

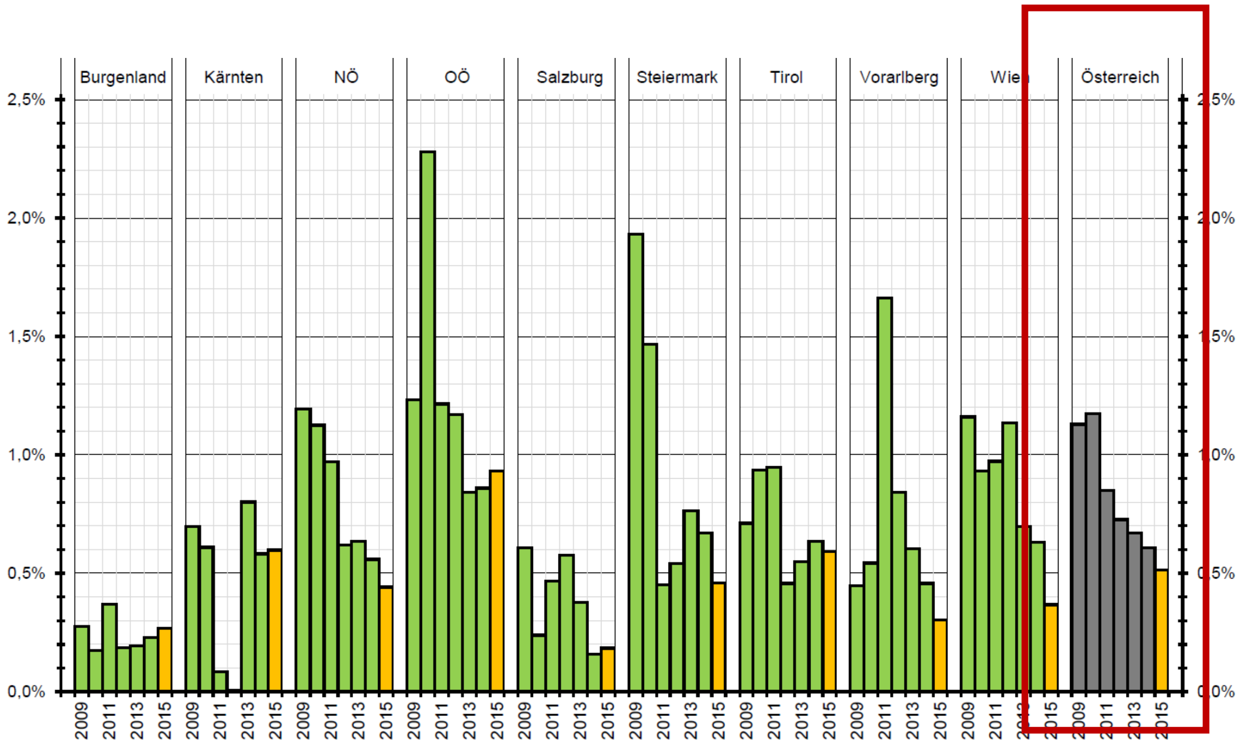


Figure 37: Refurbishment rates for comprehensive refurbishments of the years 2009 – 2015 calculated as the ratio of the actual refurbished gross floor area per inhabitant referred to the total gross floor area per inhabitant (BMLFUW, 2016)

For Figure 38 another definition of the refurbishment rate of the Federal Ministry of Science, Research and Economy is used for the year 2013. In this case the rate is defined as the ratio of the thermal refurbished residential units referred to the number of main residences. It can be seen, that the rate with this definition is with 1 % a bit higher than in Figure 37 with about 0.7 %. Moreover it is shown that if we would only consider the buildings which were built between 1919 and 1980 the goal of a rate of 3 % would be achieved. A similar result is gained by only considering the buildings which are built before 1980. That shows, that the achievement of the target refurbishment rate of 3 % strongly depends on their definition. (bmwfw, 2014)

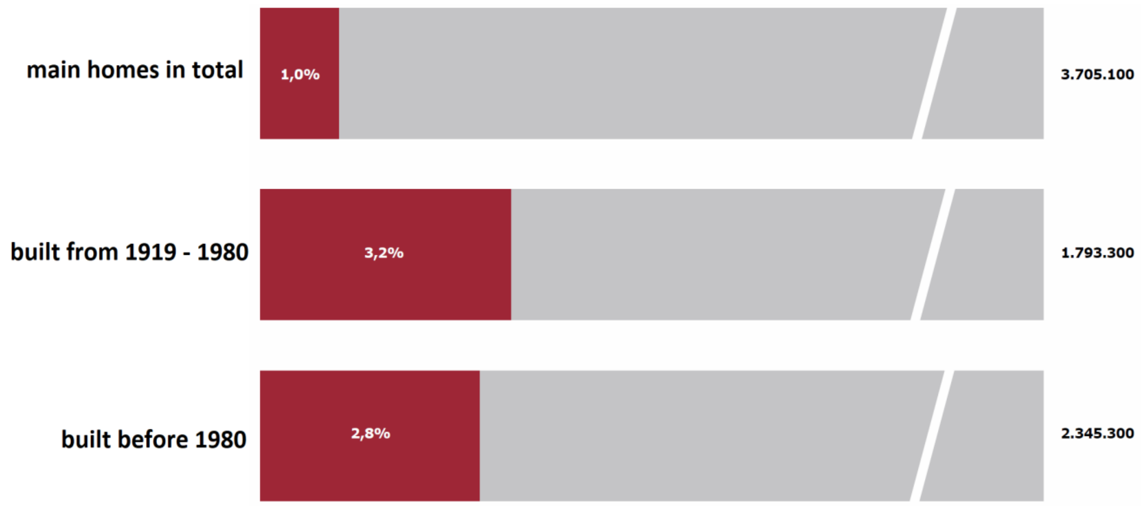


Figure 38: Building refurbishment rate in 2013 calculated as ratio of the thermal refurbished accommodation units referred to the number of main residences (bmwfw, 2014)– translated

Figure 39 shows that truly the largest energy reduction potential is located at buildings which are built before 1980. Moreover it is shown, that regarding to the building type by far the largest reduction potential exists at the single family houses (SFH). According to this figure especially the SFH which are built before 1919 and the SFH built between 1961 and 1980 should be renovated. But also the SFH which are built after 1980 as well as multifamily houses (MFH) and apartment blocks (AB) provide a relevant reduction potential. (Amtmann, 2010)

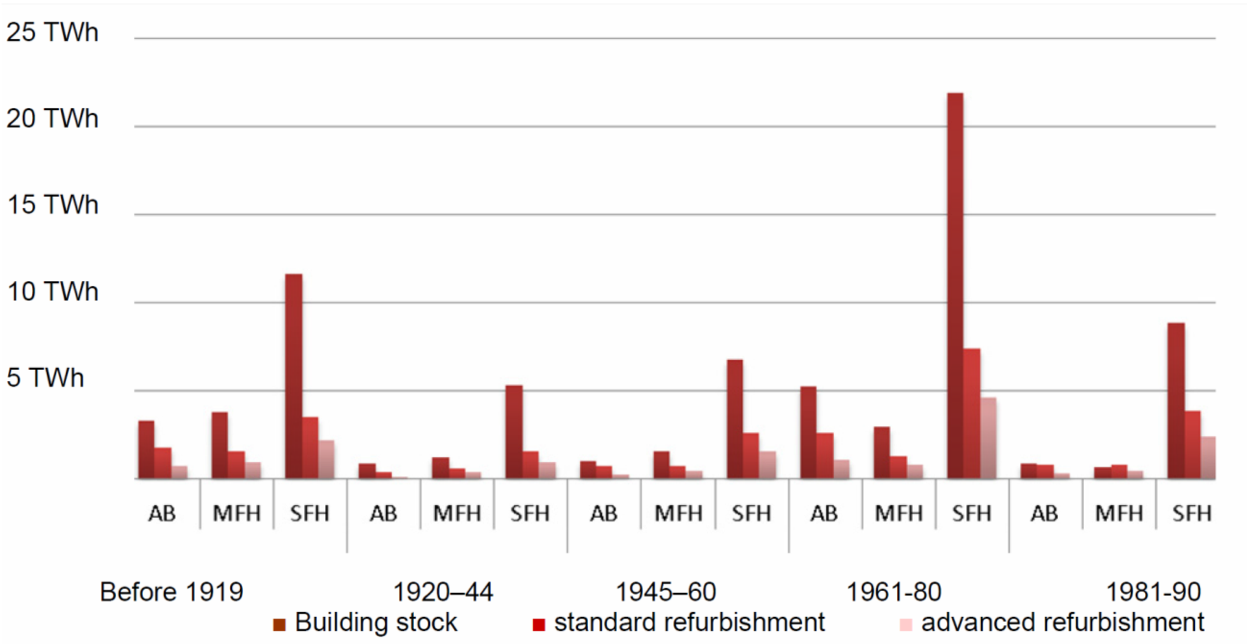


Figure 39: Based on the typology, the scenarios of possible national final energy demand reduction potentials (in TWh) per construction period and building category are generated (Amtman, 2010) – translated

Furthermore Figure 40 shows the refurbishment rate from 2001 to 2006 separated in construction periods. In contrast to the discussed reduction potentials in Figure 39 it is shown that in this period the highest refurbishment rate was achieved for buildings which were built between 1945 and 1960. Moreover it is seen that the rate was higher for MFH than for SFH.

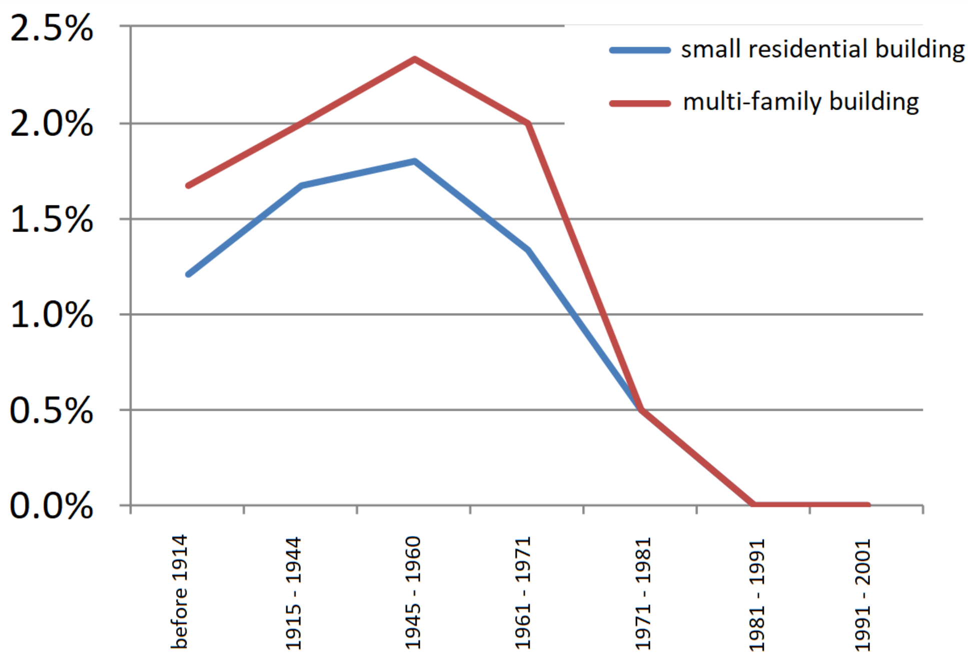


Figure 40: Building refurbishment rate in % p.a. (average in the period 2001 – 2006) (Müller, 2015) – translated

The subsidies for building refurbishments in Austria are mainly matter of the federal provinces. Figure 41 shows the amount of the whole Austrian housing subsidy budget and its distribution. It is seen that the sector building refurbishment is with about 20 % to 30 % the second largest. The funding of new built MFH makes up the biggest section while the sectors "new private home buildings" and "subject promotion (e.g. housing benefits)" only constitute a small part. (IIBW, 2016)

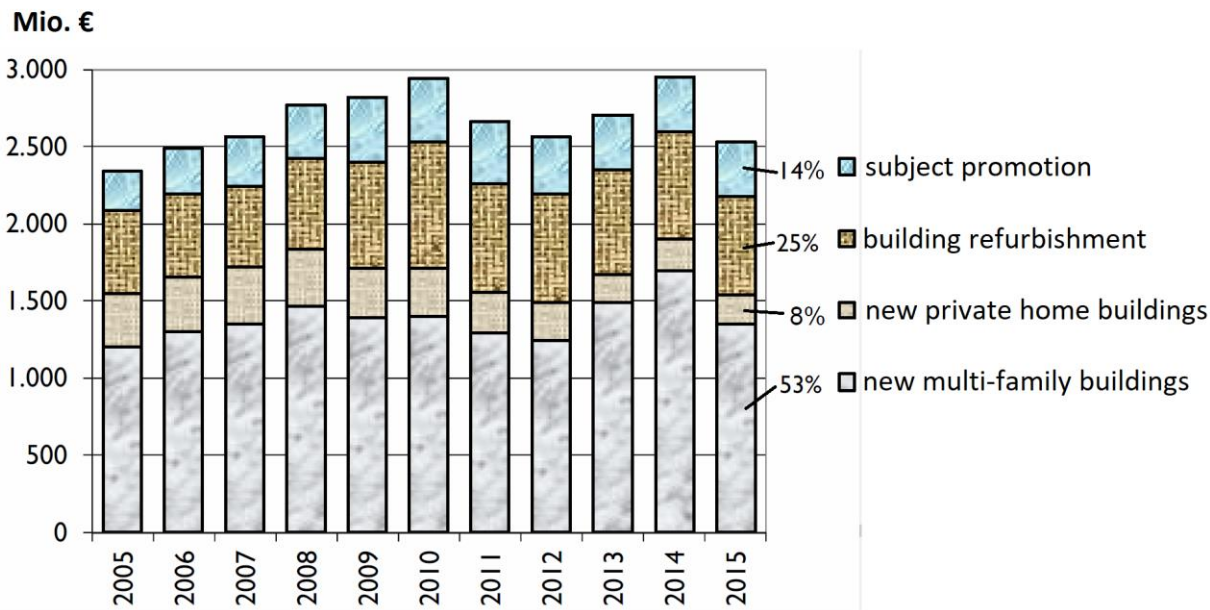


Figure 41: Expenses of the housing subsidy budget in Mio € (IIBW, 2016) - translated

In Figure 42 the expenditures for building refurbishment of the federal provinces are shown in detail. It can be seen, that the yearly amount varies between 500 and 850 Mio. Euro. The share of building refurbishment of the whole housing subsidy budget was different in the single federal provinces. For example in the year 2010 it made up 40 % in Vienna and 36 % in Vorarlberg while it only contributes less than 21 % in Salzburg, Tirol and Kärnten. (IIBW, 2013)

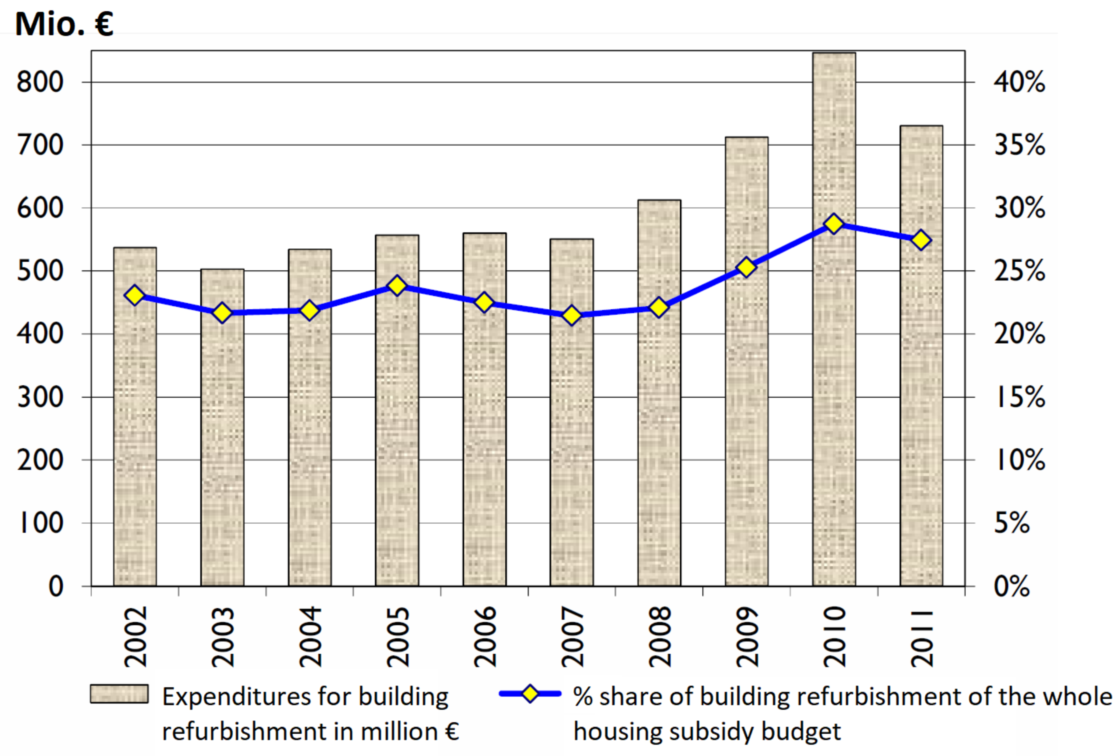


Figure 42: Expenses of the housing subsidy budget for building refurbishment (IIBW, 2013) – translated

Moreover in Figure 43 the garanteed number of financially supported building refurbishments by the federal provinces is shown from 2002 till 2011. While the number of financial supported refurbishments for MFH was relatively constant at about 60 000 per year, the number of private homes have been tripled from 2002 till 2010. In 2011 the number of supported private homes decreases again to the long-time mean value of 42 000. The main part of these refurbishments have been thermal relevant but an accurate distinction is not possible with the available data. The driving force behind the increasing numbers of financially supported private homes in 2009 and 2010 have been the stimulus programs of the federal provinces and the refurbishment cheque of the federal government. This cheque was first introduced in 2009 with a budget of 100 Mio. Euro and it was in addition to the subsidy budget of the federal provinces (except of some special cases in two federal provinces). The decrease in 2011 affect primarily the subsidy of single component refurbishments while comprehensive thermal refurbishments have been remained steady. The average costs of promoted refurbishments have also been increased from about 15 000€ to about 20 000 € in the considered years. This development underlines the focus on comprehensive thermal refurbishments. (IIBW, 2013)

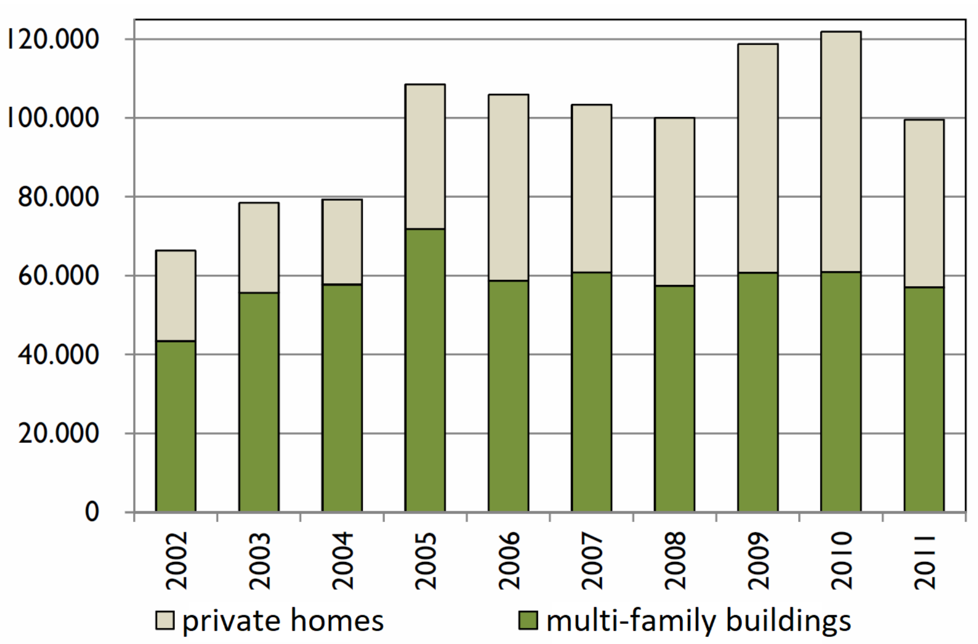


Figure 43: Number of financially supported building refurbishments from the federal provinces (IIBW, 2013)– translated

The numbers of the financially supported buildings which have been comprehensive refurbished in the year 2012 are shown in Figure 44 separated in federal provinces and in building types. The shown amount of supported buildings in the whole country is with about 30 000 much lower than the numbers in Figure 43. Since the refurbishment rate in 2012 is only 0.1 % lower than in 2011 it can be assumed that either the main part of the refurbished buildings according to Figure 43 are not comprehensive thermal refurbished, or that another counting method was used.

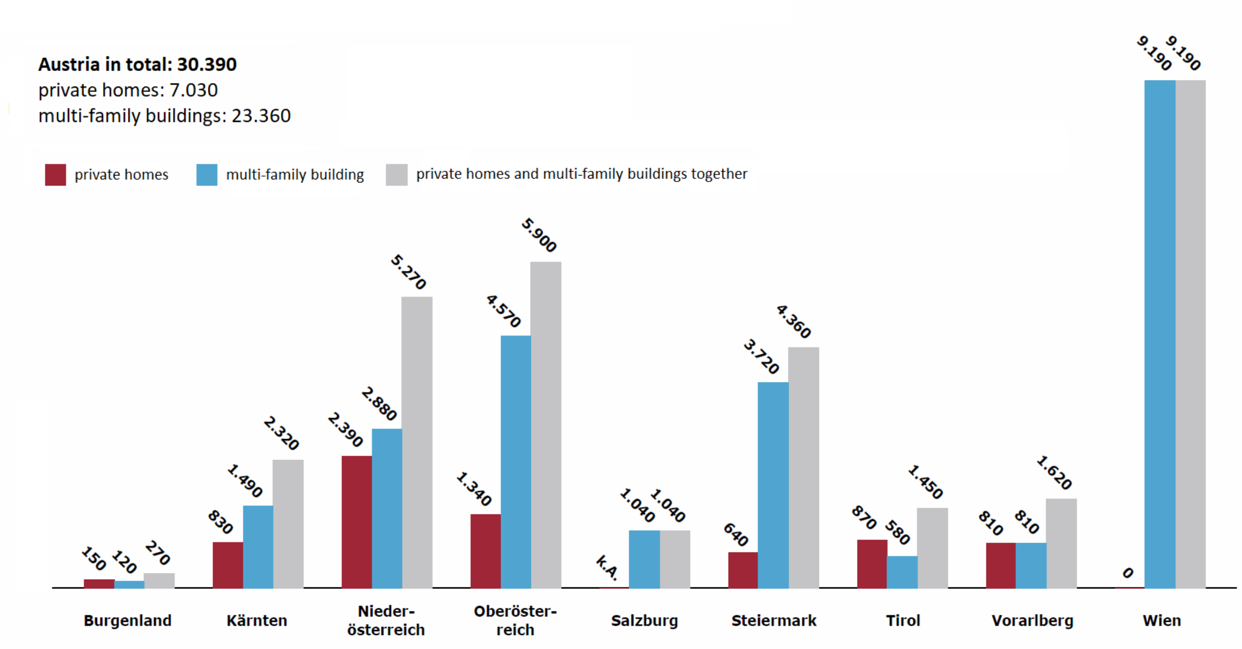


Figure 44: Comprehensive thermal refurbishment in the federal provinces in 2012 (bmwfw, 2014) – translated

In addition to the financially supports from the federal provinces the federal government grants under certain circumstances an additional refurbishment cheque. Only natural persons can apply for this cheque for comprehensive thermal or certain single component refurbishments. It is designated to have an broad impact and should be an additional incentive to the support from the federal provinces. (IIBW, 2013) However, the maximum amount of at first 20 % and now 30 % percentage of the overall refurbishment costs (plus some additional limits regarding to the total amount) is to low to make a bigger impact only by itself. (HELP.gv.at, 2017)

At the beginning the primary target group have been the owners of single family buildings because this segment had a very low refurbishment rate and a high energy reduction potential as already shown in Figure 39. Since 2012 owner and tenants of dwellings can apply for the cheque too. From 2011 till 2016 every year an amount of 100 Mio. € have been allocated for the refurbishment cheque whereby 70 % have been reserved for private buildings and the other 30 % for commercial housings. (IIBW, 2013) A detailed explanation which refurbishments under which circumstances with which amount are recoverable can be found on HELP.gv.at (2017).

Figure 45 shows how many projects were financially supported, which amount was paid out, how many workplaces this corresponds to and how much CO_2 could be saved through this investment.

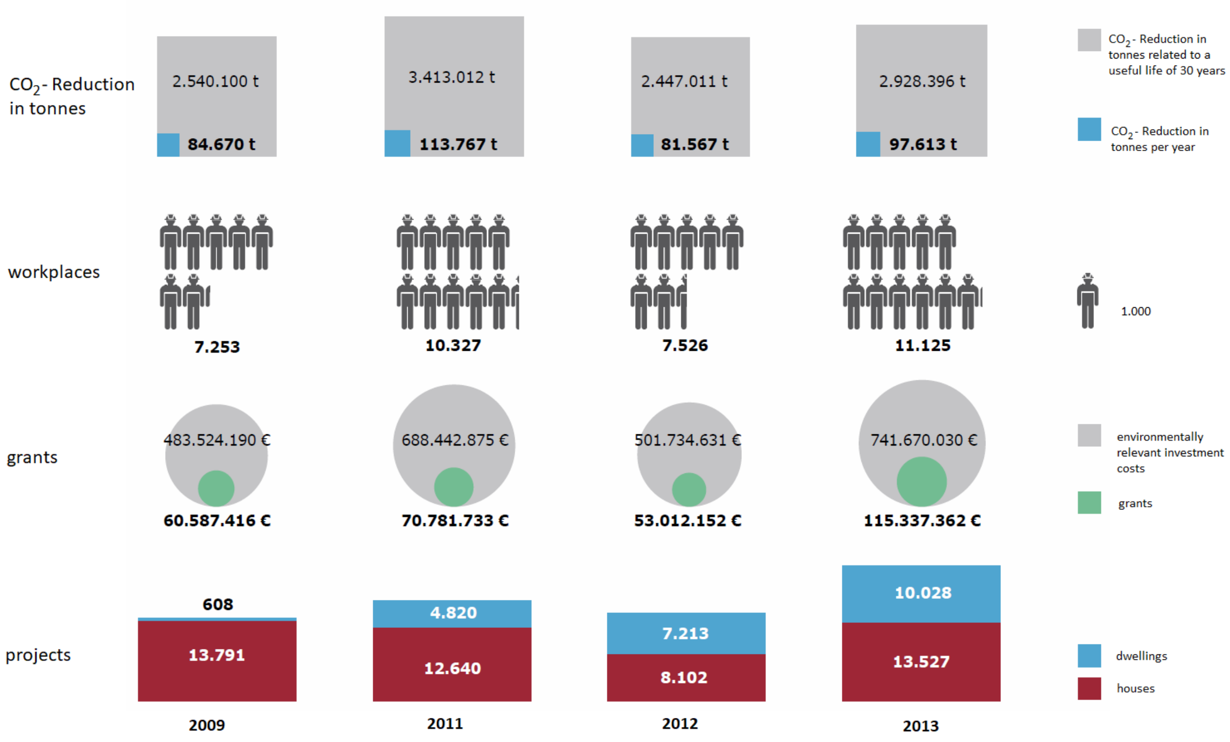


Figure 45: Effect of the refurbishment cheque from 2009 till 2013 for the private building sector (bmwfw, 2014) – translated

Summarising it can be said, that the goal of a refurbishment rate of 3 % has not been reached yet according to the usual method of calculation. Nevertheless a lot of refurbishment work has been done in Austria in the last years, what results in essential reduction of energy demand and CO_2 emissions in this section and contributes to a positive economic development.

6. Example systems of Heat Pumps in MFH

After the illustration of the building stock and the heat pump market situation in Austria this chapter should provide an insight into some projects which already have been realized. Therefore some characteristic examples will be shown and described as detailed as possible.

Based on Zahradka (2017) some of the examples are from Dimplex (Glen Dimplex Deutschland GmbH, 2017) because they provide a variety of documented reference buildings online. Moreover there are several examples from iDM Energiesysteme GmbH as well as from some more source.

6.1. Generic system layout

For the classification and the uniform presentation of the different realised systems, a generic method was developed. It enables both simple and complex plants to be presented in a simplified and above all clear way. The interaction of different heat sources and heat sinks in different distribution systems can be clearly shown. The classification combines the representation of energy flows and plant interconnections. In Figure 46 on the left side a classic system layout and IEA Annex 50 system layout on the right side is shown. In the following example systems both layouts are shown where a classic system layout was available.

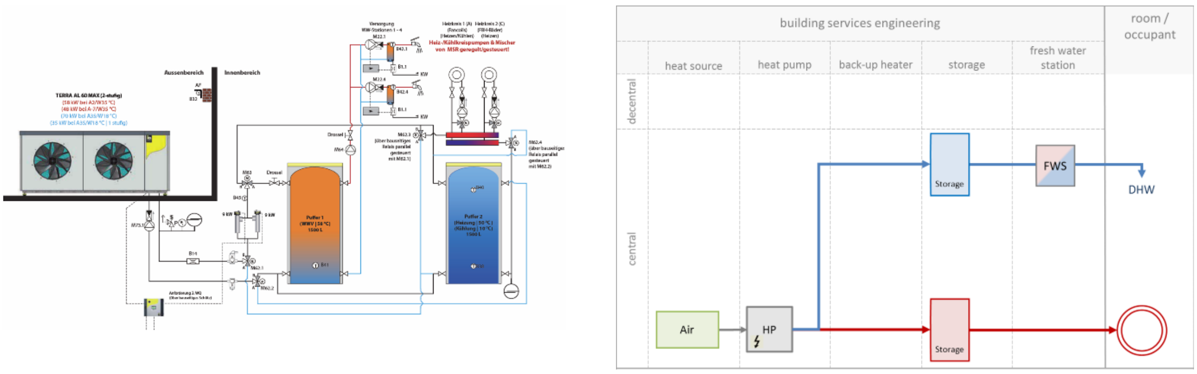


Figure 46: Example for a classic and IEA Annex 50 system layout

6.2. New construction Bad Hofgastein 1

Building details:

- Location: 5630 Bad Hofgastein
- Heated area: 450 m^2
- Year of construction: 2009
- Heat distribution system: surface heating
- Level of insulation: very good

Financial details:

- Investment costs: undisclosed
- Average electricity consumption: 8955 kWh/a
- Average electricity costs: 13 cent/kWh
- Average costs: 1164 €/a

Heat pump details:

- Heat pump type: LA 17TU (Dimplex) with outdoor installation
- Heat source/sink: Air/Water
- Nominal heat output (A2/W35): 8.2 kW
- COP (A2/W35): 3.8
- Operation mode: monovalent

DHW details:

- Number of people: 12
- Increased hot water demand: yes
- Circulation system: no
- Water heating: with heat pump
- Blocking time: none

Figure 47: Pictures of the system in Bad Hofgastein (Glen Dimplex Deutschland GmbH, 2017)

6.3. New construction Bad Hofgastein 2

Building details:

- Location: 5630 Bad Hofgastein
- Heated area: 612 m^2
- Year of construction: 2012
- Heat distribution system: surface heating
- Level of insulation: very good

Financial details:

- Investment costs: undisclosed
- Average electricity consumption: 9800 kWh/a
- Average electricity costs: 13 cent/kWh
- Average costs: 1274 €/a

Heat pump details:

- Heat pump type: LA 25TU (Dimplex) with outdoor installation
- Heat source/sink: Air/Water
- Nominal heat output (A2/W35): 11.3 kW
- COP (A2/35): 3.8
- Operation mode: monovalent

DHW details:

- Number of people: >12
- Increased hot water demand: yes
- Circulation system: no
- Water heating: with heat pump
- Blocking time: none

Figure 48: Pictures of the system in Bad Hofgastein (Glen Dimplex Deutschland GmbH, 2017)

6.4. New construction Vienna Podhagskygase

The "Wohnbauprojekt Podhagskaygasse" was realized in 2009 and consists of 65 apartments constructed in the "Patent 22" style. The energy demand for heating is provided from six water/water heat pumps with a total power of approximately 300 kW. The high groundwater level in this area made the use of ground water heat pumps possible. Especially as there is no district heating system or gas grid available. A withdrawal quantity of approximately 41000 m^3/a is necessary to cover the heat demand what effect a warming of the ground water of about 6 °K. (Magistrat der Stadt Wien, 2012)

Building details:

- Location: 1220 Wien
- Heated area: 6000 m^2
- Year of construction: 2009
- Heat distribution system: Floor heating
- Level of insulation: very good

Financial details:

- Investment costs: 360 000 €
- Average energy consumption for heating: 420000 kWh/a

Heat pump details:

- Heat pump: 6 heat pumps (type undisclosed)
- Heat source/sink: Water/Water
- Installed power 300 kW

Figure 49: Pictures of the building in Vienna Podhagskygasse (Magistrat der Stadt Wien, 2012)

6.5. New construction Vienna Residenzen Hohe Warte

All apartments in the building project “Hohe Warte” are heated or cooled by using highly efficient systems technology. A main part of this technology is the central heat pump system. It is a Brine/Water heat pump which uses 46 geothermal probes to utilize the energy from the ground. The heat dissipation take place via a floor heating system. Furthermore some smaller wall heating systems are installed too. The necessary heating temperature is 40/32 (°C). The DHW heating takes place by the central heat pump system. Moreover all common rooms can be cooled via a cooling ceiling. Apart from the geothermal probes there is no additional system for using alternative energies installed. (Niederbrucker et al., 2016)

Building details:

- Location: 1190 Wien
- Heated area: 4600 m^2
- Year of construction: 2015 - 2017
- Heat distribution system: Floor heating and smaller wall heating elements

Heat Source details:

- Type: Geothermal probes
- Number: 46
- Drilling depth: 120 m

Heating system:

- Heat pump: 4 heat pumps (type undisclosed)
- Heat source/sink: Brine/Water
- Installed power 286.3 kW
- Heat demand: 200 kW
- Cooling demand: 160 kW
- Operation mode: monovalent
- Heating temperature: 40/32 (°C)
- Cooling temperature: 24/18 (°C)

Figure 50: Pictures of the system in Vienna Residenzen Hohe Warte (Niederbrucker et al., 2016)

6.6. New construction Vienna Smart City Demo Aspern

The energy concept of the concrete/wood frame construction in the smart city consists of a number of switchable heat pumps with different heat sources. Every heat pump supplies either a low or a high temperature system. Basically three different types of heat pumps systems with four different heat sources (ground water, soil, solar and air) are used as schematically shown inFigure 51. (Niederbrucker et al., 2016)

Figure 51: Schematic diagram of the heating system in the Smart City Aspern (Niederbrucker et al., 2016)

The extraction performance of the four ground water heat pumps is about 400 kW at a temperature spread of 4 °K and a withdrawal quantity of 25 l/s. The resulting heating power is big enough to supply the whole building with heat and DHW. For the hot water supply two of the four heat pumps are operating with a flow temperature of 65 °C. All other energy sources are used to increase the efficiency of the heating system and are part of the research project. (Niederbrucker et al., 2016)

One of these is an air heat pump which uses the exhaust air from the garage where an air exchange of 1.5 is necessary. The heat pump reaches a heating capacity of about 50 kW by cooling the air down of 5 °C. (Niederbrucker et al., 2016)

A volume of about 3000 m^3 is equipped with some energy pillars to enable the charging and discharging of the soil. According to a possible temperature of 20 °C, about 40000 kWh can be stored in the soil. For the charging only the energy from the solar collector is used. This kind of energy storing makes a much better system performance possible than by using only the ground water as source. (Niederbrucker et al., 2016)

For using the solar energy three different types of collectors are installed. One thermal collector, one hybrid collector and one PV collector, each with a collector area of 150 m^2. The gained thermal energy can either used to heat the storages by using a stratification system or charged to the soil. (Niederbrucker et al., 2016)

Building details:

- Location: 1190 Wien
- Heated area: 19000 m^2 living, 100 m^2 office, 600 m^2 commercial
- Year of construction: 2014
- Heat distribution system: Floor heating

Heat Sources

- 2 extraction wells with a removal performance of 12 l/s
- Geothermal probe field with 81 geothermal baskets with a' 3 m
- Air register (evaporator) in CO-Ventilation of the underground car park

Heating system:

- Heat pump: 7 heat pumps (type undisclosed)
- Installed power 690 kW
- Heating load 350 kW
- Operation mode: monovalent
- SH heating temperature: 35/30 (°C)
- DHW heating temperature: 65/60 (°C)
- DHW system: 62000 l storage for a central water heating

6.7. New construction Wien Simmering

The considered apartment building with commercial space, which is shown in Figure 52, has a heated living area of 1500 m^2 and was built in 2008. It is a multistory building which is located in the Simmeringer Hauptsraße in Vienna. The SH as well as the DHW heating are realized with a water/water heat pump. The ground water is used as heat source and for the SH a floor heating system is installed. Therefore a two stage adjustable heat pump with a heating capacity of 85 kW is primarily used. Another one stage heat pump with a heating capacity of 26 kW is additionally installed for the DHW heating. This heat pump is specially designed for high water temperatures till 67 °C. More details can be found in the schematic diagram in Figure 53 and Figure 54. (Huber et al., 2014)

Figure 52: Picture of the building in Wien Simmering (Huber et al., 2014)

Building details:

- Location: 1110 Wien/Vienna
- Heated area: 1500 m^2
- Year of construction: 2008
- Heat distribution system: Floor heating

Heat Source

- ground water

Heating system:

- Heat pump: 2 heat pumps
- Heat source/sink: Water/Water
- Installed power 85 kW and 26 kW
- Heat demand: n.A
- Heating temperature: 35/28 (°C)
- DHW: 60 (°C)

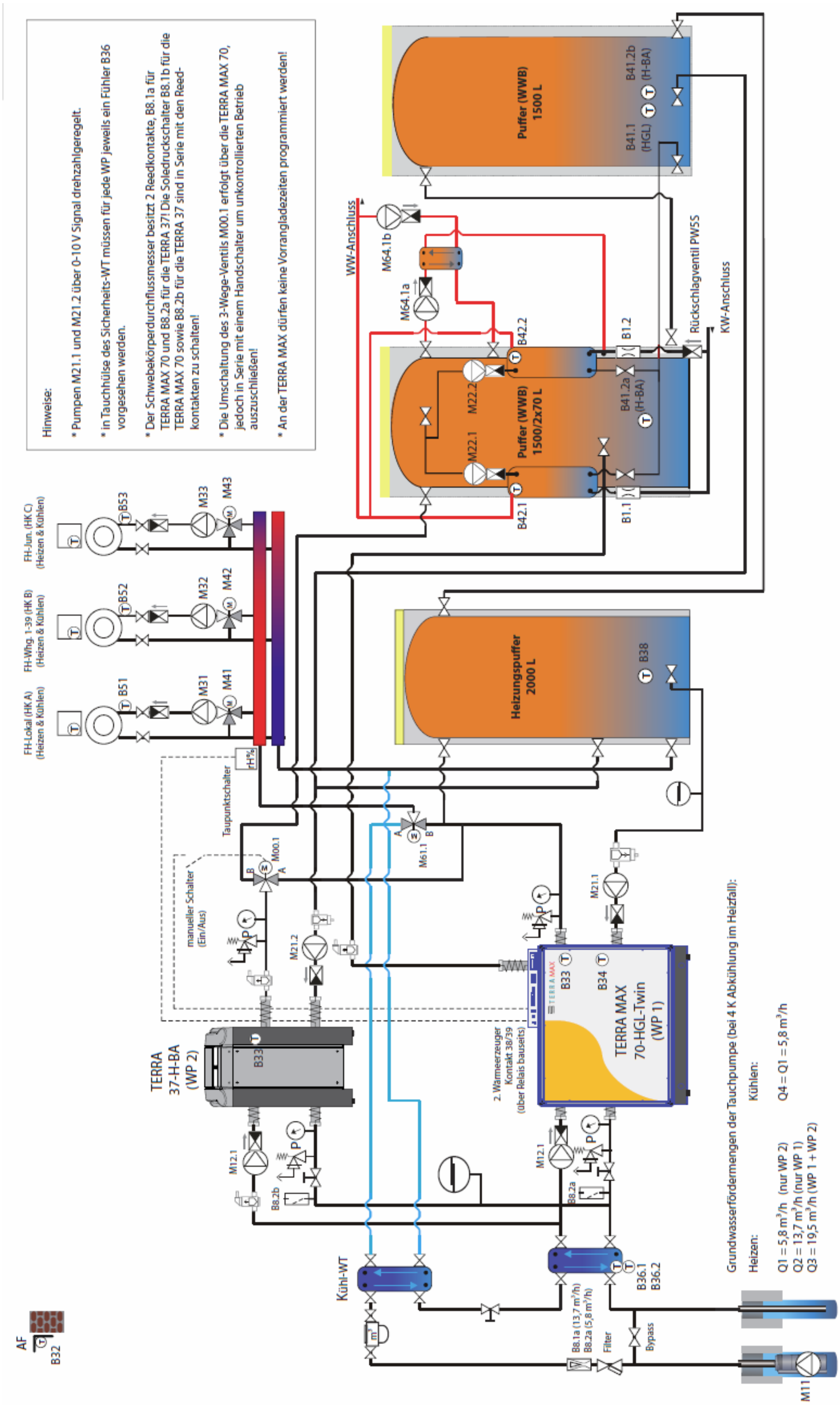


Figure 53: Schematic diagram of the system in Simmering (iDM Energiesysteme GmbH, 2017a)

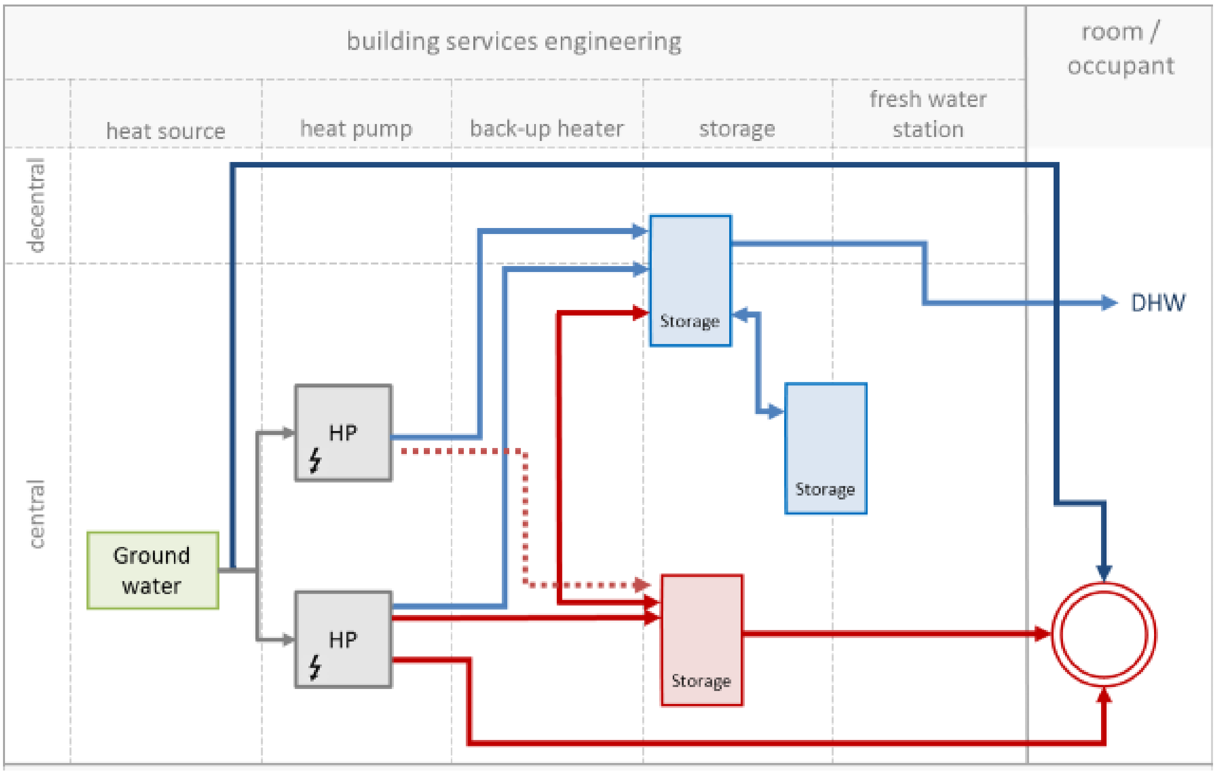


Figure 54: System layout of the system in Simmering

6.8. Roof extensions Wien Praterstraße

The four penthouses, which are built in course of a roof extension, are heated and cooled with an air/water heat pump from iDM Energiesystem GmbH. The new apartments, shown in Figure 55, are located on a multi-family building which was built in the middle of the 19 century and is protected as a historic monument. Therefore the street view to the building has to be unchanged, what also involve the chosen heating system. The decisive reasons for choosing an air/water heat pump were, that this kind of heat pump could be located on the roof which made short pipe length possible and that it is an autonomous system which can be used for heating, cooling and hot water preparation. Moreover it is, according to the economic calculation, the cheapest solution, except of gas heaters which however are far less environmentally friendly. (Redtext, 2017)

The installed heat pump with a heating performance of 60 kW is strong enough to supply the four apartments, which have a total living area of about 450 m². The heat pump is able to provide hot water temperatures up to +60 °C even at an outside air temperature of -20 °C. For a higher operational safety it consists of two separate refrigerant circuits and two evaporators which are defrosted alternately. Moreover an auxiliary heater is included as back-up system. (Redtext, 2017)

The heating and cooling mostly takes place with fan coils with a capacity of 2.72 kW for heating and 1.85 kW for cooling. An exception are the bath rooms, where a floor heating system is installed. The two puffer storages with a capacity of 1500 l, one for DHW and one for heating/cooling, ensure that enough energy is available all the time. The DHW storage is hold at a temperature of 58 °C the whole year while the other one is hold at 50 °C in the heating period and at 10 °C during the summer. (Redtext, 2017)

The chosen heat pump has an extra low noise emission during the normal operating conditions. Moreover a reduction of the fan rotation speed and a switch to one compressor stage is possible during night time. In addition to that, the heat pump is enclosed with a special noise reduction barrier to fulfil the high requirements in this densely populated area. (Redtext, 2017)

Figure 55: Pictures of the system in Wien Praterstraße (iDM Energiesysteme GmbH, 2017b)

Building details:

- Location: 1020 Wien, Praterstraße 54
- Heated area: 450 m^2
- Year of construction: -
- Heat distribution system: fan coil & floor heating (bath rooms)
- Level of insulation: very good

Financial details:

- Average electric costs for heating and cooling: 4300 €/a
- Average costs incl. investment
  calculated with a life time of 20 years: 9000 €/a

Heat pump details:

- Heat pump type: IDM TERRA AL 60 MAX with outdoor installation
- Heat source/sink: Air/Water
- Nominal heat output (A2/W35): ca. 60 kW
- COP (A2/35): 3.52
- Operation mode: bivalent
- Maximum hot water temperature: 60 °C

More details can be found in the schematic diagram in Figure 56 and Figure 57:

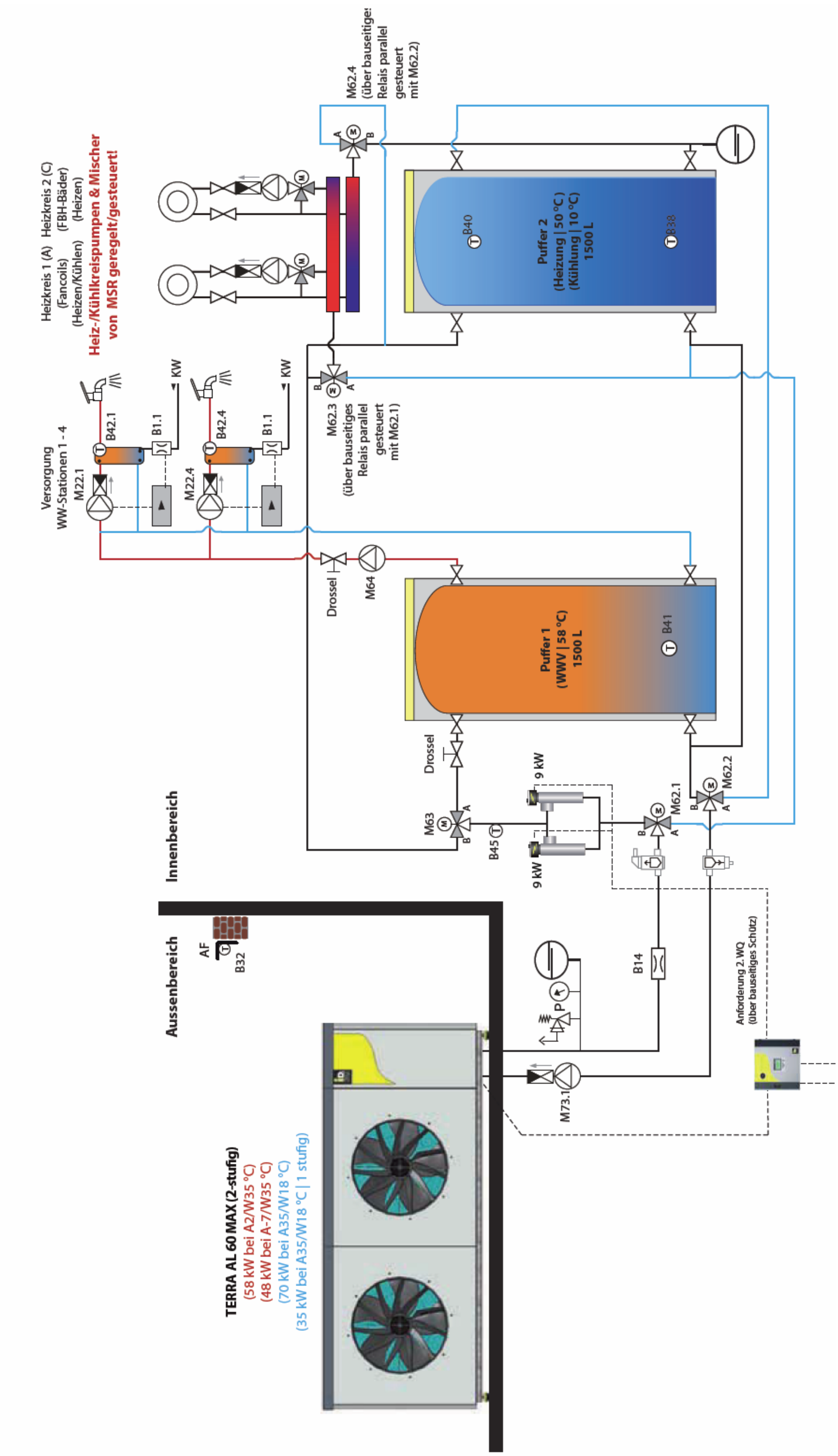


Figure 56: Schematic diagram of the system in Wien Praterstraße (iDM Energiesysteme GmbH, 2017b)

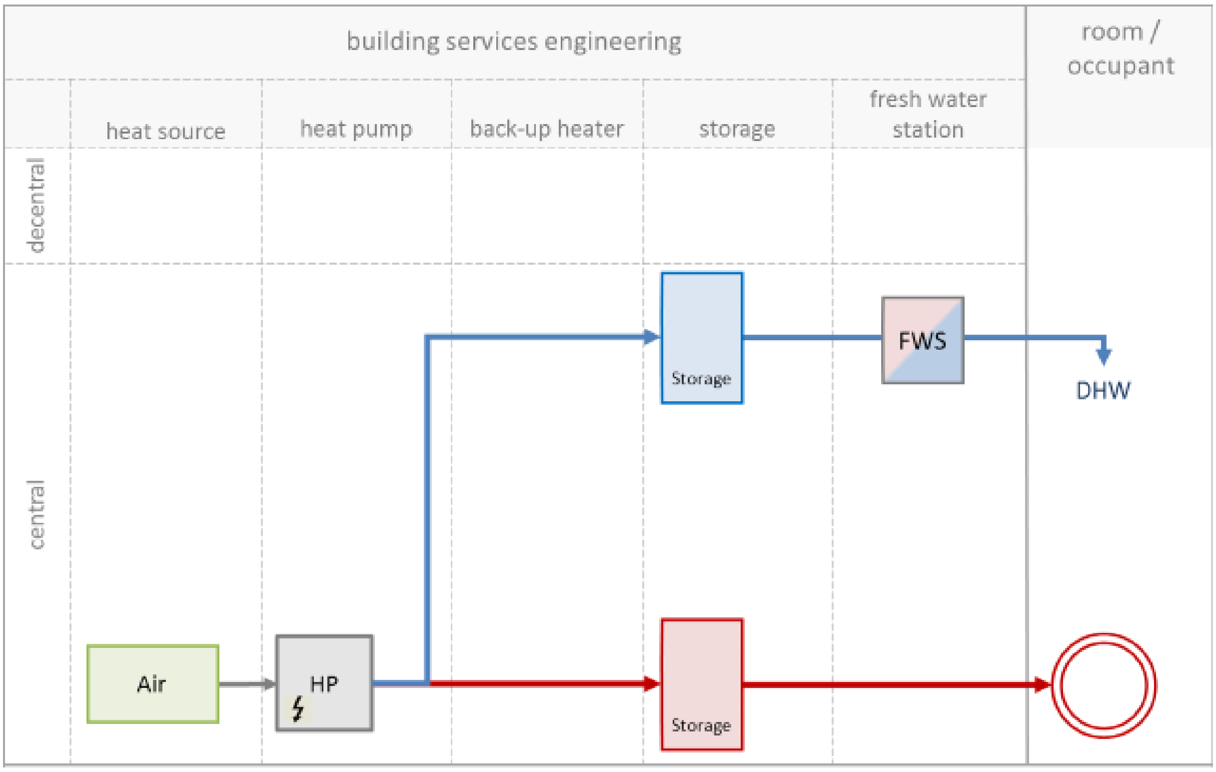


Figure 57: System layout of the system in Wien Praterstraße

6.9. New construction Villach

Another heat pump system from iDM Energiesysteme is installed in a MFH in Villach (Pictures in Figure 58). Two brine/water heat pumps of the type Terra SW 90 MAX HGL are used to supply the building with the necessary heat for SH and DHW prepartion. The desuperheater technology of the heat pump system is particularly energy efficient by heating 85 % of the water to 35 °C and only the remaining part which is used for the DHW up to 63 °C. For storing the energy four 100 l puffer stores are installed, two for SH and two for DHW. The SH is realized with a low temperature floor heating system. To enable a high failure safety the cooling circuit is designed with four separate cycles. More details are shown in the schematic diagram of the system in Figure 59. (iDM Energiesysteme GmbH, 2017b)

Figure 58: Pictures of the system in Villach (iDM Energiesysteme GmbH, 2017b)

From the financial aspect the investment costs of this heat pump system have, with about 200 000 €, been higher than the investment costs for a pellet heating system (113 000 €) or for a district heating connection (79 000 €). Nevertheless the lower operation costs tipped the scales in favour for the heat pumps system. A calculation from iDM resulted in an amortization time of 7 years for the heat pump system in comparison with the pellet heating, and a time of 9 years in comparison with the district heating. (iDM Energiesysteme GmbH, 2017c)

Building details:

- Location: 9500 Villach
- Heated area: n.A.
- Year of construction: n.A.
- Heat distribution system: Floor heating system

Financial details:

- Investment costs: 200 000 €
- Average electric consumption: n.A.
- Average operating costs: 15 000 €/a

Heat pump details:

- Heat pump type: 2x TERRA SW 90 MAX HGL
- Heat source/sink: Brine/Water
- Refrigerant R134a
- Nominal heat output (S0/W35): 2x 87,4 kW
- COP (S0/W35): 4.27
- Operation mode: monovalent
- Hot water temperature: 35 °C SH & 63 C DHW

Heat Source details:

- Type: Geothermal probes
- Number: 20
- Drilling depth: 100 m

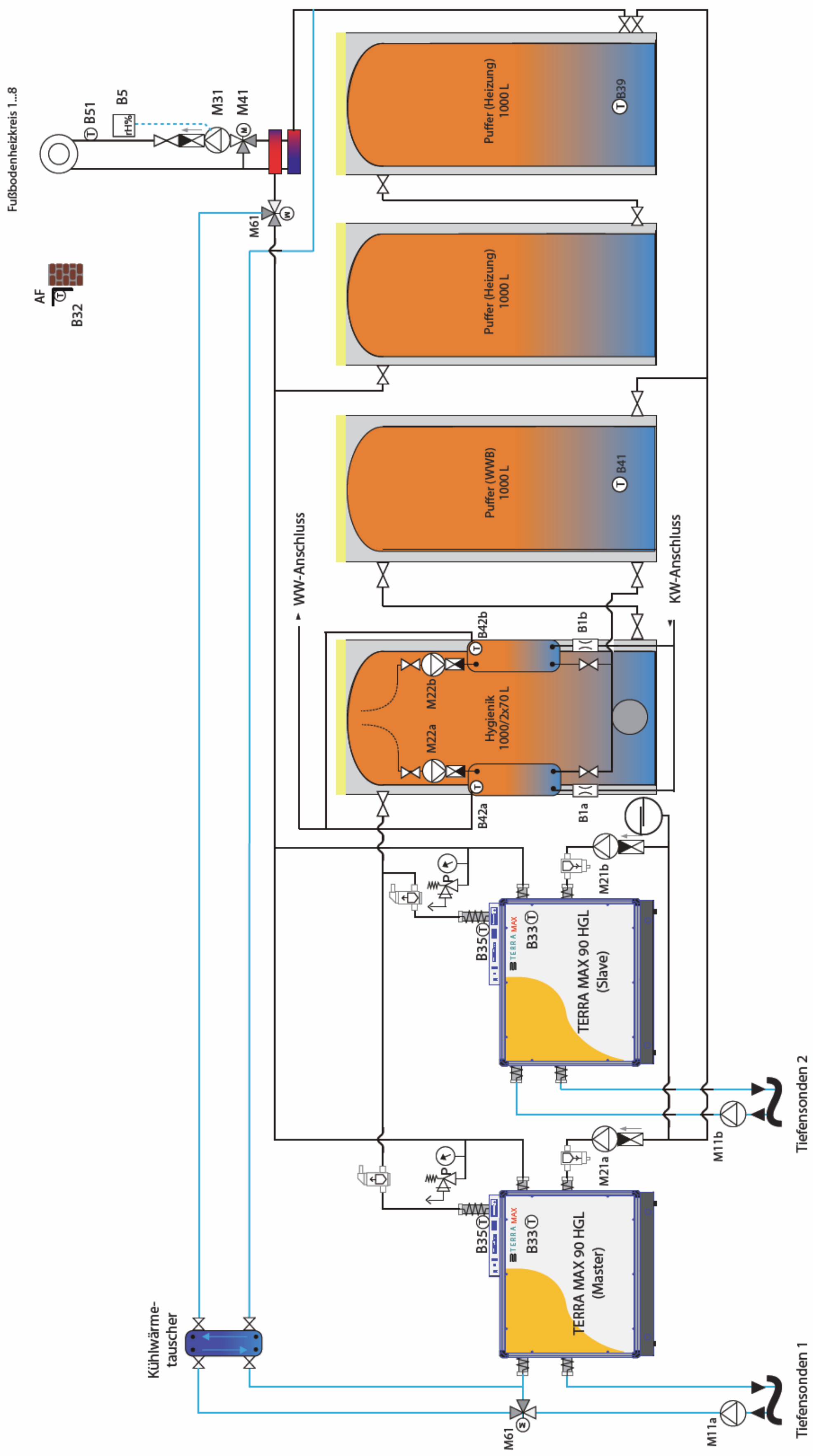


Figure 59: Schematic diagram of the system in Villach (iDM Energiesysteme GmbH, 2017b)

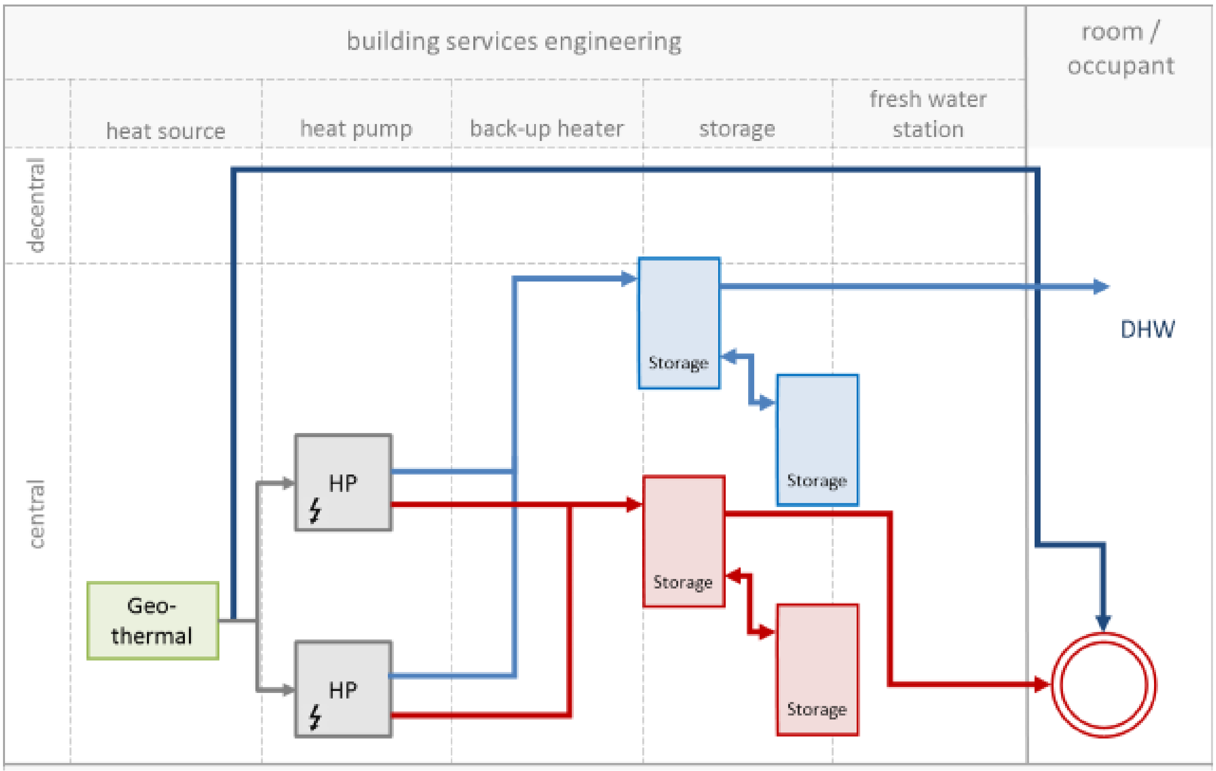


Figure 60: System layout of the system in Villach

6.10. New construction Weiz

The project "Hot Ice Weiz" is focused on the use of latent heat with two ice storages and two heat pumps in combination with unglazed solar collectors and a PV system. It is designed as a pilot project for local heat supply.

The construction of the MFH (multi-family building) which is located at Bärentalweg 6 in 8160 Weiz was finished in April 2015. The building, shown in Figure 61, is a wood frame construction which accommodates ten different apartments on three floors. The total area adds up to 1477 m^2, whereof an area of 957 m^2 is heated. It fulfils the passive house standard and has a calculated heat demand of 9.91 kWh/(m^2a).

Figure 61: Building in Weiz (Hutter, 2016)

Figure 62 and Figure 64 shows the hydraulic scheme of the heating system which is used in this building. The heat provided from the solar collector can either be put into the ice storage by a heat exchanger or fed to the heat pumps. It is impossible to use the heat from the solar collector directly to heat the DHW or the SH storage because the temperature is too low and must be brought to a higher level by the heat pumps before. Depending on the current heating requirement, one or two heat pumps work. They always work in one mode (DHW or SH storage) and ensure that the temperature in the storages remains within the desired range. Instead of the solar collector, the heat pump can also be fed from the ice storage. If both heat sources are not sufficient, there is the further possibility to heat the two storages with an auxiliary heater. During the summer, this system can also be used for cooling. For this purpose, the ice storage is used directly as heat sink (“cold source"), so that no additional chiller is needed.

A more detailed scheme of the heating system including the sensor positions for the measurement is shown in Figure 63.

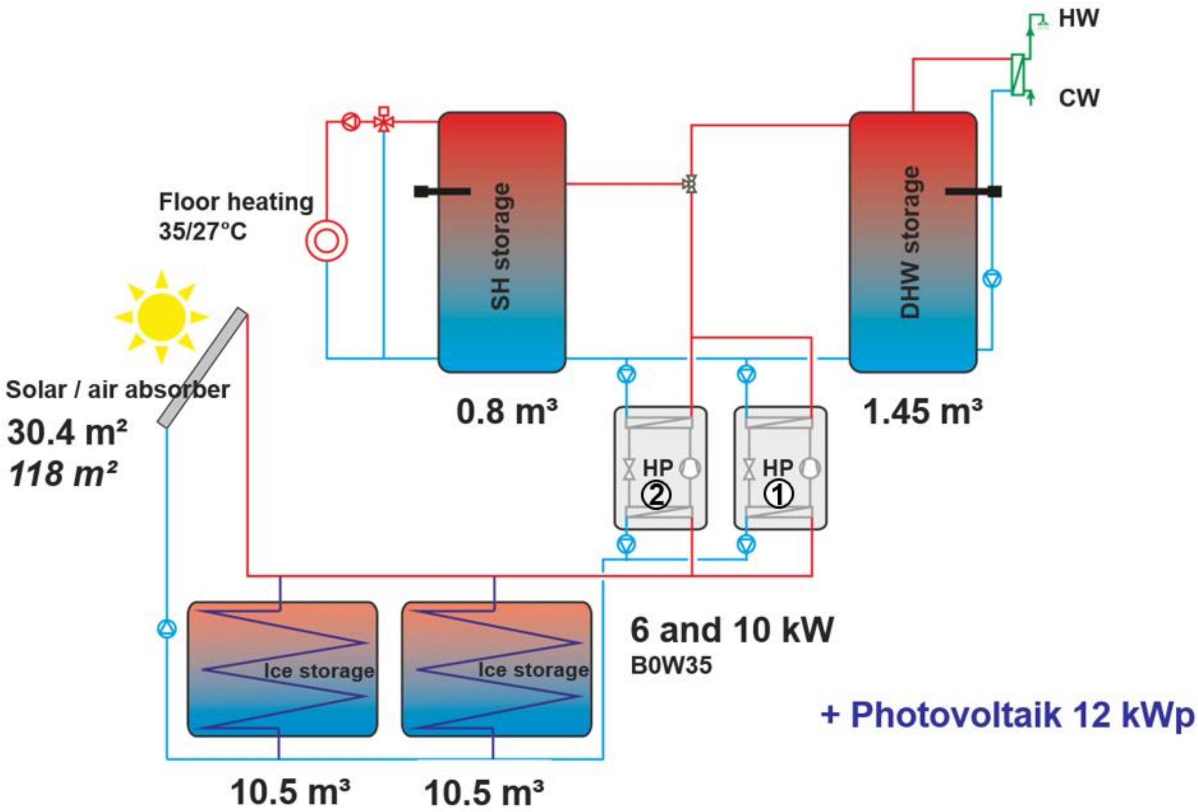


Figure 62: Hydraulic scheme (Pratter, 2017)

This system will play a greater role in the further tasks of the report of the IEA HPP Annex 50, where a detailed analysis of the actual state will be discussed and a simulation model based on this system will be developed.

Building details:

- Location: 8160
- Heated area: 957 m^2
- Year of construction: 2015
- Heat distribution system: Floor heating
- Level of insulation: very good

Financial details:

- Investment costs: undisclosed
- Electric energy consumption 2016: 16805 kWh/a
- Average electricity costs: undisclosed (PV system installed)

Heat pump details:

- Heat pump type: 2x Vitocal 300-G
- Nominal heat output (B0/W35): 6 kW & 10 kW
- COP (B0/W35): 4.51 / 4.72
- Heat source/sink: Brine/Water
- Operation mode: heat pump and auxiliary heater
- Maximum hot water temperature: 35 °C SH, 60 °C DHW

DHW details:

- Number of people: 10 apartments
- Increased hot water demand: yes
- Circulation system: yes
- Water heating: with heat pump

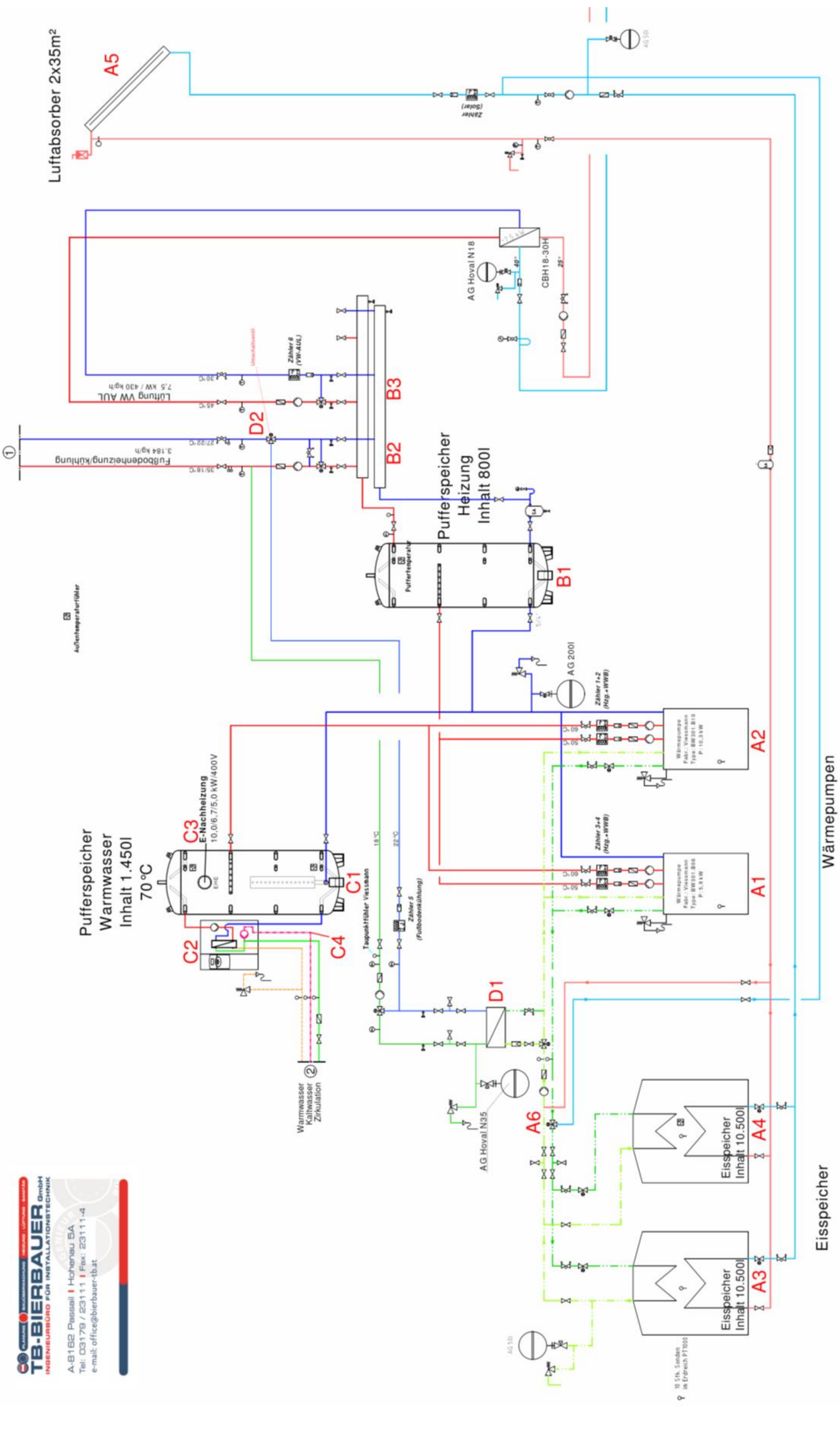


Figure 63: Measurement scheme (TB Bierbauer GmbH, 2015)

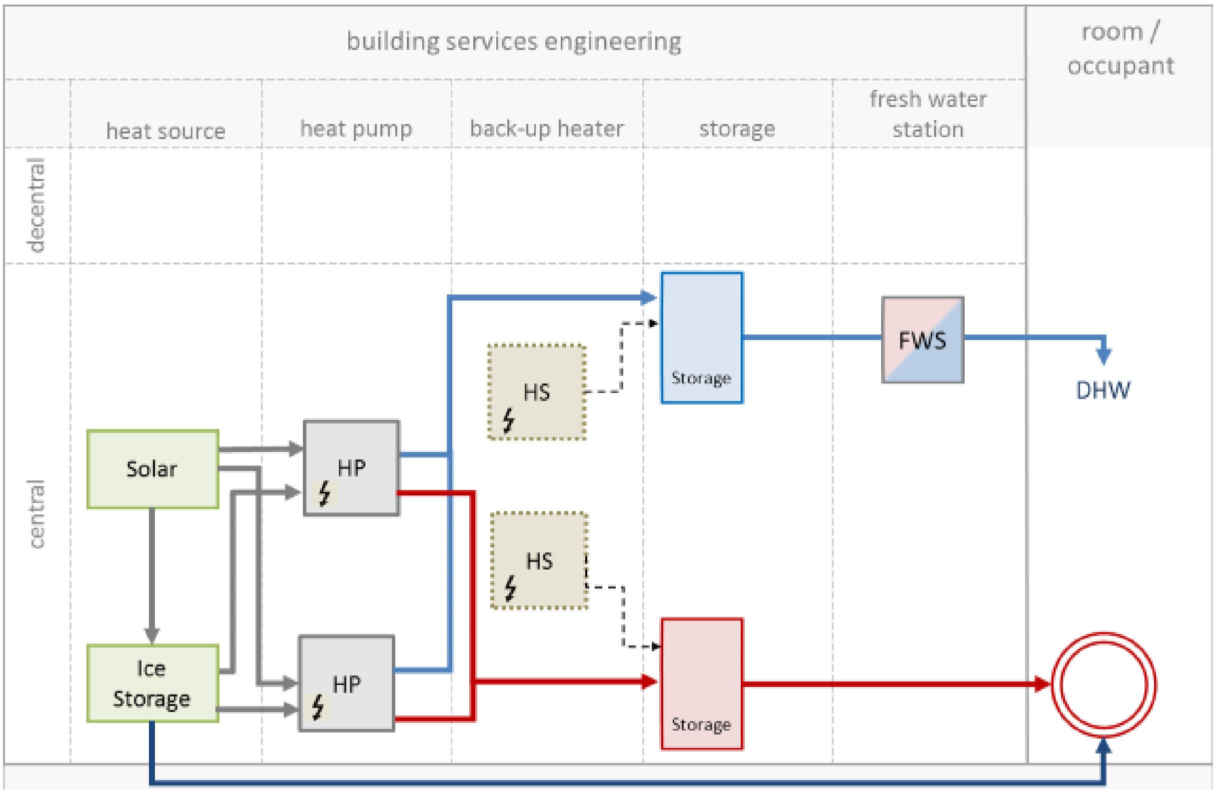


Figure 64: System layout of the system in Weiz

7. Barriers for Heat Pump Market in MFB

The development of the heat pump market in the field of multi-family buildings is hindered by several barriers:

7.1. Energy prices

The actual prices for oil and natural gas as well biomass have a high influence on the heat pump market. As the prices for crude oil and other fossil energy soucres has been falling during the last years and kept stable at low levels, there is a significant barrier for the investment in new heating technlogies. Another barrier is that the prices for electricity, which is the driving power for heat pumps, have been rising during the last years significantly. One reason is that the costs for subsidies for electricity from renewable are charged to the final costomers via levies. As the installation costs for heat pumps are higher than for conventional technology, this barrier has to be tackled by policy measures, e.g. via laws, directives or subsidies, supporting the heat pump technology.

7.2. Barriers due to limited heat sources

Most multi-family buildings are located in large cities with high building density. Therefore, the heat source potential concerning geothermal energy and ground water is limited. In many areas of Austrian cities the use of geothermal energy and ground water is restricted due to ground water protection provisions. Therfore, often the only suitable solution is the air/water-heat pump. Here, the main barrier are the sound emissions. In order to tackle this barrier, silent products are equally importand as intelligent planning and installation. Training for planners and installers are crucial in order to prevent image loss concerning the heat pump type most promissiong for application in new and refurbished multi-family buildings.

7.3. Barriers due to energy efficiency and technical restrictions

In order to reach suitable energy efficiency values and because of technical restrictions, state-of-the-art heat pumps may provide heating temperatures no superior to 70°C. Therefore, most buidlings that have an annual heating energy demands superior to 140 kWh/m², are not suitable for heat pump application. Most state-of-the-art heat pumps provide heating powers below 50 kW (see Figure 33). Only few producers offer standard products providing higher heating powers. Therfore, nowadays, standard solutions for central heating systems can be provided for energy efficient buildings only. Policy measures must assure that the refurbishment rate is raised to 3 % per year until 2020 acording to the Energiestrategie Österreich (2020).

8. Estimated Potential for HP application in MFB

Based on the data concerning heat pump market, building stock and policy framework above, a raugh estimate concerning the potential of future implementation of heat pumps in MFB can be derived as folows. In Austria, 60 % of all 260,000 MFBs (see 3.1), e.a. approx. 150,000 buildings are equiped with a centralized heating system. Some 40 % of these buildings were built after 1980. Due to themal insulation, demanded by buidling codes lead to heating energy demands below 140 kWh/m². In these approx. 60,000 MFBs heat pumps may be implemented without the need of comprehensive refurbishment. Assuming an annual refurbishment rate of 3 %, see Energiestrategie Österreich (2020), approximately 8,000 further MFBs per year may become suitable for the implementation of heat pumps for heating and DHW preparation.

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