fit4power2heat: Work Package 2

Results of the WP2 and deliverable D2.1 (Bericht zu potenziellen Anwendungsfälle von Wärmepumpen in Fernwärmebereich mit Fokus auf Strom-Fernwärme Markt Kopplung)

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Content

1 Introduction

Heat pumps provide a coupling point between the electricity and the heating sector. Therefore, they could counteract the high costs associated with the integration of renewable energies in the electricity system and at the same time increase the profitability of the heat networks. At the scope of developing both technical solutions and business models enabling heat pump integration in heating grids in Austria, the tasks within work package 2 of the project fit4power2heat gather the data and information required to perform the techno-economic simulations (see deliverables D3.1 and D4.1).

Based on various studies within chapter 2, relevant parameters have been gathered from small to large heating grids, including an overview of the market situation for local and district heating grids in Austria and of the most relevant heat production technologies overview.

Chapter 3 provides a detailed analysis on the most relevant framework conditions for heat pump pooling. Among them, historical data as well as realistic developments (based on a literature study) for various energy and balancing markets have been collected. Moreover, information on legal and regulatory framework for Power2Heat in Austria has been collected. This includes existing Power2Heat (P2H) plants in Austria (heat pumps and direct electric heaters), electricity costs and subsidies for P2H plants as well as the impact of P2H on different electricity market actors (e.g. aggregator, supplier, balance group responsible party, control area manager and distribution grid operator).

In order to assess the use cases under current and future framework conditions, chapter 4 presents an overview on current and future market developments in the electricity sector (day-ahead, intraday and balancing markets) and the heat sector (fuel prices, end energy prices, heat density, heat demand trends, etc.).

2 Energy market situation in Austria (Task 2.1)

The results from the work in Task 2.1 of the project fit4power2heat are summarized into three main parts: section 2.1) market situation for local and district heating grids, section 2.2) heat production technologies overview and section 2.3) relevant electricity markets for the sectors coupling (heat and electricity).

2.1 Market situation for local and district heating grids

In Austria, district heating is provided by various actors. These are mostly municipal companies. The main areas of coverage are larger cities such as Vienna, Graz, Linz, Salzburg, Klagenfurt, St. Pölten and Wels. However, district heating also plays an increasing role in smaller communities with local heating grids [1].

The local and district heating is an energy service based on producing heat and distributing it from available heat sources to direct usage by customers. In Austria in 2016 25% of the residential sector was supplied by district heating. The district heating share of buildings with 10 to 19 apartments was 42% and in buildings with 20 or more apartments about 52%. Especially in urban areas, with the highest heat demand density, this type of heat supply is mostly used. Figure 1 shows the increase of connected buildings to district heating [2]. According to Figure 1, the residential sector represents 42% of the district heating sector share, followed by a 45% of public and private services and 13% for production/ industry.

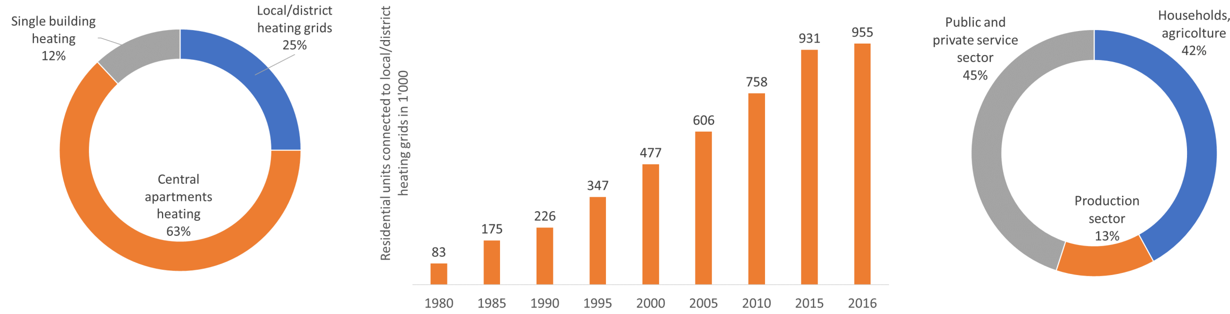

Figure 1: Residential sector heat market split in 2016 (left) [2]; development of connected buildings to local and district heating grids (center) [2]; Local and district heating grids sector split in 2016 (right) [2]

The cumulative length of the heat networks in Austria, which are operated by utilities, according to Figure 2 is around 5.000 km. The Association of Gas and Heat Supply Companies (FGW) states that companies will continue to invest in the consolidation and further expansion of their grids in the future. In addition, between 2017 and 2026, companies are planning annual increases in district heating pipelines between 21 and 58 km with an average annual rate of expansion of around 37 km [2]. The trends have reduced from 2014, when the district heating expansion rate was forecasted 92 km. The reasons for the reduced expansion are the connection densification in cities as well as more difficult framework conditions [1] & [3].

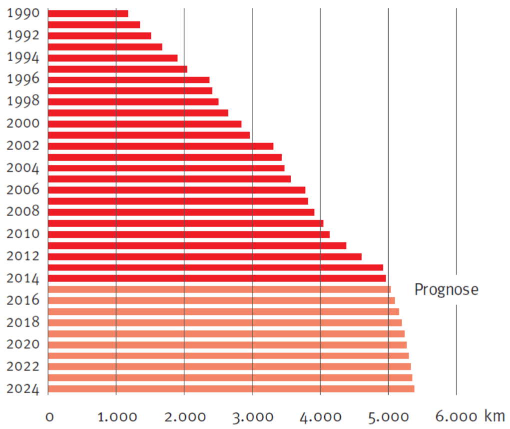

Figure 2: Cumulated local and district heating grids [4]

2.2 Overview of heat production technologies

About half of the heat generation in the Austrian local and district heating networks in 2016 is based on renewable fuels (heat generated from biomass plants contributes for around 21%), see Figure 3[1]. Including the use of natural gas for heat generation, almost 90% of local and district heating was generated by means of CO2-neutral or low-CO2 primary energy sources. However, the further development is uncertain. The reason for this is the change in the international energy markets, which means that gas-fired cogeneration plants cannot be operated profitably in part because of low electricity prices on the markets and higher gas prices. Due to the more difficult economic conditions for CHP plants, in recent years the use of district heating has increasingly shifted from highly efficient CHP plants to pure heating boilers. This trend is shown graphically in Figure 4.

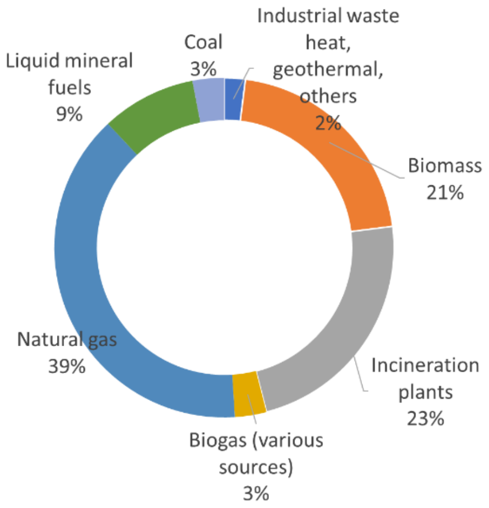

Figure 3: Fuel expenses for heat production [2]

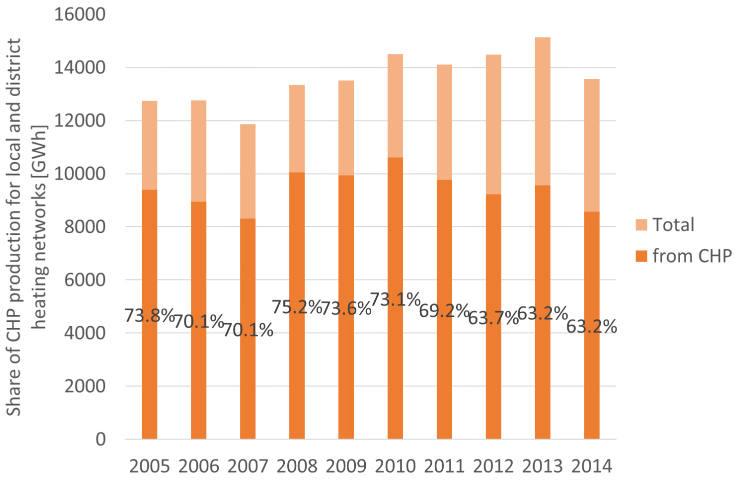

Figure 4: Heat production from combined heat and power plants [2]

Although there are no limits to the combination of different heat sources in a local or district heating network, the supply structure can be divided into two categories [5]:

- Large cities: the heat networks are increasingly fed with heat from large generating units, which are usually owned by municipal energy suppliers. Above all, waste incineration plays a major role as well as biomass. Additional boilers act primarily as a peak load and failure reserve.
- Small towns and communities: these heat networks are mostly supplied by energy from biomass fuel. Heating or cogeneration plants serve as energy producers, whereby oil or gas boilers are also used to cover the peak load and as a back-up reserve.

Following sections give an overview of the heat production plants under consideration within the project fit4power2heat; the focus is on the use cases developed together with the project partner ENGIE Austria GmbH. Details of the use cases are given in deliverable D3.1.

Biomass heat plants: Austria is confronted with a large amount of existing biomass plants and according to [6] there are about 900 plants larger than 1 MW with about 2600 MW of total installed heat capacity. About 900 MW of this installed capacity has been installed between 15 and 20 years ago [7], Figure 5. The focus of the project fit4power2heat is on the possibility to enhance the economic rentability of the grids where those plants, at the end of

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[1] Due to different statistical methodology and used data, different numbers can be found in literature, e.g. [53], [54]

their technical life, run at lower efficiencies compared to newer technologies (e.g. new biomass plants and/or heat pumps).

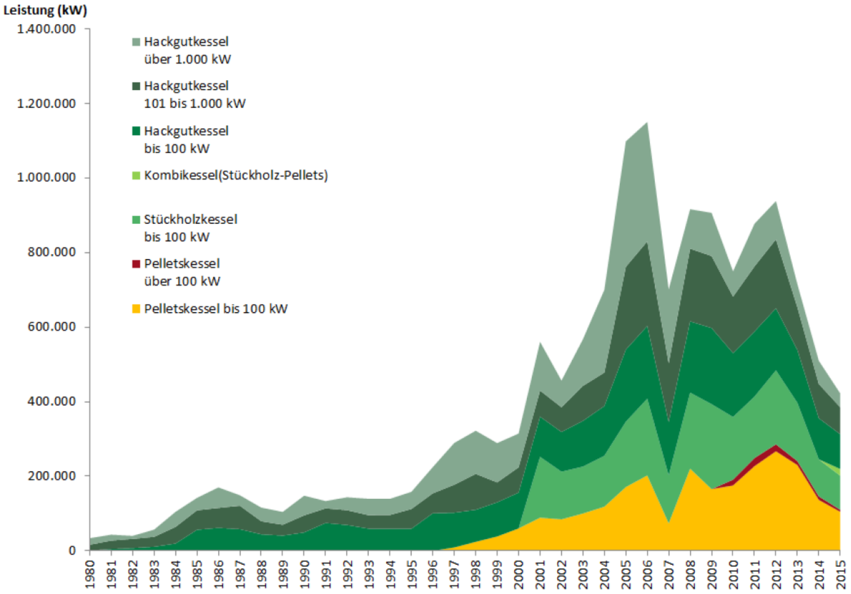


Figure 5: Development of installed capacity for biomass heat plants from 1980 until 2015 [7]

Heat pump systems: Heat pumps represent a technology capable of providing a coupling point between energy sectors (heat and electricity) and efficiently harvest renewable and alternative sources (e.g. industrial waste heat, natural sources, etc.). As described in [8], the heat pump market (at small, medium and large-scale sizes) continues to be governed by three major trends:

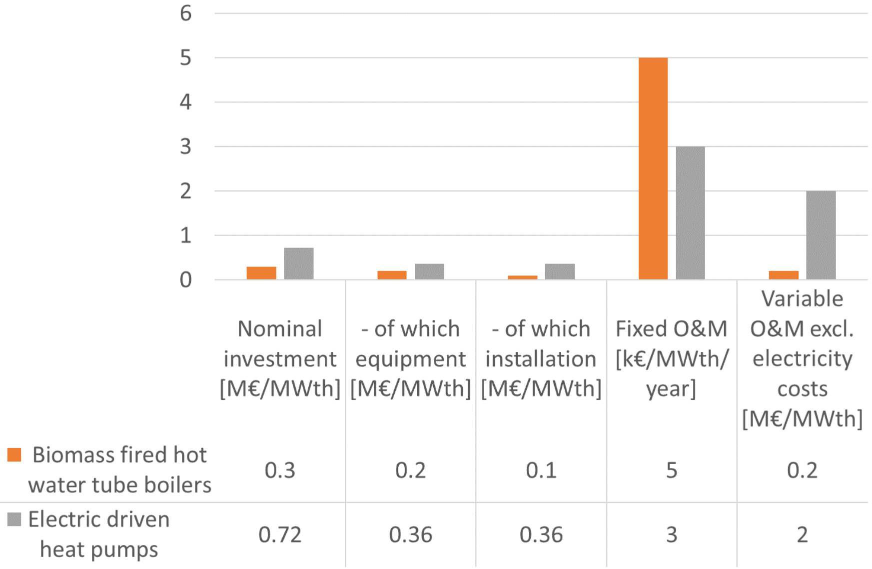
1. Air is and will remain the dominant energy source for mall scale heat pumps
2. Domestic hot water heat pumps are the fastest growing heat pump segment across Europe. This category is the only one showing double-digit growth. Sanitary hot water units combine a heat pump and a hot water storage tank.
3. Larger heat pumps for commercial, industrial and district heating applications are increasingly popular. They quite often use geothermal or hydrothermal energy. However also here, air is an energy source used by several installations. Air, water and ground can either carry renewable energy or waste heat from processes.

According to the market analysis [9] the historical development of the Austrian heat pump market is a significant market downturn in the 1990s and a strong market diffusion of heat pumps heating from the year of a first phase of strong market diffusion of water heat pump in the 1980s, 2001 marked. The distribution of heat pumps held an energy-efficient and economically attractive deployment year 2001 parallel to the market diffusion of energy-efficient buildings, which at low heat requirement and low heating flow temperature.

Within the framework of the fit4power2heat project *electric boilers* have been excluded and only heat pumps are considered.

Figure 6 provides technical and financial data for biomass heat plants and compression heat pumps, based on results from the study [10]. The provided information is considered in the simulation tools within the fit4power2heat project to assess the techno-economic performance of the use cases developed. Capital expenditure (CAPEX) of the nominal investment is split into the two groups: main equipment and installation (which includes labour costs). With regards to the main equipment it is assumed that there are no significant differences within Europe, since core elements are only produced by a handful of international technology companies with different supply chains and several locations for the final assembly.

Figure 6 shows the differences between the two technologies (biomass plants and heat pumps) in terms of capital costs and operational costs. Technical and financial data has been adapted to the local conditions based on the information provided by ENGIE Austria GmbH and details are given in the deliverable D4.1.



	Nominal investment [M€/MWth]	- of which equipment [M€/MWth]	- of which installation [M€/MWth]	Fixed O&M [k€/MWth/ year]	Variable O&M excl. electricity costs [M€/MWth]
🟧 Biomass fired hot water tube boilers	0.3	0.2	0.1	5	0.2
⬜ Electric driven heat pumps	0.72	0.36	0.36	3	2

Figure 6: Financial data for biomass heat plant and compression heat pumps [10]

2.3 Relevant electricity markets for sector coupling

There are three different market-driven applications that enable the integration of heat pumps in district energy systems and thus reducing operational electricity costs and gaining further revenues by offering flexibility:

a) electricity costs for the operation of the heat pump compressor can be optimized by offering a certain flexibility in operating it by considering the day-ahead and intraday spot market prices;
b) additional revenues can be achieved when the heat pump compressor (electrical load) is offered in one of the balancing markets (an overview of the technical details of the different markets conditions is given in section 3.1.2);

In the following chapter 3 an overview about the relevant electricity markets and prices is given.

3 Definition and determination of the most relevant framework conditions (Task 2.2)

As a basis for the use case development and successively for the business model definition, the economic and regulatory framework for the operation of Power2Heat plants (heat pumps in the case of the fit4power2heat project) in Austria has been analyzed. This study therefore gives an overview of the relevant short-term market places and price developments in Austria, focusing especially on those aspects relevant for Power2Heat plants. Furthermore, the composition of electricity costs for a heat pump, integrated in a district heating system, are studied.

3.1 Overview of the Austrian short-term energy and balancing markets

There are three different market-driven applications for short-term flexibility in the electricity system: First, operator can reduce their electricity-costs by optimizing their consumption according the Day-ahead and Intraday spot market. Secondly, they can make additional revenues by participating in one of the balancing markets. Thirdly, the operator can use their flexibility to minimize the imbalance settlement costs for their balancing group.

3.1.1 Day ahead and intraday spot market

On the spot market, electricity is traded short term, meaning for the same day (intraday) or the next day (day ahead). The trade can either be over-the-counter or on an electricity exchange. The electricity exchange has standardized products and processes, as well as the advantage of a higher liquidity and it reduces the counterparty risk. The two most important market places for Austria are the EXAA, the Austrian electricity exchange (day-ahead only) and EPEX Spot, which is part of the European Energy Exchange (EEX) and both day-ahead and intraday can be traded there.

At the **day ahead market** uniform pricing is used; this means that all selected bids get the same price independently from their bid price. At EPEX Spot, auctions take place at 12:00 o'clock noon. For Austria hourly products as well as larger block sizes are implemented. The minimal trade-volume is 0.1 MW. Prices can range between -500 €/MWh and 3.000 €/MWh. Figure 7 shows the price development for 2016 (data from 2017 was not available when the deliverable was developed) for the base price as well as the peak price, as published by E-Control in their yearly report. The depicted prices are the daily mean values; therefore, on an hourly basis the occurring price spread was much bigger, ranging from negative prices of -130 € to a maximum 105 €. The yearly average price at the day-ahead auction for 2016 was 29 €.

At EXAA auctions take place at 10:15 a.m, each day. Therefore, EXAA is an important price indicator for the Over-the-Counter market. Prices are available for every 15 minutes, as well as hourly products and larger block sizes. Figure 7 also shows the spread between the EXAA and EPEX Spot prices. With a few exceptions, the prices at the two market places are very similar. The average price at EXAA for 2016 was 29.15€. Considering the similar prices trends it was decided within the framework of the fit4power2heat project to assess the various use cases only taking into consideration the EPEX Spot market.

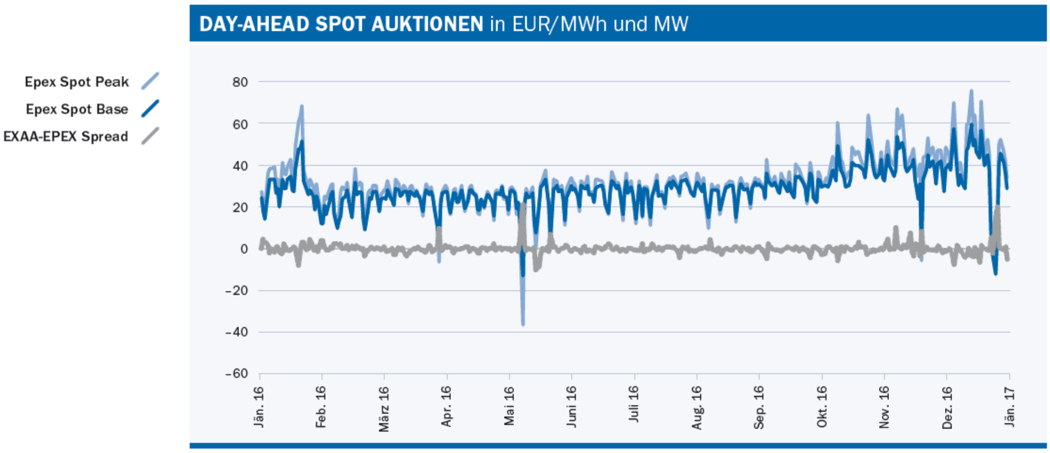


Figure 7: EPEX Spot price development 2016 [11]

Main considerations for P2H: Considering the technical framework/constrains, market participation of P2H plants at the day ahead market is relatively easy. Either, plant operational optimization towards a cost optimum can be performed individually or aggregators can offer it as a service by means of operating a device in a larger pool of devices. In this case bidirectional communication is not necessarily required for the market participation; it is sufficient that the plant operator gets the price signal from the aggregator. However, the potential savings are not as big as in other markets, since the spreads between high and low prices are typically smaller than for example on the intraday market.

At the Austrian **intraday market**, trade is continuous, and prices are set via the pay-as-bid method, where every bid gets paid their buying/selling price. The most relevant market place for Austria is the EPEX Spot market. Trade is possible until 30 min before the delivery. The minimum volume increment is 0.1 MW and the price range is set at -9 999.99 € to 9 999.99 €. The product size is 15-min or in hourly blocks. Figure 8 shows the traded prices for 2016 depicted are the lowest and highest price. The yearly average base price in 2016 was 29.1 €, the yearly average peak price 35.3 € [12].

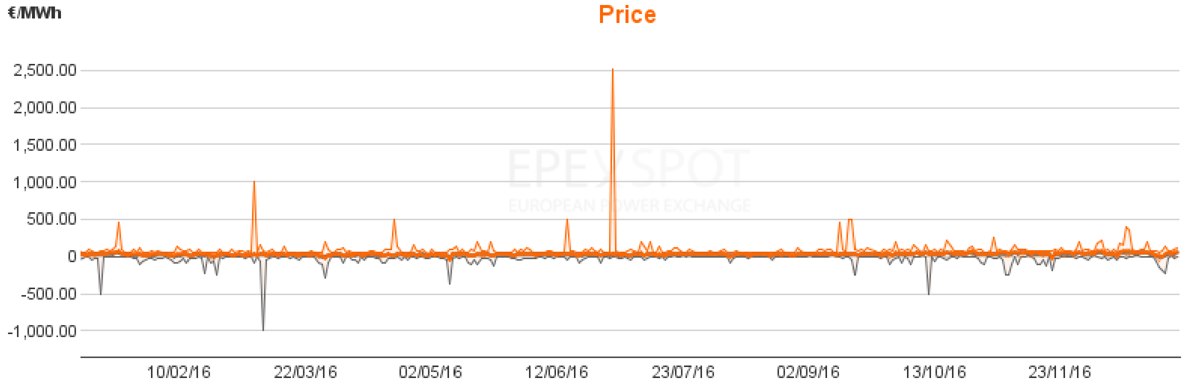


Figure 8: EPEX Spot Intraday prices 2016. Orange: Highest price, grey: lowest price [12]

Main considerations for P2H: Due to the short time nature of the EPEX Sot Intraday market, the available flexibility from the P2H devices can be predicted easier (since e.g. the weather and heat demand are known in more detail). Furthermore, the higher price fluctuations mean potentially higher revenues for flexible units. However, due to the short-term nature of the intraday market, having bidirectional communication from the P2H plant to the trader is very advantageous. If the aggregator knows the current status of the plant, they can better predict their short-term flexibility and technical availability.

3.1.2 Balancing markets

While the imbalance energy incentivizes the balancing group to be balanced and charged deviations within a balancing group, the balancing energy corrects deviations within a control area. The balancing energy is divided in three products, the primary balancing energy (frequency containment reserve, FCR), secondary balancing energy (automatic frequency restoration reserve, aFRR) and the tertiary balancing energy (manual frequency restoration reserve, mFRR). The Austrian Power Grid (APG) is the control area manager and thus responsible for acquiring the balancing energy in Austria.

In order to participate on the balancing market, each supplier must fulfill technical and organizational requirements (see Table 1) and prove them in a so-called prequalification process.

Table 1: Overview of some requirements and specifications of the Austrian balancing markets [13]

	FCR	**aFRR**	**mFRR**
Reaction time	a few seconds	a few seconds	12 min
Time to full power	30 sec	5 min	12 min
Call time	30 min	12 h – 60 h (*)	4 h
Product length	1 week	peak/offpeak (*)	4h peak, 4h offpeak (*)
Gate closure time	Tuesday, 3 p.m.	Wednesday, 3 p.m. (*)	Thursday, 1 p.m. / on work days, 10:30 a.m. (*)
Control signal from APG	decentralized	Centralized on request	Centralized on request
Variability in called amount	yes	yes	no
Min. pool size	±1MW	+/- 5MW (in 1-MW steps)	+/- 5MW (in 1-MW steps) (*)
Pooling	yes	yes	yes
Participation of P2H plants	Very large, modulating P2H-units / a very large pool, to compensate the short-term variability	Modulating P2H or large pool, to compensate the short-term variability and make long call times possible	large pool necessary to make long call times possible (when participating as a pure P2H pool)

(*) will change in July 2018 (Data not available when the deliverable was developed)

For **FCR** the reaction times are shortest and the activation of the flexible unit is automatically through a deviation from the set frequency (50 Hz). Traditionally FCR is provided by the rotating mass in large power plants. Theoretically, it would be possible for P2H to provide FCR, however, the unit or the pool would need to be very big and modulating, as the required power is constantly changing. Due to its very complex technical requirements, the FCR market is not considered in this project.

To participate in **aFRR**, a unit must react within seconds and be able to provide the required full power within 5 min. While the fast reaction times could be met with current P2H units, the large product times (12 h peak/ 60 h offpeak) could only be reached with a large pool or when acting as a base load in a heating grid, i.e. when the full availability can be assured. However, in October 2017, APG has announced that the product size for aFRR should be changed to 4 h with daily tenders by July 2018 [14] . This will make the market participation for smaller or time restricted units much easier/possible.

mFRR already has 4 h products for each day, in a mixture of weekly and daily tenders. However, it is in discussion by APG Austrian Power Grid to change this to have only daily tenders at each day of the week by the mid of 2018. The minimum bid size is currently 5 MW, this will be lowered to 1 MW. Both of those changes will make it easier for demand response units like P2H to participate in the market.

Figure 9 and Figure 10 show the weighted average of the offered bids for power and energy on the Austrian mFRR and aFRR market in 2016. The very high values in the aFRR energy prices occurred since some market participants offered very high bids at the end of the merit order (80.000€/MWh and above), which also lead to high average prices. However, it should be noted that these are the average offered prices and not the average paid prices; the actual revenues also strongly depend on the call probabilities and the position on the merit order.

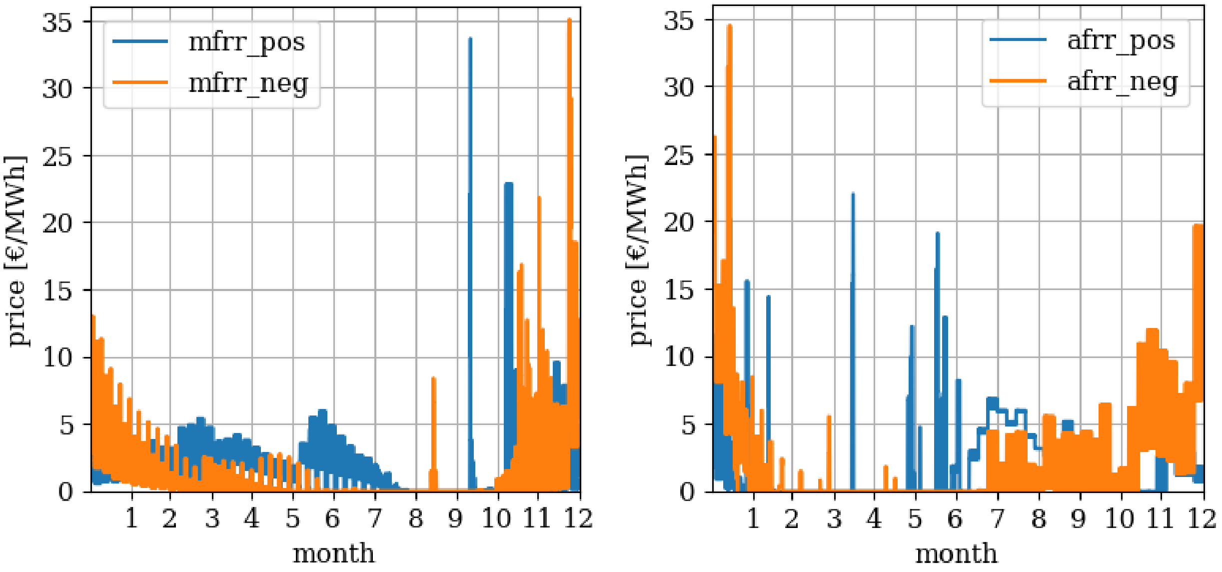


Figure 9: Balancing power prices 2016 [15]

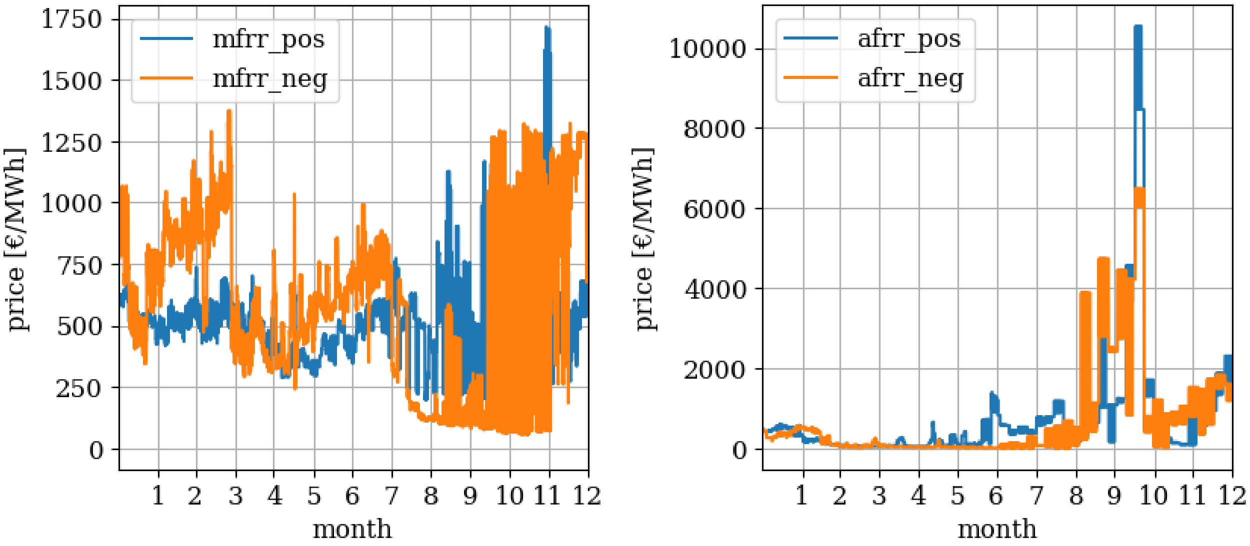


Figure 10: Balancing energy prices 2016 [15]

Figure 11 shows the probability that a bid was called on the market, assuming a position on the merit order curve at half of the merit order: This is explained with an exemplary merit order curve Figure 12: The left figure shows the complete merit order curve, the right figure is the same curve, but zoomed in to better visualize the lower end. The middle position is marked in red. In this example, if half of the total offered balancing energy was called, the price for the bid in the middle would have been 50€/MWh.

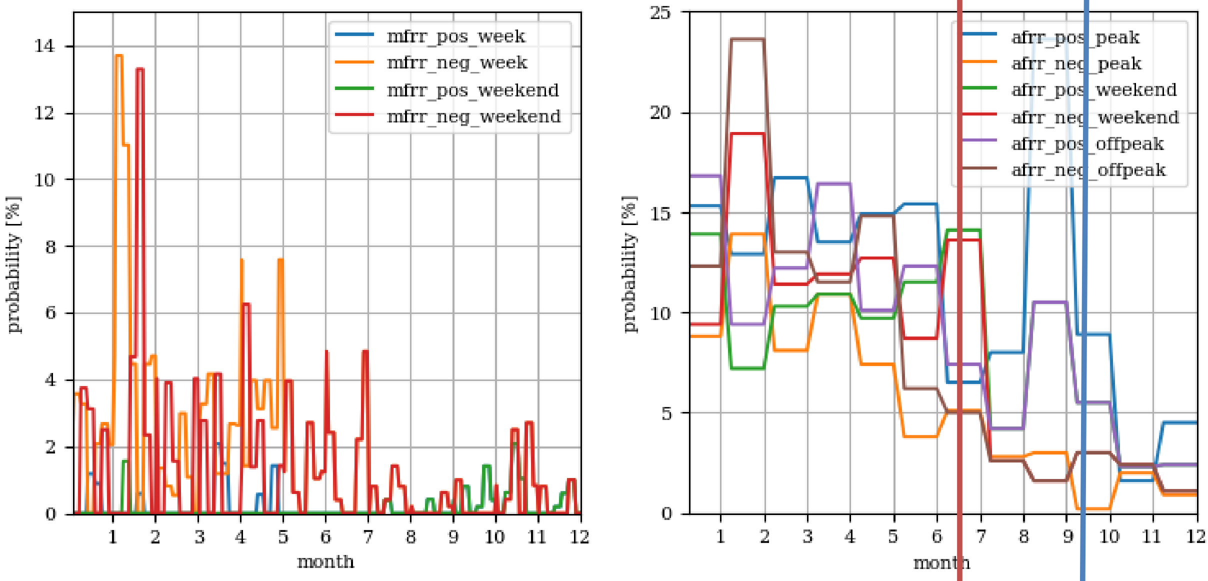


Figure 11: Call probabilities 2016 for the middle position in the merit order

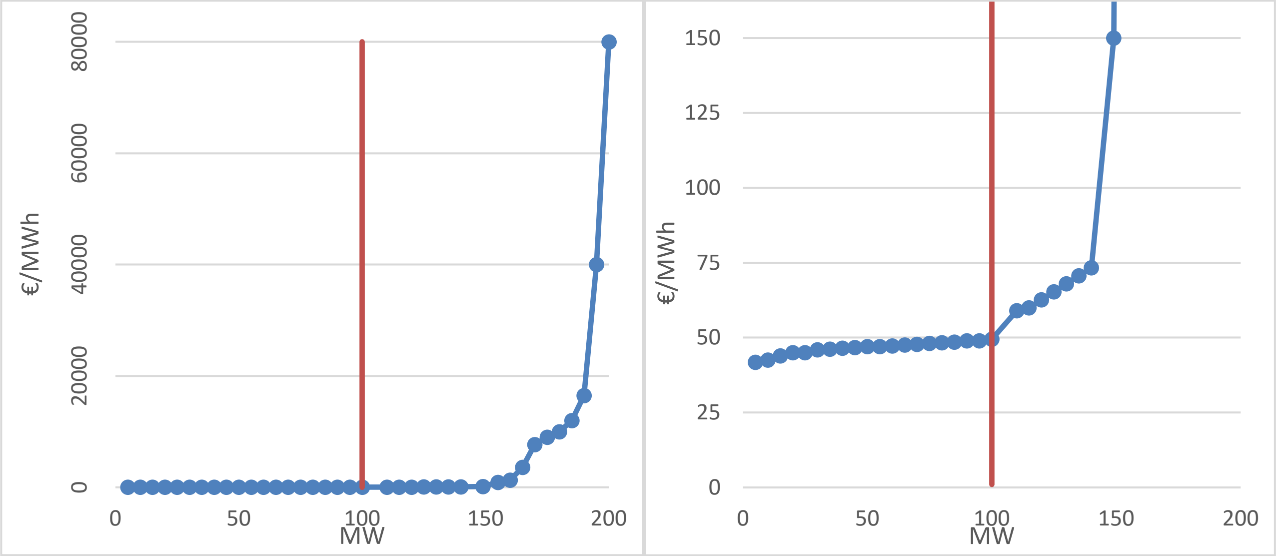


Figure 12: Exemplary merit order curve for aFRR; bids in blue, called balancing power in red. Left: Total merit order curve. Right: Zoom in on lower prices.

In order to estimate realistic revenues, the detailed merit order curve would be necessary. However, this is not published for mFRR and APG only started publishing it for aFRR in the middle of 2016. To get a first feeling of the potential revenues, it is assumed to have a bid right in the middle of the merit order, as shown in the figure above. APG does publish the weighted average price of all offered bids in each tender; the average of those weighted average prices is given in Table 2 (1). However, since the merit order is strongly non-linear (see Figure 12), the average price and the median price (= the price of the bid in the middle) are not the same. The average price in this case is usually higher than the median price. Therefore (1) acts as an upper boundary for the real price.

Also published is the weighted average price and the amount of the energy which is actually called. With this, the weighted average price for all times where half of the merit order was called can be calculated Table 2 (2). Since this is the average price of all bids offered at a certain time, this value is lower (or equal) than the price of the actual middle bid. It can therefore act as a lower boundary for the real price.

To get a feeling for the actual price of the middle bid, two approaches are used: First, the mean value between the two boundaries (1) and (2) is calculated. However, this likely overestimated the prices, especially for aFRR due to the very high prices at the end of the merit order. Therefore, as a second approach, the activation prices (1) are scaled up with a factor 1.5 to take into account the low prices at the beginning of the merit order.

Table 2: Calculations of the price (€/MWh) for the middle bid in the merit order for 2016

	mFRR, pos	mFRR, neg	aFRR, pos	aFRR, neg
(1) Average weighted average prices from tender	501.64	-586.10	714.20	-740.39
(2) Average weighted average price when activating 50% of the merit order	225.47	-183.19	90.67	-53.65
Mean (1,2)	338.55	-384.64	402.44	-397.02
Activation price (1)*1.5	338.20	-274.78	136.01	-80.48

3.2 Legal and regulatory framework for Power2Heat in Austria

In the following, the legal and regulatory framework for Power2Heat plants in Austria is summarized. Special focus lies on the electricity grid costs and the subsidies for P2H, since they will serve as inputs for the later pre-feasibility study.

3.2.1 Existing Power2Heat plants in Austria

Currently there are P2H plants in three different locations in Austria: Energie AG operates two resistant boilers (2x 4 MW) in Riedersbach, Upper Austria. Salzburg AG operates two electrode boilers of 2x15 MW [16]. Since October 2017 Wien Energie also has two electrode boilers of 2x10 MW in Leopoldau, Vienna. Hall AG, operating in Tyrol, is planning a 20 MW Boiler in combination with the existing Biomass Plant [17].

According to E-Control, the first Power2Heat plants for district heating already started participating in the Austrian balancing markets in the year 2015 [18].

As one of the results from the national project "open heat grid" (FFG-Projektnummer 845161) Power2Heat installations can be financed solely by the participation on the negative balancing market [16].

3.2.2 Electricity costs

The electricity price comprises of three parts, the energy price, the system charges and the taxes and surcharges. The figure below shows the distribution between those three parts for an exemplary industrial customer.

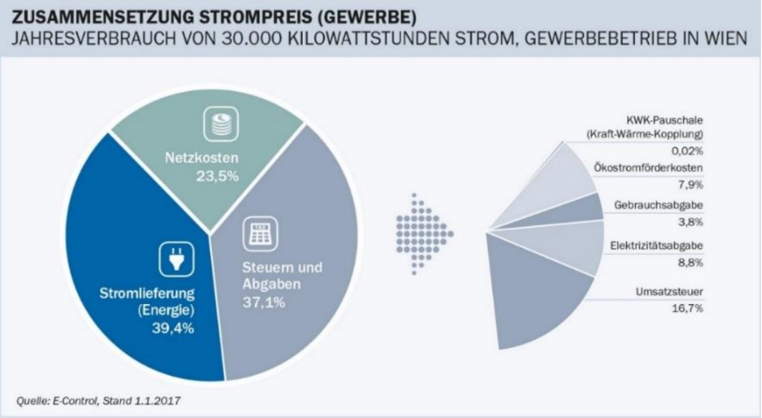


Figure 13: Exemplary electricity costs for an industrial customer in Vienna [19]

System Charges

The system charges are regulated in the „Systemnutzungsentgelte Verordnung“ [20] and comprise of the following parts:

- System utilization charge (“Netznutzungsentgelt”): They are charged from all consumers per meter point and comprise of a power dependent and an energy dependent part. The charge is dependent on the network level and the state. Suppliers of balancing power pay reduced system utilization charges. Currently this only applies to the network levels 1-6, however in 2018, the charges should also apply to customers on network level 7 [21].
- Charges for system losses (“Netzverlustentgelt”): All consumers and producers have to pay the charge for system losses, per meter point. They depend on the consumed/produced energy and are also dependent on the network level and the state.
- Metering charge (“Entgelte für Messleistungen”): The metering charge can be determined by each grid operator, however, the Systemnutzungsentgelte Verordnung determines the maximum allowed charges per month. The charges are defined for different types of measurements. For a connection power of more than 50 kW and a yearly consumption of more than 100.000 kWh, which is typical for a P2H plant, a load profile meter is required [22] and for currents of more than 50 A, an additional instrument transformer is necessary [23]. For the MV- grid, the charge for a load profile meter including transformer are max. 75 €/month, for the LV-grid 52 €/month (50€/month without the transformer).
- System provision charge (“Netzbereitstellungsentgelt”): Consumers have to pay this charge once, when connecting to the grid. It is dependent on the network level they want to connect to as well as their electric power.
- Charge for system services (“Systemdienstleistungsentgelt”): This has to be paid only by electricity producers and is therefore not relevant to Power2Heat plants.
- System admission charge (“Netzzutrittsentgelt”): This is usually calculated individually, depending on the actual costs necessary for a new connection. Some grid operators also have flat rates, especially for the low voltage grid, like for example Wiener Netze [22].
- Supplementary service charge („Entgelt für sonstige Leistungen“): For additional services, like changes in the metering device or payment reminders.

Taxes and Surcharges

Electricity consumers also have to pay a variety of surcharges and taxes, which are listed on the homepage of E-Control [24]

- Electricity levy (“Elektrizitätsabgabe”): This is a fixed levy of 1.5 cent/kWh and is determined by the Elektrizitätsabgabegesetz (BGBl. Nr. 201/1996 idF BGBl. I Nr. 26/2000).
- Community levy („Gebrauchsabgabe“): This levy has to be paid in some areas and is determined by the municipality. In Vienna, 6% of the net system charges and energy costs have to be paid [22].
- Value added tax („Umsatzsteuer“): The VAT for all electricity cost components is 20% in Austria.
- Renewables contribution („Ökostromförderbeitrag“): The renewables contribution is a percentile increase of the system utilization charges and the charges for system losses. It is published yearly in the Ökostromfördereitragsverordnung; for 2016 this was 37.11%, for 2017 26.8% and for 2018 it is 24.58%.

- Flat-rate renewables charge per metering point („Ökostrompauschale“): Additionally a flat rate has to be paid to promote growth of renewables. This is a yearly charge per metering point, dependant on the network level. It is published in the Ökostrompauschale-Verordnung (Artikel II, Ökostrompauschale-Verordnung 2015):
    - NE 1-4: 104.444€/a/Zählpunkt
    - NE 5: 15.517 €/a/Zählpunkt
    - NE6: 955 €/a/Zählpunkt
    - NE7: 33€/a/Zählpunkt
- Flat-rate CHP charge („KWK-Pauschale”): The CHP charge has to be paid by all consumers and is determined by their network level. It is published in the „Bundesgesetz, mit dem Bestimmungen auf dem Gebiet der Kraft-Wärme-Kopplung neu erlassen werden“ or short „KWK-Gesetz“:
    - NE 1-4: 4950 €/a
    - NE 5: 745 €/a
    - NE 6: 43 €/a
    - NE 7: 1.25 €/a

Energy Price

In general, P2H plants have access to the standard energy prices for industry. For example, the classical industry tariff from Wien Energie “MEGA Klassik” is 6.7 cent/kWh, according to the E-Control tariff calculator. There are also special tariffs for heat pumps, which are usually “interruptible”, meaning the grid operator is allowed to switch the heat pump off during certain hours per day. They often have varying prices for different times of the day. An overview of special tariffs for heat pumps in Austria is provided by stromliste.at [25].

An example is the heat pump tariff from ENAMO for enterprises, which is 7 cent/kWh between 6 – 22 o’clock and 5.6 cent/kWh during the night [26]. Another example is the provider aWATTar, who already offers hourly prices, which correlate with the day-ahead spot prices. They have currently a beta test of an intelligent control tool “Syncer” which allows for automatic control of heat pumps towards the cheapest prices [27].

3.2.3 Subsidies for heat pumps and P2H

There are no dedicated subsidies for Power2Heat plants in Austria, which is a discrimination in comparison to Power2Gas and pumped storages [28]. However, there are some general subsidies for heat pumps in Austria. Wärmepumpe Austria lists an overview of the different available subsidies on their page [29].

- For enterprises, which install new heat pumps < 400 kW_{th} there is an investment subsidy provided by BMLFUW. This applies to heat pumps used for heating or hot water provision. The subsidy depends on the type of heat pump and installed power and ranges between 35 €/kW and 85 €/kW.
- For municipalities, a similar investment subsidy is available, ranging from 21 €/kW to 51 €/kW for heat pumps < 400 kW_{th}.
- For heat pumps > 400 kW_{th} municipalities can get a subsidy of 9% of their investment costs, deducting the costs of a fossil production unit that has the same installed power.
- This also applies to business customers, who get between 15-20% of their investment costs refunded, again deducting the costs of an equivalent fossil production unit.
- BMLFUW also provides a subsidy for thermal waste heat usage. Heat pumps used for increasing the temperature of the waste heat to use it for heating get an investment subsidy of up to 35%, as well as low-energy/anergy grids with consumer-side heat pumps.
- Some energy providers and states also have individual heat pump subsidies; however, most of them only apply to residential buildings.

In Germany, there is currently an interesting concept called “nutzen statt abregeln”, which is regulated in § 13 Absatz 6a EnWG: Existing CHP plants (> 500 kW_{el}) reduce their power production, while activating additional P2H-plants, to consume excess energy. The operator then gets a refund on their investments costs for the P2H plant by the grid operator; furthermore, they get a subsidy for the missed production of the CHP plant and the additional consumption of the P2H plant [30].

3.2.4 Power2Heat impact on different market actors

Aggregator: For an aggregator, Power2Heat provides potential revenues. The potential revenue streams depend on the role the aggregator takes: They can act as an independent aggregator or as a supplier and be either be part of a balancing group or act as a balancing group responsible party themselves. The different aspects of this triangle “supplier-aggregator-balance group responsible party” are discussed in detail in [31].

If the aggregator is also a supplier, they can optimize the P2H towards cheap electricity prices on the day-ahead and intraday spot market. They can also use the flexibility to reduce the balancing energy of their own balancing group (if they act as balance group coordinator) or of their associated balancing group (if they are just a member of a balancing group). Aggregators can also pool P2H plants from one or several balancing groups for the different balancing markets. However, it should be noted that also here the aggregator themselves always belong to one specific balancing group (the “supplier-BG”) [21].

Supplier: When some of the customers of a supplier’s portfolio participate in an independent aggregator’s pool on the balancing markets, this will also have some impact on the supplier, even though they are not directly involved. The operation on the balancing market can influence their schedule: first, the supplier needs the information when balancing energy was called in order to consider this for their forecast. Although they are able to get this information via the “Datenkarussell” from APG, it does mean additional work for them. Second, while the called balancing energy itself does not cause an imbalance settlement, there are other effects surrounding balancing energy, which might cause problems for the supplier: When balancing energy is offered, aggregator usually aims for too much rather than too little provided energy, since they may not deviate from their promised balancing energy. However, this “over-shooting” can cause an imbalance for the supplier. Furthermore, imbalance settlement also needs to be paid for the ramping at the beginning and end of a balancing energy call. However, currently APG is already aware of this issue and they are searching for solutions [32].

In addition, possible catch-up effects and their impact on the imbalance settlement of the supplier need to be considered here. Österreichs Energie has published a standardized contract (“Abwicklungsvereinbarung”) for aggregators, balance group responsible parties and suppliers, which should help to settle those issues [33].

Balance group responsible party: For a balance group responsible party it can be advantageous to have a P2H plant in their balancing group, since it can help to reduce imbalances.

Like mentioned above, an aggregator always belongs to exactly one balancing group. (“supplier balancing group”). However, the aggregator can also manage flexible units in other balancing groups, the “provider balancing group”. In this case it is the responsibility of the supplier BG to distribute the activated balancing energy to the other provider BGs. [21].

Control area manager: The P2H plants can provide flexibility for the balancing market and thus support the control area manager. If they are part of the pool of an independent aggregator, this additional market placer can also improve the competition and thus lower the prices for the balancing energy. This is an advantage especially in Austria, where historically there were very few players on the balancing markets.

However, the control area manager also gets new responsibilities with the new market players. In Austria, the so-called “Datenkarussell” should ensure that all participants get the necessary data from each other. In this concept, the Austrian control area manager APG is responsible for collecting, aggregating and distributing the data to the different market actors. The aggregator sends their offered balancing energy to APG; APG then aggregates the offers of all aggregators separately for each balancing group, supplier and distribution grid aggregator and sends them out [32].

Distribution grid operator: As part of the "Datenkarussell", the DSO gets the information of the activated balancing energy in their grid. They have to take this into account for the reduced system utilization charge during times of activation. Furthermore, during the prequalification, the DSO has to check whether it is possible for a customer to participate in the balancing market at a certain grid connection point [34] [35].

Furthermore, the P2H plant could also provide flexibility to the DSO and help them to reduce their grid investment costs or support them during an outage.

4 Baseline and future scenarios (Task 2.3)

The technical solutions and business models investigated in the f4p2h project are developed in the framework of the current energy market. Heat production technologies, energy prices and regulatory framework are considered in order to evaluate the feasibility of the solutions provided from the technical, economic and regulatory point of view. It is also important to consider future trends in the heat and electricity sector to estimate the potential of the business models in the future.

4.1 Future developments in the electricity sector

In all markets the introduction of demand response has been getting easier during the last years. In the last years the gate-closure-times were shifted closer to real-time and to shorter product times is visible. When the intraday gate-closure-time is moving closer to real-time than the activation of the "slower" balancing markets is influenced – especially the balancing markets that have an activation time close to the one of the intraday markets as the tertiary balancing energy (also manual frequency restoration reserve). In contrast to lower activations of tertiary balancing energy, the "fast" balancing markets, where the technical units can react very fast, show a slight increasing trend (frequency containment reserve and even faster balancing markets that are currently in development). In the balancing markets the trend to an increased need of flexibility that is close to real-time can be seen as for example the volume of frequency containment reserve in Germany was gradually increased by 4 – 41 percent per year, developing from 593 MW beginning of January 2014 to 1388 MW beginning of July 2017. Even closer to real-time products than frequency containment reserve are currently tested/implemented for example in Ireland by the transmission system operator EIRGRID.

The prices for the balancing markets have shown a decreasing price trend in the last years. Therefore, with decreasing activation probabilities and prices, the business case for flexibility in the balancing markets was decreasing in the last years. The business case for flexibility in the spot markets is expected to increase, whereas not the price level alone, but the volatility of the prices is the most relevant factor.

These trends are described in more detail in the following chapters for the spot and balancing markets.

4.1.1 Day-ahead and intraday spot markets

The Austrian energy exchange EXAA has introduced 15 min prices for their day-ahead markets on 3rd September 2014 to improve the inter-hour trading [36]. By this, the power steps around the hourly products can be reduced, thereby reducing the need for balancing energy during these periods and also the imbalance settlement costs that have to be paid by the balance responsible parties for deviations from their schedule. In Germany the still only hourly products are traded day-ahead. The development on the day-ahead spot markets in the last years can be seen in the following graph. It can be seen that in the year

2016 had on average the lowest prices and in 2017 the prices show a higher average price and a higher volatility.

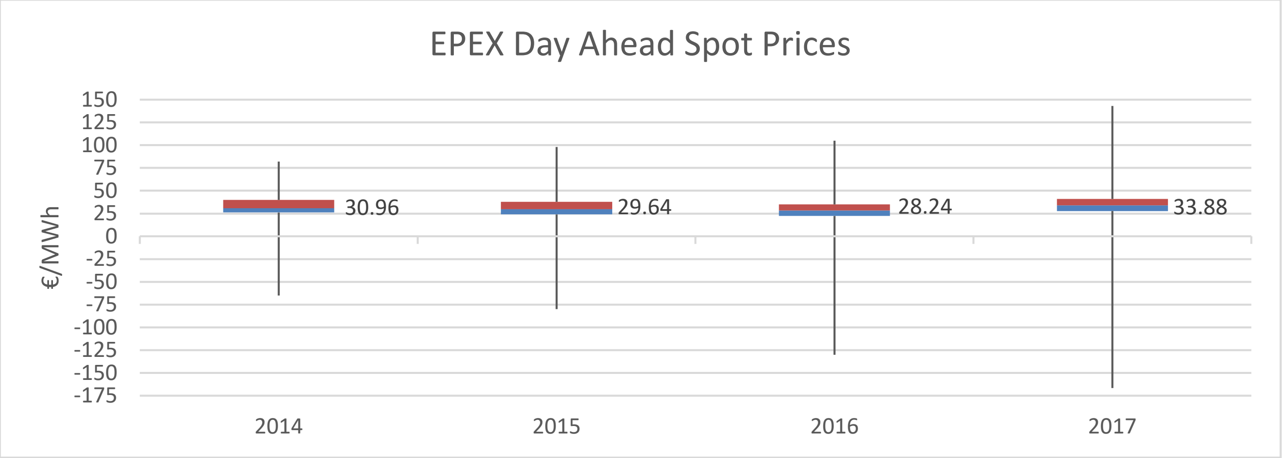


Figure 14: Developments of the EPEX Day Ahead Spot Price. The median values are written in the figure; red is the upper Quantile, blue the lower Quantile and the line shows the total range of the prices.

On 1.10.2018 the market split between Germany and Austria was realized. Therefore, the prices in Austria and Germany are derived separately for each area. The average price increase between Austria and Germany 2019 was +7 € from October 2018 until mid-February [37]. Moreover, it was shown that the price spread is highest during winter times, therefore, the average price spread between Austria and Germany is expected to be less than the price spread from the last months [37].

The study "Stromzukunft Österreich 2030" provides an outlook on the Austrian electricity market in 2030 with focus on the storage requirements, the system flexibility and the effects of increased sector coupling [38]. The quantitative analysis is based on the use of three complementary energy system models (HiREPS, EDisOn and Green-X), all developed at the TU Vienna. The results show that an increased share of renewable energy can be expected in the coming years. However, the use of storage technologies, e-mobility and the coupling of electricity and heat generation will absorb a part of the feed-in of renewable energies.

In the HiREPS 2030-RES Flex scenario the minimum spot market price increases from about -60 €/MWh to over 40 €/MWh. Furthermore, the additional flexibility provided by the sector coupling leads to a strong increase in the market value of RES feed-in with an average spot price increase by almost 10 €/MWh. In addition, the volatility of prices is significantly reduced (see Table 3).

Price peaks continue to increase, as the additional electricity demand due to sector coupling is not completely flexible. Thus, the forecast number of hours with an electricity price of more than 100 €/MWh increases from about 60 to more than 200 hours in 2030. Nevertheless, supply security remains guaranteed at all times, as any generation bottlenecks can be compensated by imports.

Table 3: Scenarios for spot price development in 2030 [38]

Analyzed Scenarios	**Average spot price [€/MWh]**	**Standard deviation [€/MWh]**
EDisOn 2030 – RES weighted average	65.30	17.77
HiREPS 2030 – RES Flex	70.76	43.14
HiREPS 2030 – RES No Flex	61.73	119.28

The results of this study are consistent with Deloitte's outlook report for German electricity market [39]. They also expect spot prices to increase to 50-60 €/MWh and high volatility on intraday market due to rising PV and wind capacity. This study also assumes that the number of hours with spot prices of more than 100 €/MWh will increase sharply. This price development is being driven primarily by the phasing out of nuclear power by 2022 and the closure of coal-fired power plants.

CE Delft [40] also expects electricity prices to rise for the Dutch and German electricity markets by 2030. In their study electricity prices were simulated with the PowerFlex market simulation model. Simulations were executed for three future years and with two variants (NER and high-RES) for the year 2030, based on carbon price paths. As a result, prices are expected to increase modestly from 2020 to 2030 scenario years due to rising fuel and CO_2 prices. The 2030 high-RES scenario is the exception; in this scenario the majority of prices tend to be lower but there are also some higher prices or price extremes. Over time, the volatility of the electricity price is expected to increase significantly, which goes hand in hand with the results of the aforementioned studies.

The high-RES scenario for 2030 shows that in this scenario, there is a clear need for demand response that can absorb excess RES feed-in of wind and solar. The high share of RES feed-in makes balancing the system more expensive during the hours with lower RES feed-in, leading to higher prices. This will ask for flexible power production to accommodate the times without much wind and solar.

More and more volume is traded on the intraday markets, showing the importance of short-term flexibility. For example in Germany the intraday market increased by 5 percent from 2015 to 2016 (AT-DE price zone) [41] [42]. This trend was enhanced by the introduction of an intraday auction next to the continuous intraday market. It was shown in (Neuhoff, Ritter, Salah-Abou-El-Enien, & Vassilopoulos, 2016) that the additional auction in the intraday market increases liquidity, leads to a higher market depth and to a reduced price volatility. Figure 15 shows the distribution of price differences between the weighted average intraday prices and day-ahead prices. The distribtion curves show that the intraday prices are very similar during most of the times compared to day-ahead prices. The intraday prices are on average just slightly higher than the day-ahead prices. Overall, the difference between the intraday and day-ahead prices range from about -10 €/MWh to +10 €/MWh. Future research could include the spread of the intraday markets.

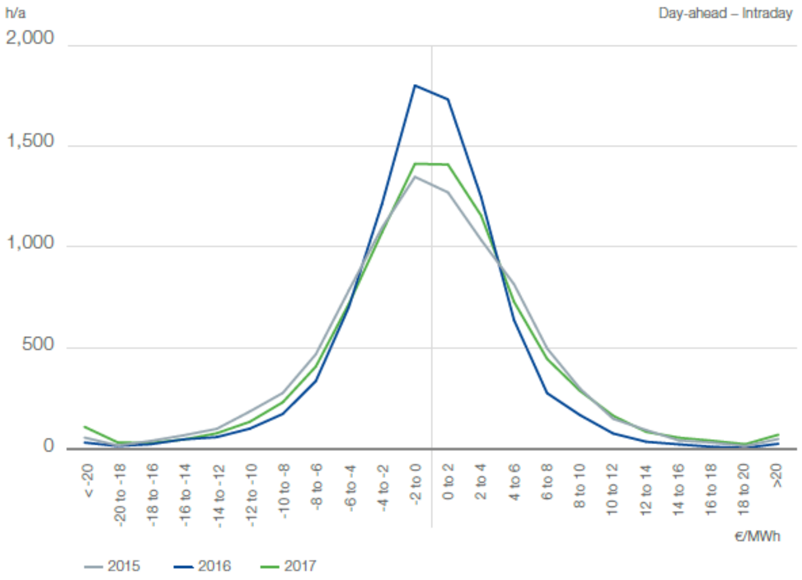


Figure 15: Differences between German Day-ahead and Intraday Prices [43]

On the day-ahead and also intraday spot markets, flexibility, e.g. from power-to-heat applications, enhances the value of renewable energies by increasing the market price at times of high fluctuating RES penetration (see for example [44], [45]).

4.1.2 Balancing markets

In general, the revenues a flexibility can earn on the balancing markets are influenced by the balancing capacity price (the price that the capacity is available), the balancing energy prices (the price for the activation of the flexibility) and the call probability (the amount of the time that the flexibility is activated). Therefore, the development of all three components will be analyzed in the following for automatic frequency restoration reserve (aFRR) and manual frequency restoration reserve (mFRR).

The historical average call probabilities from 2014 until 2017 for a bid at the beginning of the merit order (highest call probability) and for a bid on the middle of the merit order are shown in Figure 16. The bid at the beginning of the merit order has a much higher call probability for aFRR than for mFRR. The call probability for aFRR (beginning of merit order) was quite stable and shows a slight increasing trend. The trend for mFRR in the last years shows a steep decrease especially for negative mFRR. It can be seen that the call probability of a bid at the middle of the merit order for both aFRR and mFRR was decreasing in the last years and it was very low in 2017 for both products. The introduction of the imbalancing netting cooperation International Grid Control Cooperation (IGCC) in 2016 was one of the reasons that the call probability of aFRR was decreasing [46]. Thereby, when in one country positive balancing energy and in an other negative energy is needed, then only the difference of these amounts is activated (when transmission grid capacity is available).

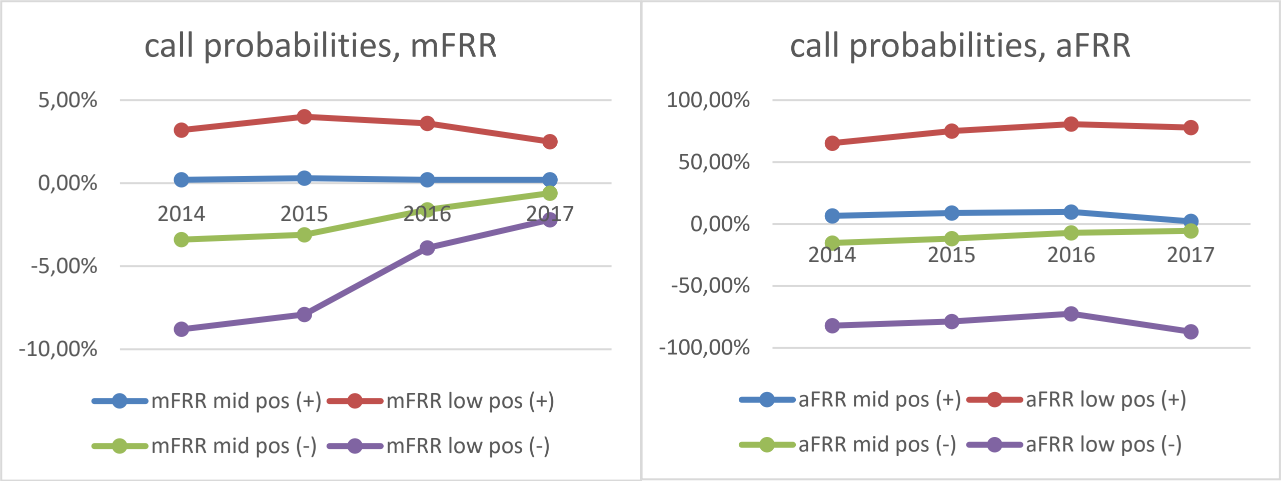


Figure 16: Development of the call probabilities of manual (left) and automatic (right) frequency restoration reserve for a bid at the beginning of the merit order (low pos) and in the middle of the merit order (mid pos)

In the future, the need for flexibility - driven by the expansion of fluctuating renewable energies and the forecast error of wind, PV and load - will continue to rise. Even if the forecast quality continues to rise, there will be an increase in the amount of control energy required of approx. 15 % by 2025 [47]. Also others studies come to the conclusion that the demand for balancing energy will increase, but it will still continue to be a niche market [48].

The historical prices of the balancing markets are described in Chapter 3.1.2 for the year 2016. As can be seen at the example of the year 2016, the balancing energy prices for both aFRR and mFRR show a very high volatility. They are very dependent on the current market design and the design of the tender. Before October 2018 the selection of the bids for aFRR was done only based on the capacity price. In October 2018 this was changed and now the selection rule also includes the energy price weighted with an average call probability of the quarter of a year [49]. The average positive aFRR balancing energy prices from Germany were reduced from 1384 €/MWh three months before the introduction of the new rule to 85 €/MWh three months after the introduction of the rule. In contrast the balancing capacity prices were increased from 1.3 €/MW*h) to 4.3 €/MWh.

4.2 Future developments in the heat sector

The development of the energy systems is strongly influenced by numerous factors such as the energy consumption, energy prices and future building stock. In the framework of the study “Energieszenarien bis 2050: Wärmebedarf der Kleinverbraucher” developed by TU Wien, two future energy scenarios are modelled for small scale consumers covering the period until the year 2050. “WEM 2017” scenario considers a reduction on energy generation from 85 TWh (year 2015) to 57 TWh (year 2050), for space heating and hot water preparation requirements, while “WAMplus 2017” scenario assumes a total energy generation of 44 TWh by 2050. Considering the level of uncertainty that forecasting implies, especially when it comes to fuel and electricity prices, the focus of this section lies on scenario “WAMplus 2017”, which is established under more conservative assumptions. This approach prevents from overestimating favourable conditions for the investigated business models and establishes the basis of the future market perspective.

Considering the forecasts, future scenarios seem very favourable for the integration of heat pump technologies. As illustrated in Figure 17, the heat supply share for decentralised renewable energy sources (biomass, solar thermal and heat pumps) will steadily increase to 29% by 2020 and to almost 50% by 2050. In this scenario, the share for district heating is supposed to stabilize, reaching by 2050 a similar share as in 2015 (from 22% in 2015 to

24% in 2050). Electric energy remains almost constant below 10%. However, a sharp drop is expected for the fossil fuels, from the current 40% of share to around 20% in 2050.

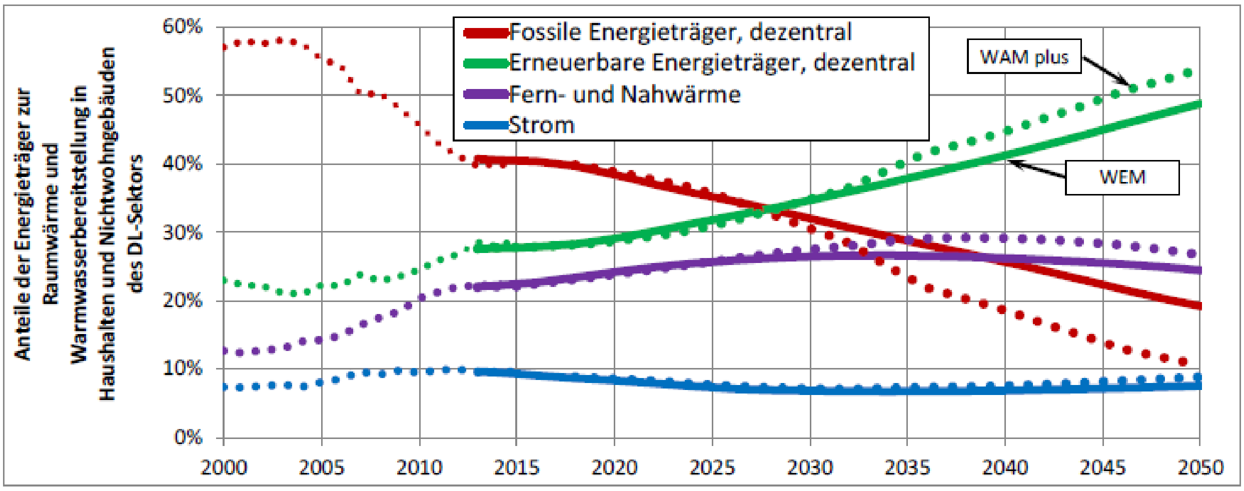


Figure 17: Development of the heat supply share in scenarios WEM and WAM plus [50]

The future perspectives for heat pumps are as well positive according to the Austrian Technology roadmap for heat pumps [51]. Table 4 presents a future market scenario based on the annual sales and heat pump units in operation for the year 2030. A low, average and high scenario has been developed for different heat pump types and capacities. Considering the medium scenario as a reference, the installed heat pump stock for space heating in 2015 is expected in overall to be doubled by 2030 and the stock of heat pumps in operation is forecasted to be about three times higher.

Table 4: Scenario 2030 for various heat pump types and capacities [51]

	HZ-WP bis 20 kW	HZ-WP größer 20 kW bis 50 kW	HZ-WP größer 50 kW	Wohnraum-lüftungs WP	Industrie WP	Brauchwasser WP	Summen
	jährlich neu installierte Wärmepumpen in Stück (Verkaufszahlen)						
Status quo 2015	16.070	1.201	180	49	18	5.482	23.000
2030 Nieder Szenario	8.193	960	331	130	26	6.460	16.099
2030 Mittel Szenario	31.030	2.020	1.176	1.393	277	11.895	47.791
2030 Hoch Szenario	56.403	3.288	2.365	2.814	512	46.992	112.374
	in Betrieb befindliche Wärmepumpen in Stück (Bestandszahlen)						
Status quo 2015	143.118	13.511	1.453	4.685	102	78.700	241.569
2030 Nieder Szenario	242.302	19.200	4.500	2.600	485	113.987	383.074
2030 Mittel Szenario	418.078	28.841	9.076	7.368	1.658	151.549	616.571
2030 Hoch Szenario	572.504	36.940	14.555	12.333	2.570	335.193	974.095

The accumulated installed and operative heat pump stock only for space heating purposes until the year 2030 is represented in Figure 18: Development of the aggregated installed and operating heat pump stock until 2030 for low, average and high scenario .

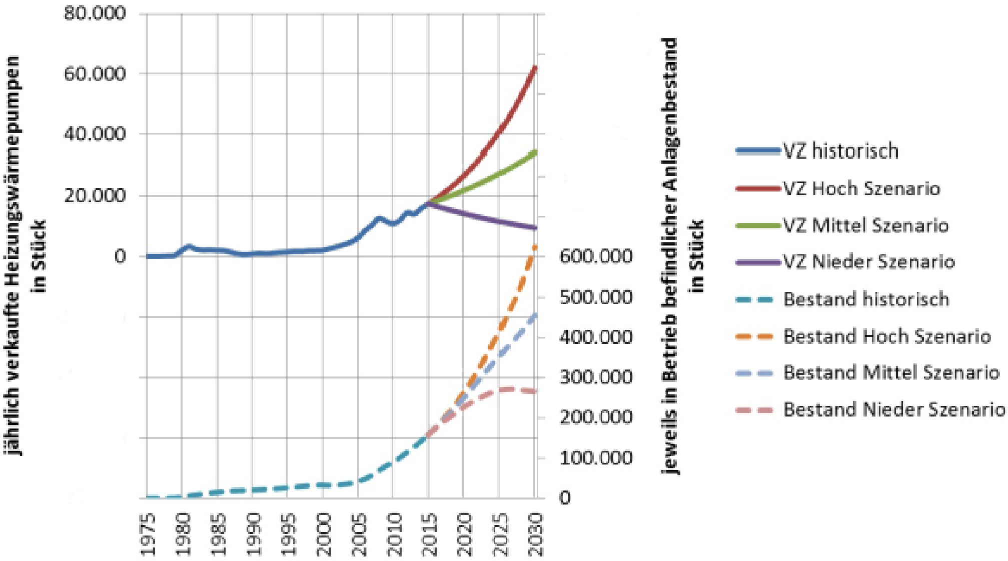


Figure 18: Development of the aggregated installed and operating heat pump stock until 2030 for low, average and high scenario [51]

The future development of the heat pump stock depends among other factors on the refurbishment rates achieved, as well as future fuel prices. According to an average scenario represented by the dashed lines in Figure 19, the price for wood chips and natural gas is expected to increase in around 22%, while electricity prices will rise up to 47%.

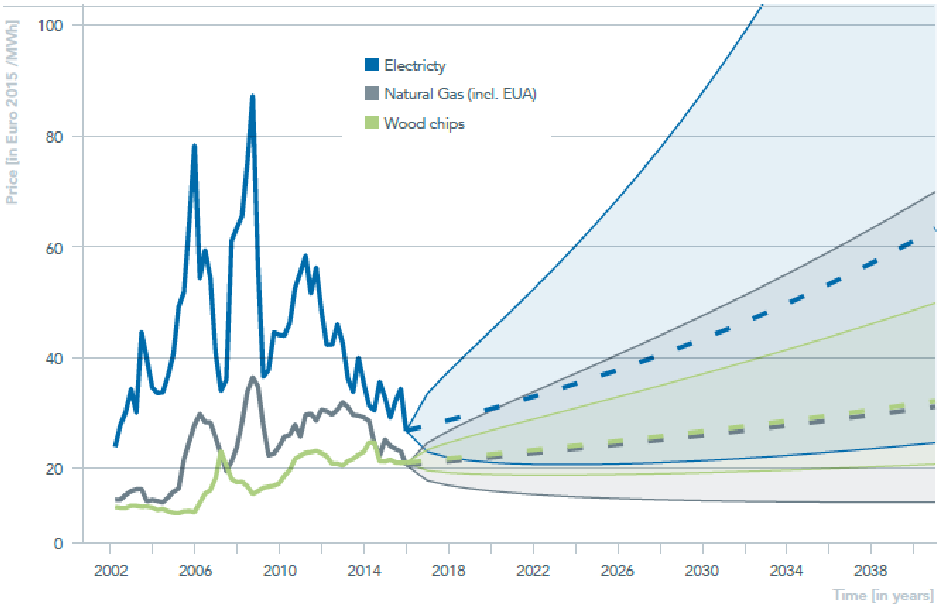
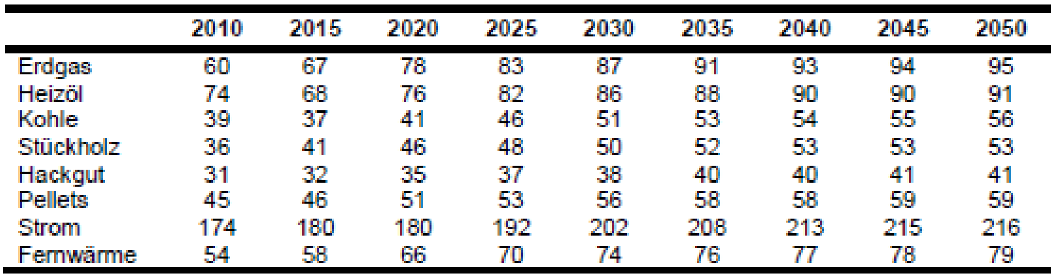


Figure 19: Development of energy prices for electricity, gas and wood chips up to 2040 [52]

More specifically, future trends of energy prices for households is shown in Table 5. Natural gas and oil prices will increase from 67€/MWh and 68€/MWh in 2015 to 95€/MWh and 91€/MWh respectively by 2050. Electricity prices are expected to increase 20% by 2050, while district heating prices will rise by 36% in 2050.

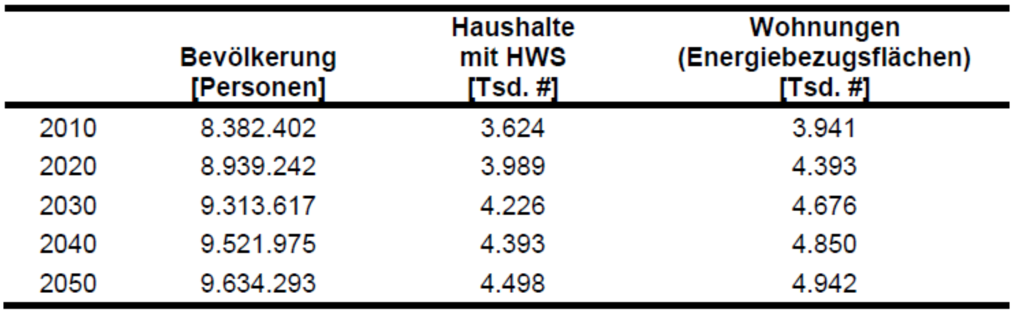
Table 5: Development of end energy prices (including taxes and fees) in €/MWh. Consumption independent running costs are included [50]



	2010	2015	2020	2025	2030	2035	2040	2045	2050
Erdgas	60	67	78	83	87	91	93	94	95
Heizöl	74	68	76	82	86	88	90	90	91
Kohle	39	37	41	46	51	53	54	55	56
Stückholz	36	41	46	48	50	52	53	53	53
Hackgut	31	32	35	37	38	40	40	41	41
Pellets	45	46	51	53	56	58	58	59	59
Strom	174	180	180	192	202	208	213	215	216
Fernwärme	54	58	66	70	74	76	77	78	79

According to Table 6 , the building stock will increase around 24% between the years 2010 and 2050, since the population is assumed to reach 9.6 million inhabitants by 2050 in Austria.

Table 6: Development of population, number of households and apartments in the period 2010-2050 [50]



	Bevölkerung [Personen]	Haushalte mit HWS [Tsd. #]	Wohnungen (Energiebezugsflächen) [Tsd. #]
2010	8.382.402	3.624	3.941
2020	8.939.242	3.989	4.393
2030	9.313.617	4.226	4.676
2040	9.521.975	4.393	4.850
2050	9.634.293	4.498	4.942

The expansion of the building stock will result in an increase of the total heated gross area from 490 million m^2 in 2015 to 555 million m^2 in 2030 and 595 million m^2 in 2050 (Figure 20).

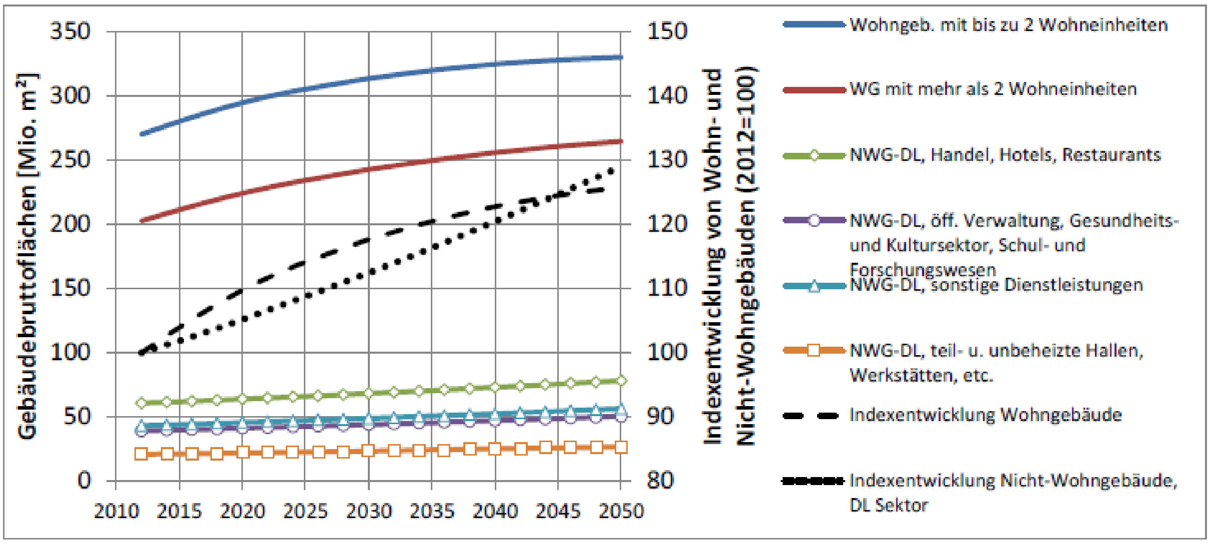


Figure 20: Development of total heated gross area [50]

The development of the heated area shown in Figure 20 is strongly influenced by the number of households required due to population growth. However, the development of the area cannot be exclusively attributed to external factors and refurbishment activities should also be considered. The built, refurbished and demolished area for different periods is represented in Figure 21. Assuming a conditioned area of approximately 630 km² in 2014, it is expected to increase up to 780 km² by 2050. In the considered scenario, 94 km² (15%) of the existing area (construction period previous to 2012) will be demolished in regions with decreasing population numbers. The newly built area in the period 2015 to 2050 amounts to 286 km². Approximately 213 km² of existing areas (construction period previous to 2012) will be thermally renovated in the period up to 2050, while 328 km² (60%) will not go through this process.

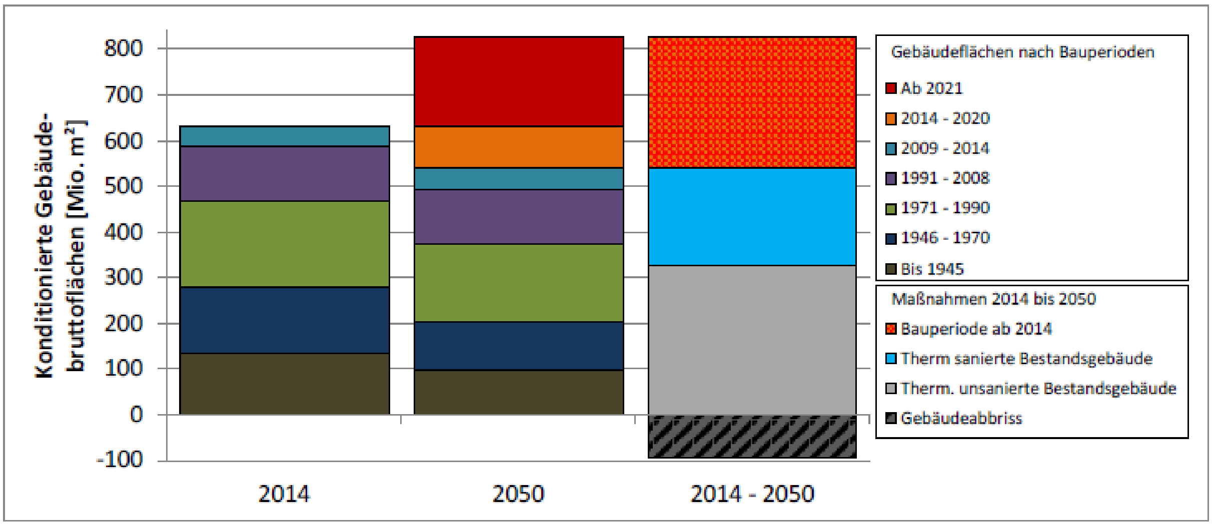


Figure 21: Conditioned gross area for 2014 and 2050 considering construction periods, refurbished buildings and demolished buildings [50]

Figure 22 shows the development of the refurbishment rates for the building stock in different periods. According to the forecast, it will gradually decrease from 1.3% in period 2015-2020 to 0.9% in 2046-2050 in the residential sector.

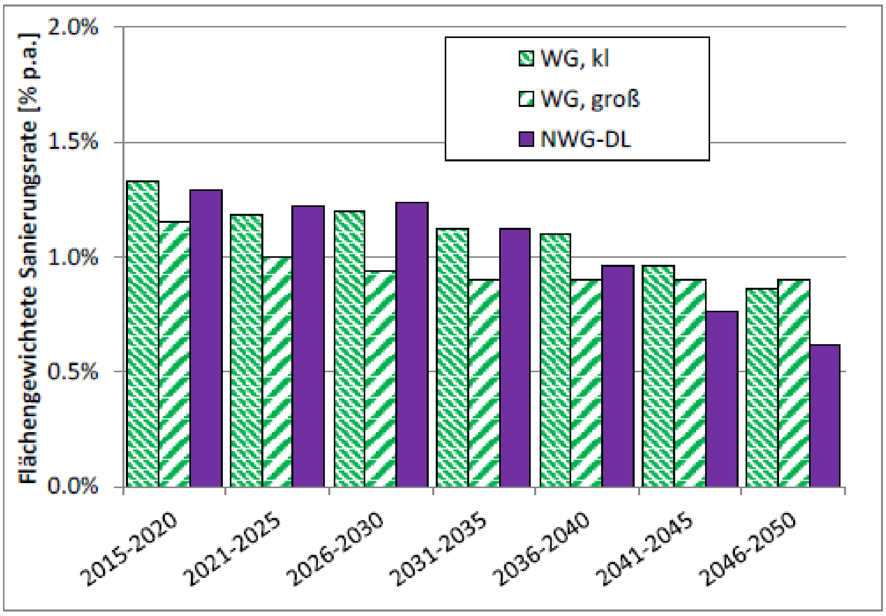


Figure 22: Development of refurbishment rates (WG,kl: small apartments; WG,groß: large apartments; NWG-DL: not residential building) [50]

The development of energy consumption by energy source is illustrated in Figure 23. In overall, the total energy input will decrease in the period 2015-2050, due to energy efficiency and refurbishment measures for instance. The generation from fossil fuels, electricity and wood as well as district heating networks will decrease, while the generation from pellets, wood chips, solar thermal energy and ambient heat will increase in absolute terms. The strongest reduction is noticed in oil.

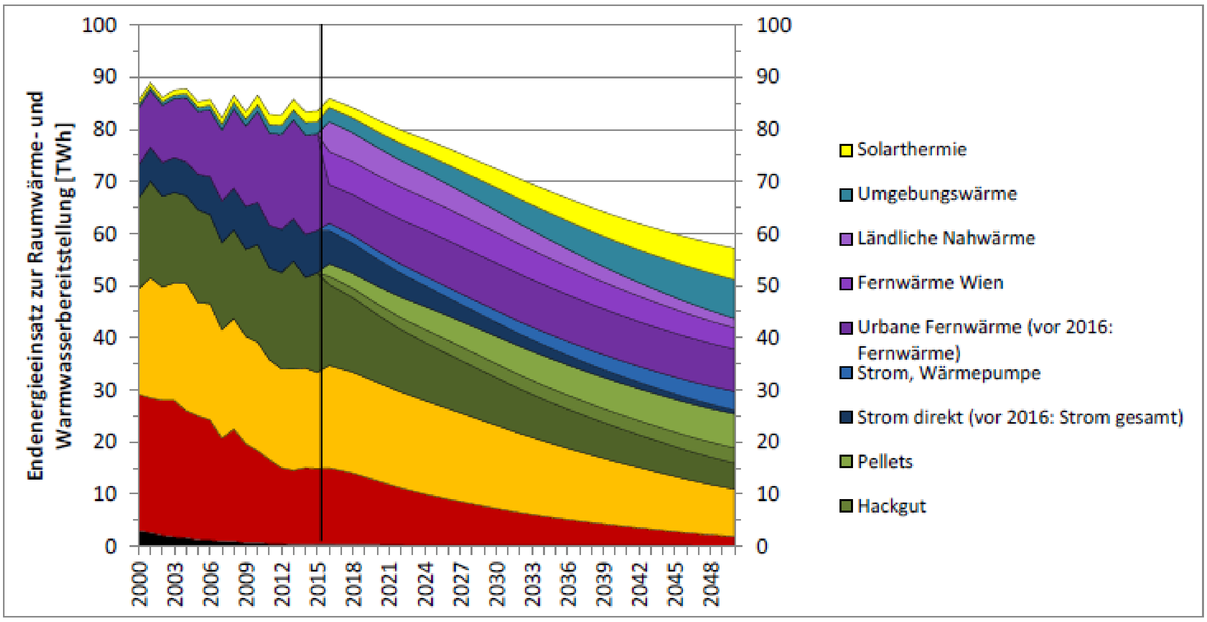


Figure 23: Energy input for space heating and domestic hot water preparation according to energy sources [50]

The change in absolute energy quantities and relative energy shares for different decades is shown in Figure 24. Oil heating declines sharply in all four decades. The energy share in the heating sector will be reduced from about 22% in 2012 to 5% in 2050. The absolute natural gas usage will remain constant until 2020, while the relative will barely vary until 2030. In absolute terms, natural gas consumption is reduced in around 50% by 2050 compared to 2012, with the relative share falling by a quarter. District heating remains approximately constant until 2030, decreasing around a quarter in the period afterwards. Solar thermal and ambient heat energy rise above all sources in the period after 2030 and together they provide about 23% of the final energy input in 2050. The use of biomass and electricity for heat production is reduced in absolute amounts of energy but both energy sources maintain their relative shares.

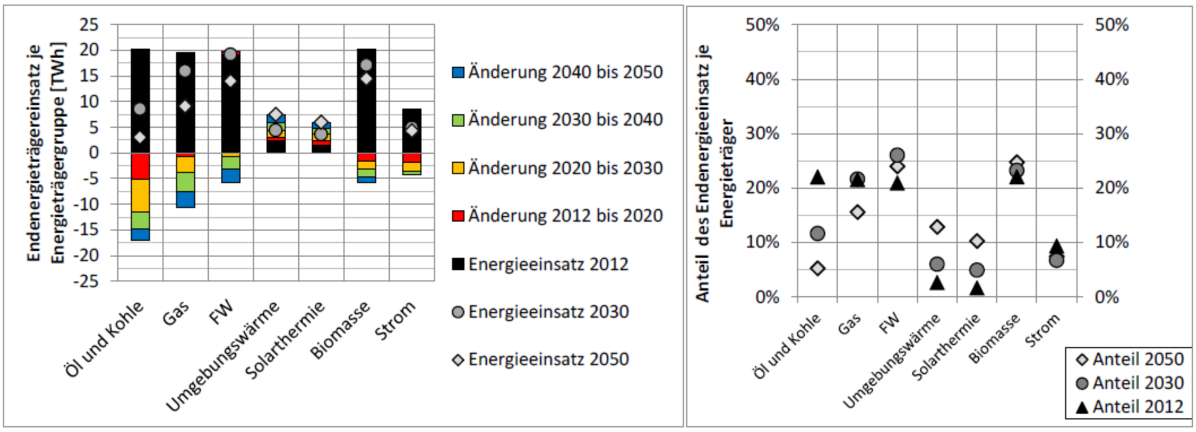


Figure 24: development of the end energy share by energy sources for future decades [50]

The share of the energy sources varies when the heated area is considered (Figure 25). The total area supplied by district heating will be slightly reduced after 2040. On the contrary, the areas supplied by biomass are expected to increase in about 50% by 2050 and from 19% to 26% when it comes to the relative share. The usage of heating systems such as conventional radiators or infrared heaters will drop from 8% to around 2%. The largest growth is expected for the heat pumps (from around 5 % share in 2012 to almost 30% share by 2050). The total current available space (50 million m^2) is predicted to exceed 200 million m^2. In overall, about 25% of the building area will be heated by district heating, biomass or heat pumps, which is a promising scenario for the heat pump pooling concepts investigated within the framework of the project fit4power2heat. Natural gas will supply less than 20% of the area and the shares of oil and conventional heating systems will sink to 5% each.

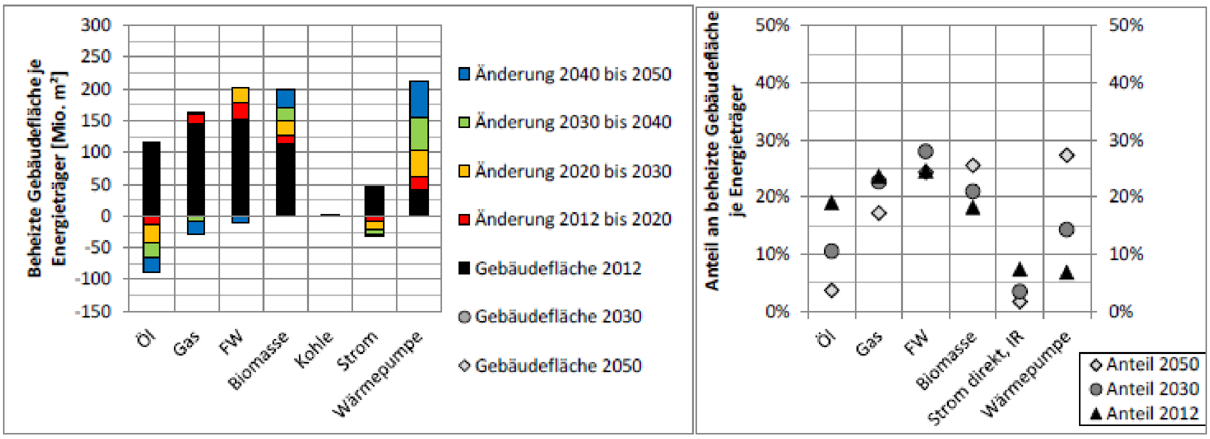


Figure 25: Development of the heated gross area by energy sources for future decades [50]

5 References

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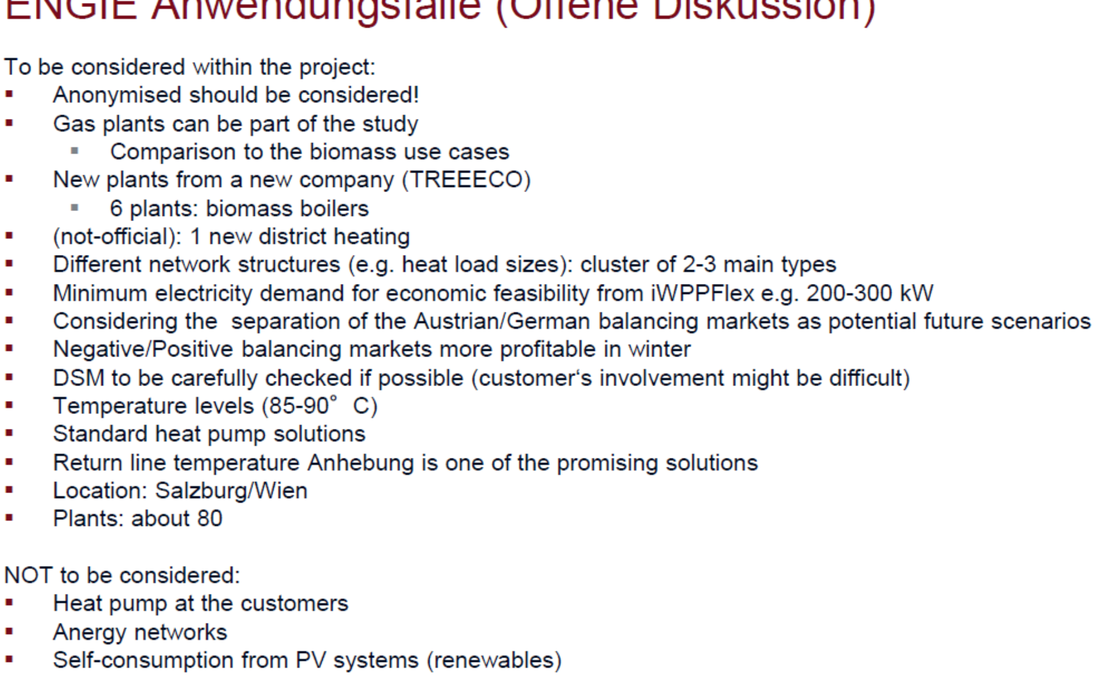

ENGIE Anwendungsfälle (Offene Diskussion)

To be considered within the project:
- Anonymised should be considered!
- Gas plants can be part of the study
  - Comparison to the biomass use cases
- New plants from a new company (TREEECO)
  - 6 plants: biomass boilers
- (not-official): 1 new district heating
- Different network structures (e.g. heat load sizes): cluster of 2-3 main types
- Minimum electricity demand for economic feasibility from iWPPFlex e.g. 200-300 kW
- Considering the separation of the Austrian/German balancing markets as potential future scenarios
- Negative/Positive balancing markets more profitable in winter
- DSM to be carefully checked if possible (customer's involvement might be difficult)
- Temperature levels (85-90° C)
- Standard heat pump solutions
- Return line temperature Anhebung is one of the promising solutions
- Location: Salzburg/Wien
- Plants: about 80

NOT to be considered:
- Heat pump at the customers
- Anergy networks
- Self-consumption from PV systems (renewables)

III/2

line].

ergi

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