The Consumer Costs of Decarbonised Heat in Austria

Executive summary

for

Umweltinitiative MUTTER ERDE

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Key Messages

Low carbon heating

- This study analyses the cost to consumers of low carbon heating options in the year 2040 in Austria. We have investigated several archetypal homes and present detailed results for four of these archetypes, typical older (pre-1970) single-family homes and more modern (post-1970) flats in multi-family homes both in valley and mountain climates.
- We have examined five low carbon heating options within these archetypes: air-source heat pumps (referred to simply as "heat pumps" in this report), hybrid heat pumps, green hydrogen boilers, biomass boilers, and low carbon district heat networks. Ground-source heat pumps were not investigated specifically.
- 2040 electricity costs are predicted using the Element Energy Integrated System Dispatch Model (ISDM), which predicts electricity system operation on an hourly basis, and utilises all available sources of power system flexibility in an integrated manner to determine the optimised operation of the power system when high levels of variable renewables are connected. We assume the Austrian electricity grid has significantly decarbonised by 2040 in line with net zero targets.
- Green hydrogen costs are estimated using Element Energy's green hydrogen costing tool. This includes Austria-specific renewable generation profiles and projections for the 2040 cost of hydrogen production technologies, as well as estimated costs for the distribution of hydrogen through the converted gas network.
- Retail electricity costs are predicted to be about 205-215 €/MWh, while retail green hydrogen costs estimated to be between 130-170 €/MWh, depending on how hydrogen production interacts with the wider energy system.
- Biomass boilers, district heating and heat pumps provide the most cost-effective route to decarbonisation of home heating in Austria in valley climate across the dwelling archetypes analysed.
- Hybrid heat pumps provide a cheaper decarbonisation route than air-source heat pumps in mountain climate in Austria. Biomass boilers and district heating system costs are still lower than hybrid heat pumps in mountain climates.
- The older single-family home using a heat pump is predicted to pay around €2.200/y for heating in valley climate and €3.800/y in mountain climate. With a hydrogen boiler, the same dwelling would see costs close to €3.300/y and €5.500/y respectively. The more modern flat is predicted to pay €1.300/y in valley climate and €1.800/y in mountain climate for heating with a heat pump, rising to €1.700/y and €2.600/y respectively if heated with hydrogen. This includes the annualised cost of the heating system as well as maintenance and fuel.
- Hybrid heat pumps can provide a similar cost of heating as heat pumps in homes in mountain climates. In valley climate, we find the cost of heating from hybrid heat pumps is about 10-20% higher than for heat pumps alone. We therefore anticipate there is a role for hybrid heat pumps in older and larger Austrian dwellings connected to the gas network in mountain climate, provided that the technical challenges of retrofitting the gas grid to deliver hydrogen are overcome. There is also a risk that hydrogen used by hybrid heat pumps could be more expensive than estimated here if the majority of households adopt fully electric systems and the gas network is maintained although used by relatively few households.
- Although heat pumps have a larger up-front cost than hydrogen boilers, we expect that the running costs of these will be significantly lower than other options for

decarbonising heating, except biomass. The actual cost of biomass is nevertheless difficult to estimate as it is expected to increase the more biomass consumers there are. This is because cheaper feedstocks get used first. This means there may need to be some policy support in place (such as direct grants, affordable green loans and green mortgages) so that consumers are enabled and incentivised to purchase these high capex appliances.

- The results shown are consistent with the other two archetypes investigated (post-1970 single family homes and pre-1970 multi-family homes). The archetypes are representative of typical Austrian homes but do not capture the full diversity of the Austrian housing stock of around 4.5 million dwellings. Some segments of the housing stock may be unsuitable for heat pumps due to high heat loss and barriers to the installation of additional energy efficiency measures.

Energy efficiency

- Installing energy efficiency can provide cost savings to consumers in some cases, and comes with additional benefits for health, thermal comfort and system flexibility.
- In some cases, energy efficiency retrofits will not pay back in energy bill savings alone. However, increasing the rate of energy efficiency rollout above current targets can reduce the total energy system costs (including the cost of energy efficiency) if combined with flexible operation of the electricity system.
- Policies may therefore be needed to enable and incentivise consumers to improve the fabric efficiency of their homes to realise the benefits to the wider energy system.
- Where deeper energy efficiency improvements are less cost-effective, installing domestic-scale thermal storage to enable flexible operation of heating enables a reduction in total electricity system costs.
- Consumer incentives through the market (e.g. ability to purchase lower cost electricity or rebates for providing flexibility) or policy supports (e.g. assistance covering the upfront cost of thermal storage) are likely to be needed to incentivise consumers to provide this service to the energy system.

Smart and flexible heating

- Austrian households using heat pumps have several routes to providing flexibility services to the electricity grid. Buildings that undergo deep retrofit to achieve a high level of building fabric efficiency can operate their heat pumps intermittently without impacting comfort. Alternatively, households may use a heat battery or a hybrid heat pump to enable flexible heat pump operation.
- Operating the energy system flexibly lowers the total energy system cost by 1% in a high heat pump scenario, an annual savings of €0,5 billion. This requires investments in energy efficiency improvements in buildings to enable flexible operation of heating. Some investments which will not pay back if the building is considered in isolation may in fact be cost-effective if impact on the wider energy system is considered.
- Smart and responsive heating can reduce the annual consumer cost of heating, saving consumers up to 14% for multi-occupancy buildings, and up 18% in single family homes.

District heat networks

- Low carbon district heat networks can provide domestic heat at comparable cost to building level heating systems and offer a high level of demand flexibility. In many cases heat networks will be simpler to decarbonise due to the relative ease of replacing centralised heating plant compared with disruption in hundreds or thousands of homes. Maintaining existing district heating networks and decarbonising them comes with significant consumer and carbon benefits if suitable consumer protections are in place.

Contents

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Acronyms

AT Austria

ATM Austria mountain climate

ATV Austria valley climate

DH District heat

DSR Demand side response

HP Heat pump – all heat pumps referred to in this report are air-source unless specified

HHP Hybrid heat pump – all heat pumps referred to in this report are air-source unless specified

kWh kilo Watt hours

ISDM Element Energy's Integrated system dispatch model

MFH Multi-family home

MWh Mega Watt hours

SFH Single family home

1 Introduction

1.1 Context and objectives

Heat is recognised as one of the hardest sectors to decarbonise. Currently most consumers use fossil fuels to provide their heat, but to meet emissions targets they will have to swap to a cleaner technology. One possible solution is to electrify heating via heat pumps, however since the seasonality of heating is far greater than of electricity demand this may create a large winter peak in electricity demand causing issues for generators and the distribution network. Another possible option is to decarbonise the gas grid by injecting hydrogen rather than natural gas into it, this might reduce the impact of electrification on the electricity system, but creates challenges in producing zero carbon hydrogen, and converting the distribution network. Since there is significant uncertainty around the costs and risks of these two methods of decarbonising heat, this study aims to understand the impacts of different future scenarios and particularly focuses on the possible impacts on consumers.

In addition to the technologies used to heat dwellings in the future, the installation of energy efficiency upgrades is considered. Currently, Austria has an ambitious target for energy efficiency installation, this study aims to show both the benefits to the energy system of energy efficiency whilst also understanding the potential financial risks to consumers of these installations. We also consider the possible benefits of going beyond current energy efficiency installation targets for consumers.

This study considers the energy system in 2040, this is because it is sufficiently far in the future that significant steps towards the decarbonisation of heating will have been taken by then, we model that 100% of homes are using decarbonised heating by this date, but near enough to the present that accurate projections of the electricity generation mix can be found. The choice of this year will allow us to analyse with greater certainty the cost of different scenarios than we would be able to if choosing a year further into the future.

This study determines what the overall cost of heating will be to end users In Europe, under different heating delivery scenarios (primarily electric heat pumps, green hydrogen boilers and hybrid options, and including both individual building and district heating approaches). All costs are determined, including purchase, installation, and maintenance, and the fuel cost, which covers the commodity itself (gas or electricity) and the cost of the infrastructure required to deliver it to homes and to run a safe and secure energy system. The key aims of the study are to:

- Assess the costs of decarbonised heating options from a consumer perspective.
- Analyse the cost and benefit from building fabric energy efficiency measures to individual consumers and the energy system.
- Determine the impact of smart and responsive heating on the energy system and the financial benefits to heat consumers who provide flexibility to the energy system.
- Compare the costs of decarbonised district heating systems with individual dwelling level approaches.

A previous study for BEUC has produced reports on four European Member states (ES, IT, AUSTRIA, PL), as well as one overall report providing insights into EU-wide consumer impacts. This report summarises the key findings and conclusions about decarbonised heating in Austria, and makes recommendations around policies that should be implemented to protect consumers.

1.2 Technology scenarios

For this work, three technology deployment scenarios for 2040 were created. These three scenarios were focused on the deployment of a single technology as the main low carbon heating option, these were air source heat pumps (ASHP), hybrid heat pumps (ASHP + hydrogen boiler), and hydrogen boilers. The technology mix for each scenario in Austria is shown in Figure 1. These scenarios are used to analyse the likely cost of different technology options in Austria under different possible futures and are not intended to be projections or predictions of the likely future technology mix.

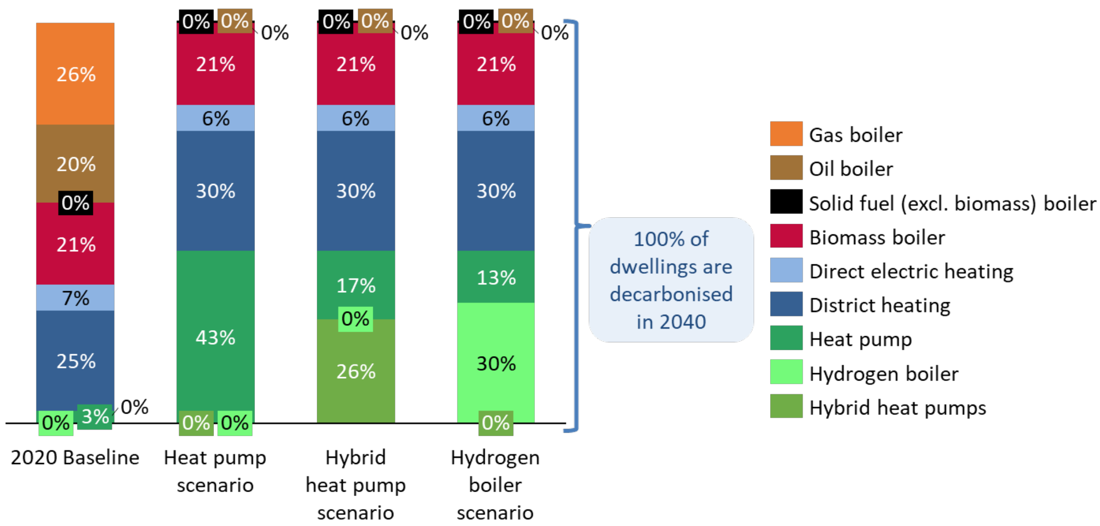

Figure 1 - Fraction of dwellings with each technology in 2040 in each scenario.

In these scenarios the hydrogen boiler and hybrid scenarios are based on the gas network transitioning to hydrogen. This is likely to be a phased process. In these scenarios hydrogen for heating is modelled as “green” hydrogen produced from electricity via electrolysis.

Each of the three technology deployment scenarios are analysed in two ways:

1. The **Baseline-Passive** scenario includes fabric energy efficiency deployment at a rate of 2% of buildings per year, and energy demands such as heating continuing to operate in a passive way.
2. In the **Efficient-Smart** or **Flexible** scenario a higher rate of fabric energy efficiency rollout of 2,25% of buildings per year is assumed, and heating systems behave in a flexible way, responding to the needs of the energy system as a whole.

In addition, in the Baseline-Passive scenario it is assumed that hydrogen is produced by grid-connected electrolysers, whereas in the Smart-Efficient scenario hydrogen is produced by dedicated renewables collocated with electrolysers and grid curtailment to produce cheaper hydrogen with less impact on the overall energy system.

1.3 Case study buildings

The housing stock in Austria is made up of a large range of different buildings. To present results in this report the key building level results for consumers are presented for four typical buildings. These typical buildings are a single-family home (SFH) built before 1970 and a multi-family home (apartment, MFH) built after 1970 in valley and mountain climates. These buildings are chosen to illustrate the trends that consumers are expected to see, however since all buildings are different there will be some variation from the trends presented for individual buildings. Table 1 shows the characteristics of the selected dwellings.

Table 1 Details of the four key archetypes that results are presented for in this report

Feature	Archetype 1	Archetype 2	Archetype 3	Archetype 4
Type	SFH	MFH	SFH	MFH
Age	Pre-1970	Post-1970	Pre-1970	Post-1970
Assumed climate	Vienna (valley)	Vienna (valley)	Innsbruck (mountain)	Innsbruck (mountain)
Floor area (m^2)	111	76	111	76
Annual heating demand (kWh)	13.355	5.136	23.520	9.045
Annual hot water demand (kWh)	2.634	1.798	2.634	1.798

1.4 Method

An overview of the method is shown in Figure 2 below. The key steps in the modelling are:

1. The archetype stock model calculates the heat demand and final energy consumption on an annual and hourly basis for domestic dwellings in Austria. The outputs are generated at the building level and at the country-level (i.e. including all buildings). Non-domestic buildings are included in the national demand although they are addressed with less detail than the residential stock.

2. Each residential building archetype undergoes a flexibility assessment to determine whether and how much its heating demand can be shifted to accommodate the needs of the wider electricity system.

3. The energy demands and flexibility potential of the heating system is used by the ISDM in modelling the hourly behaviour of Austria's energy system throughout 2040. The ISDM predicts the retail costs of electricity and green hydrogen. A more detailed description of the ISDM model is given below.

4. The upfront and ongoing costs of heating are calculated by the consumer cost model for the selected Austrian building archetypes.

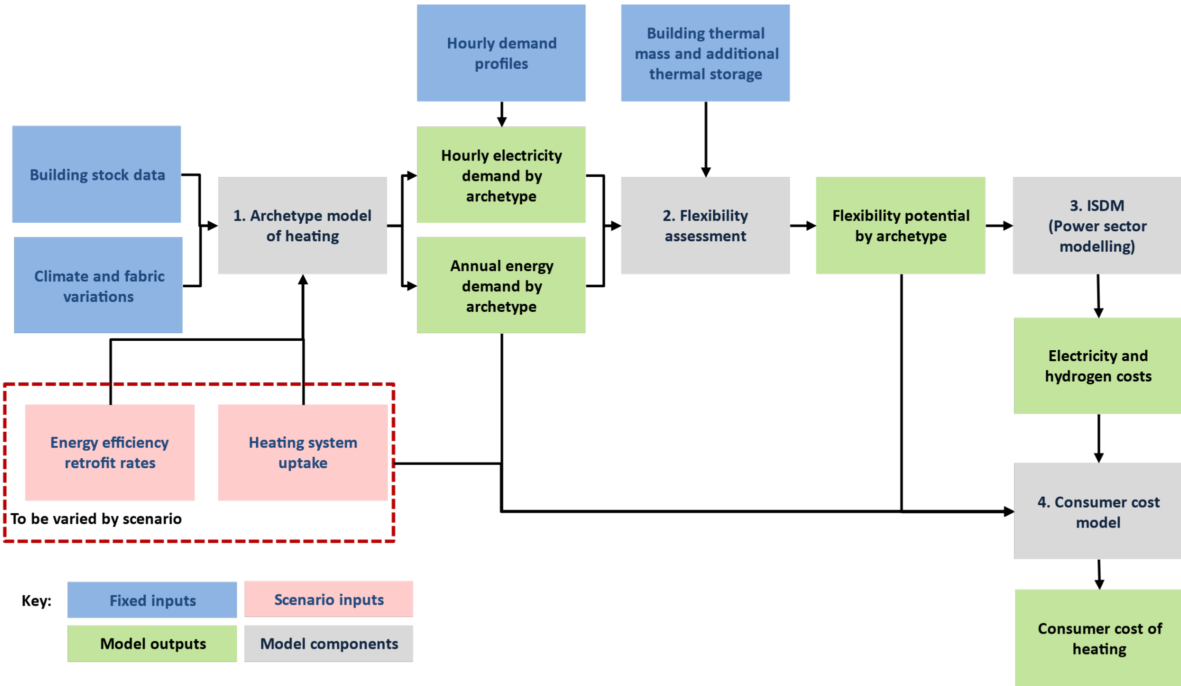

Figure 2 - Full heating system costing model flowchart.

1.5 Energy system modelling

Element Energy's Integrated Supply and Demand Model (ISDM) was developed to overcome limitations of typical power system dispatch models when applied to zero carbon systems. Many such models continue to treat the power system as it currently is: highly dispatchable and reliant on thermal sources for flexibility on the supply side. Future low carbon systems, where variable renewable energy is dominant, will require flexibility on the demand side to support the integration of high levels of renewable energy, while minimising curtailment and reliance on backup thermal plant. ISDM utilises all available sources of power system flexibility in an integrated manner to determine the optimised operation of the power system.

The main principles of whole system operation are summarised here. The starting point for the modelling is a set of hourly energy demand profiles for each sector. Some demand profiles are fixed (no flexibility), while others are able to be shifted over defined periods. For heating, these demands are based on the building heat loss, heating technology and outside air temperatures. Transport demand is based on the stock of electric vehicles, their efficiency, the daily usage, and arrival/departure times from home and work to generate baseline electrified transport demand. Grid-responsive smart charging can schedule charging to times of most use to the grid, while still providing vehicles with sufficient charge for transport. Flexibility provided by thermal storage and thermal mass of buildings allows heat demand to move demand to times most useful to the grid, without reducing thermal comfort in homes and offices.

Hourly weather data is also used to generate hourly load factors for wind and solar production. Using the assumptions on the installed VRES generation capacity, the model calculates the hourly VRES generation. By subtracting this from the demand profiles, initial net load curves are generated. Demand shifting, as enabled through smart EV charging and smart heating is deployed to minimise the peak system demand and therefore the required network capacity. Further demand shifting is then applied to reduce curtailment of renewables and fossil fuel use, by moving demand from hours of high to hours of low net demand. By reducing the peak net demand, demand shifting leads to a decreased requirement for dispatchable generation capacity.

The dispatchable generation fleet is then deployed in merit order to fill in the supply gap. Once all hourly demand is met, annual system performance metrics are evaluated, among them fuel and carbon cost, variable OPEX, VRES curtailment, peak demand (for determining the required network capacity), and peak net demand (for determining the required dispatchable generation capacity).

The electricity fuel cost modelled and used to calculate consumer cost of heating includes generation, networks, and tax individual components, as shown in Figure 25.

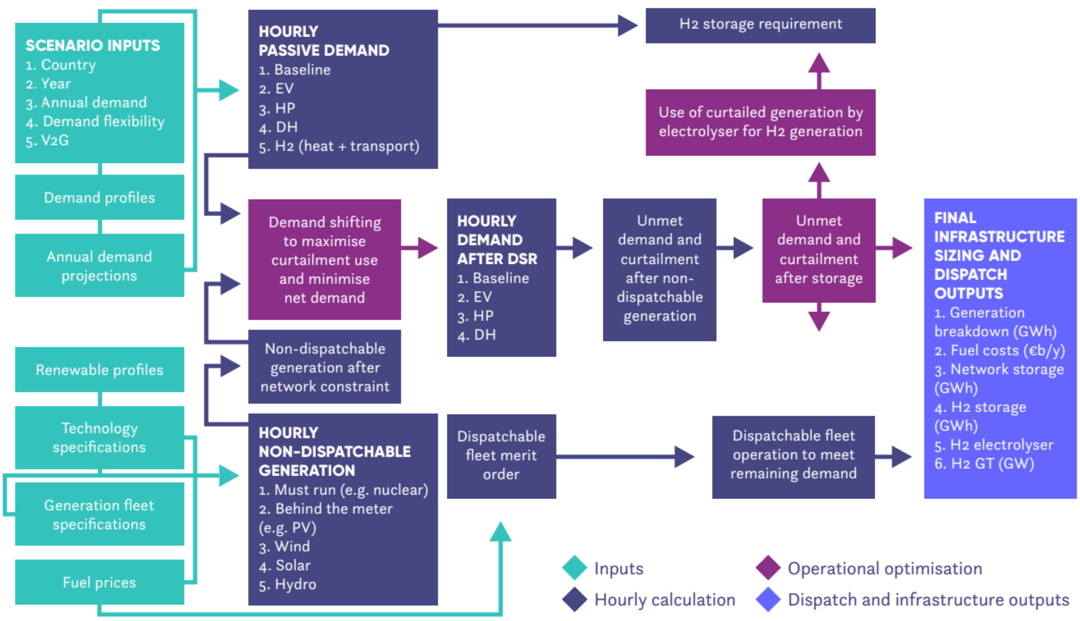

Figure 3 – Schematic of the calculation within the ISDM

1.6 Costing hydrogen for consumers

The cost of producing green hydrogen produced from electricity with electricity was modelled in this project. In the baseline case, it was assumed that the electrolysers were connected to the electricity grid, and pay a wholesale price (excluding grid fees) for their electricity. The cost of hydrogen distribution and storage was then calculated based on a parameterised model of the gas grid and costs of converting the low-pressure distribution grid to hydrogen. The costs of hydrogen production and transmission used were taken from the BEIS hydrogen supply chain evidence base[1]. In the flexible case it was assumed

1 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760479/H2_supply_chain_evidence_-_publication_version.pdf

that hydrogen production would not be connected to the electricity grid. Hydrogen production electrolysers and renewable generation were assumed to be collocated and the production of hydrogen was found on an hourly basis to optimise the relative generation and electrolyser capacities for the cheapest hydrogen cost.

Country-specific renewable generation profiles were calculated from NASA MERRA-2 data, and the cost of renewable generation was found from the BEIS 2020 cost of generation report[2]. In addition to this the curtailed electricity produced from renewable generation for the rest of the electricity system was also used to produce hydrogen in the flexible case at 0 cost for the electricity. The cost optimal production of green hydrogen through dedicated renewables was modelled spatially in Austria, using spatial load factors map. The resulting levelised hydrogen costs are shown in Figure 4. The costs of hydrogen in the Baseline and Flexible scenarios for the high hydrogen scenario are shown in Figure 5. Both wind and solar generation to produce hydrogen were considered, but in Austria onshore wind was the cheapest way to produce hydrogen and this was used for the purpose of costing production in the flexible case. To find the cost per kWh the capex of generation and electrolysers was annualised over the expected lifetime of the technologies at a discount rate of 5% in the consumer cost case and a 3% discount rate in the system cost case. Hydrogen storage was also costed, in Austria this storage was modelled as a liquid organic hydrogen carrier, with round trip efficiency and other energy use included in the costing.

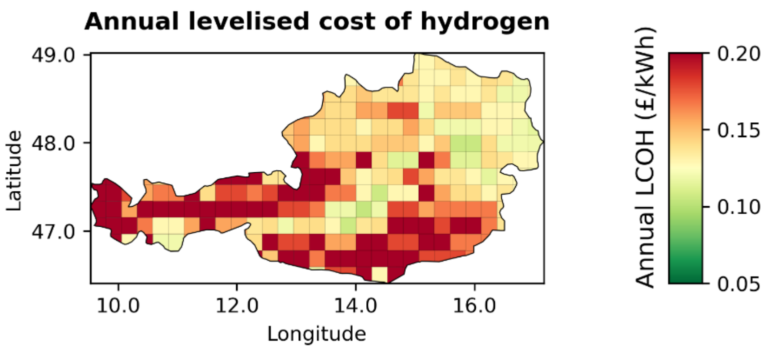

Figure 4 – Levelised cost of hydrogen production modelled across Austria using electrolysers co-located with on-shore wind

[2] https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020

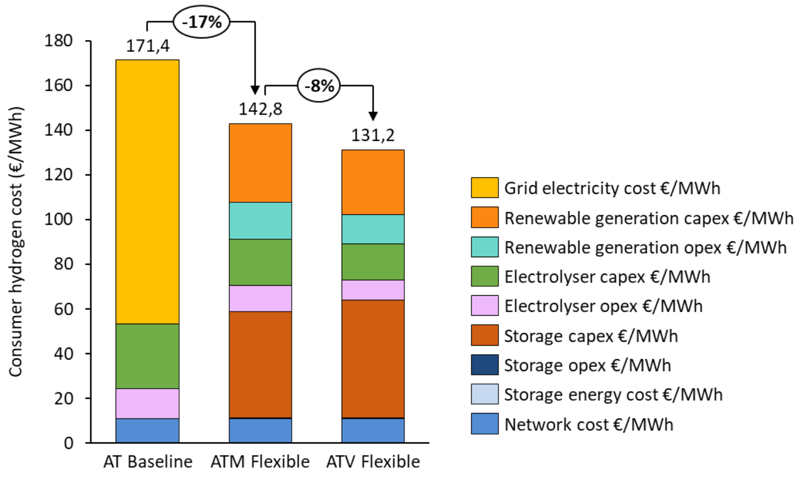

Figure 5 - Cost of hydrogen for consumers in the baseline case, which applies to both ATM and ATV, and in the flexible case for each climate region separately

2 Impact of ambitious energy efficiency deployment

2.1 Energy efficiency scenarios in Austria

In Austria, two energy efficiency rollout scenarios were analysed, one baseline scenario with rollout at the rate equivalent to existing targets and one very ambitious rollout rate combined with smart heating system operation. Energy efficiency rollout was analysed by using two packages, one shallow/medium (referred to below as the 'shallow' package) and one deep retrofit. In the 'shallow' package, the older single-family home adopts a medium level of retrofit while the modern flat adopts a shallow level. The costs and energy savings of the two packages are based on the ZEBRA2020 study of energy efficiency in buildings across Europe[3].The rollout rate of these packages in the different scenarios is shown in Figure 6. In the current study we have not modelled the energy efficiency retrofit of non-domestic buildings, even though we expect it to be similar to that of domestic stock, because we are interested in assessing the domestic consumer heating cost only. It is believed that the rollout rate to reach net 0 by 2040 in Austria should even be of 3%.

In the efficient scenario, additional retrofit is taken up when this allows the homes to become flexible, in other word that it allows them to lose less than 1 degree in 4 hours.

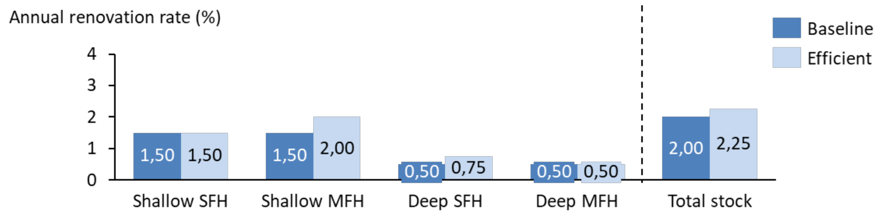

Figure 6 - Energy efficiency rollout rates in the baseline and efficient scenarios

Figure 7 shows the breakdown of the 2040 housing stock in the two energy efficiency rollout scenarios in Austria. In the efficient scenario 2% more of the stock has had an energy efficiency retrofit than in the baseline scenario. The next chart, Figure 8 shows the reduction in heating demand in typical buildings from a shallow and deep retrofit. Shallow packages reduce the heating demand by about 30% in older single-family homes and 20% in newer multi-family homes. Deep packages give savings of about 70% in the older single-family homes and 60% in newer multi-family homes.

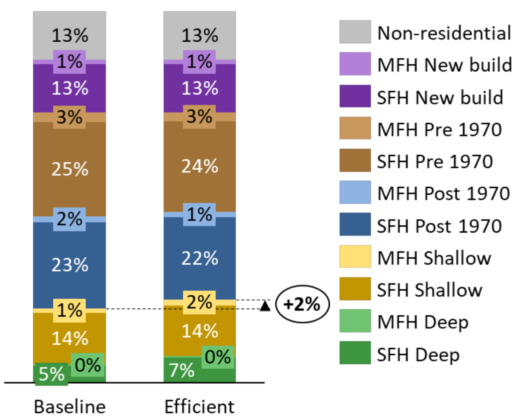

Figure 7 - 2040 housing stock in baseline and efficient scenarios.

[3] nZEB technology solutions, cost assessment and performance, ZEBRA2020: NEARLY ZERO-ENERGY BUILDING STRATEGY 2020, https://zebra2020.eu/publications/nzeb-technology-solutions-cost-assessment-and-performance/

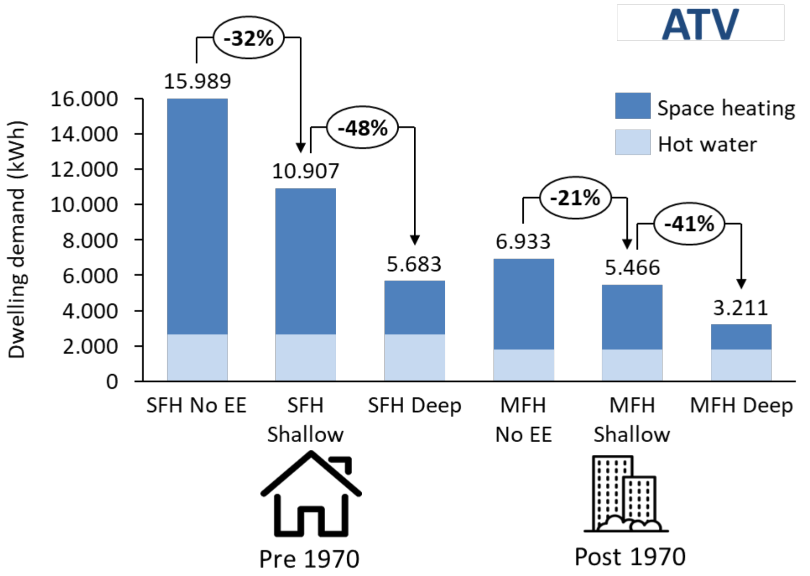

Figure 8 - Reductions in heating demand of typical buildings in valley climate.

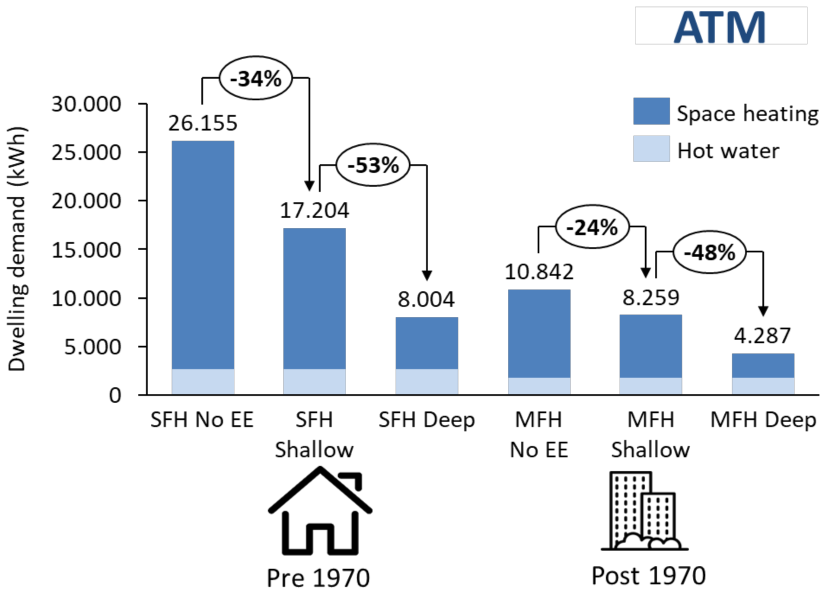

Figure 9 - Reductions in heating demand of typical buildings in mountain climate.

Figure 10 and Figure 11 show the heating demand changes between the baseline 2020 housing stock and the two 2040 scenarios. The baseline scenario has 3-4% less heating demand than 2020 and the efficient scenario has 5-6% lower heating demand than the baseline. Both of these reductions are despite the fact that 14% of the building stock in 2040 is made up of new buildings and that we have not modelled energy demand reduction in non-domestic buildings. New buildings are assumed to have heating demand similar to or lower than a building which has undergone a deep retrofit.

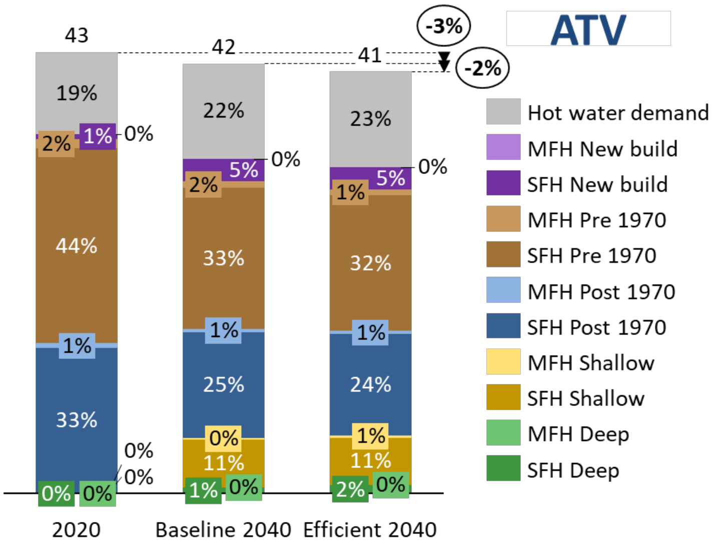

Figure 10 - Residential heating demand by scenario in valley climate, in TWh.

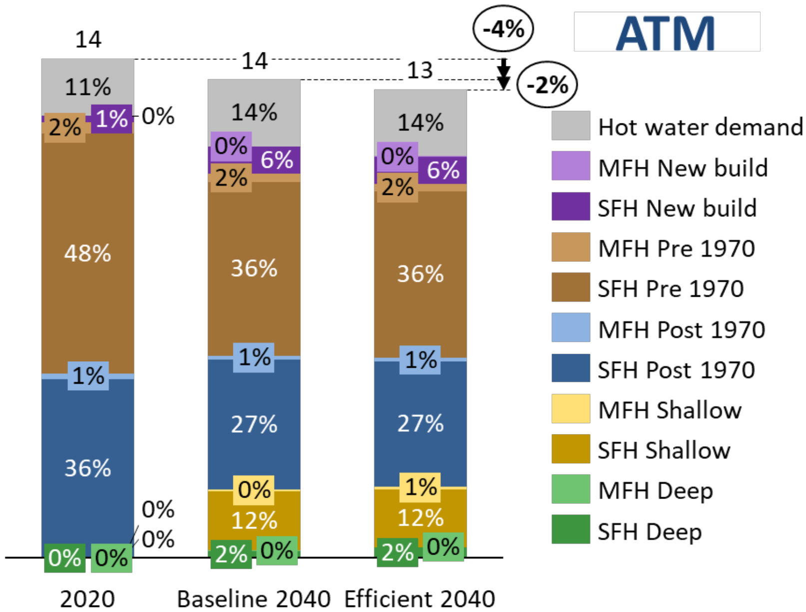

Figure 11 - Residential heating demand by scenario in mountain climate, in TWh.

Figure 12 and Figure 13 show the building level heating cost in € per year for the four key archetypes with different energy efficiency packages installed. The energy efficiency costs have been annualised based on an expected 30 years lifetime. The results presented here assume that all electricity consumers benefit from the flexibility provided by residential consumers that have taken up energy efficiency to become flexible, i.e. that all cost savings are socialised. With these assumptions, across the whole stock, the cost of retrofit is too large to allow consumers to see cost benefits through fuel savings only. Consumers who do install energy efficiency measures despite their high capital cost will see lower fuel bills.

In reality, the building stock is a lot more diverse than represented in this study, and even with the current assumption on savings being socialised across all electricity users, energy efficiency retrofit is expected to be cost-effective in poorly insulated homes with high heat demand.

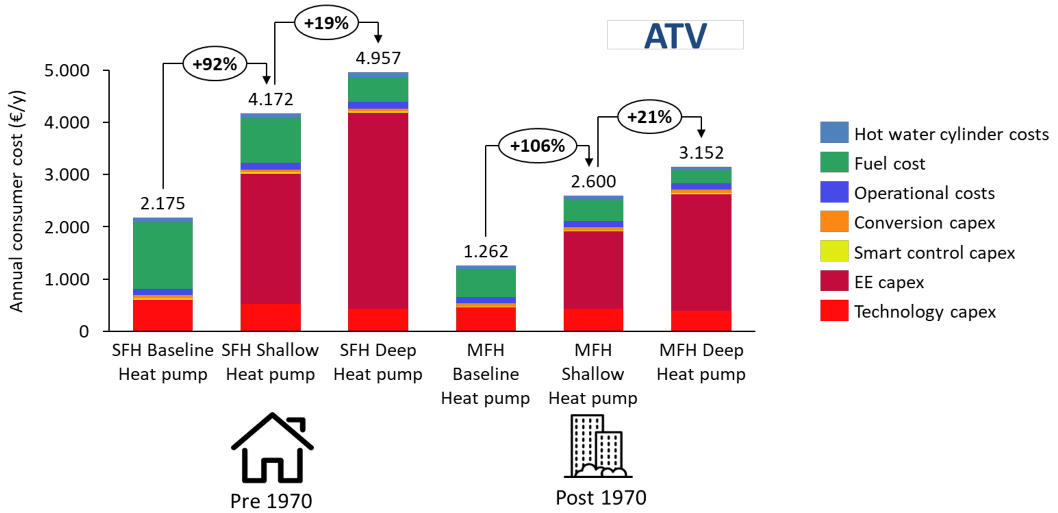

Figure 12 - Household level costs (€/y) and savings of energy efficiency in typical archetypes in valley climate.

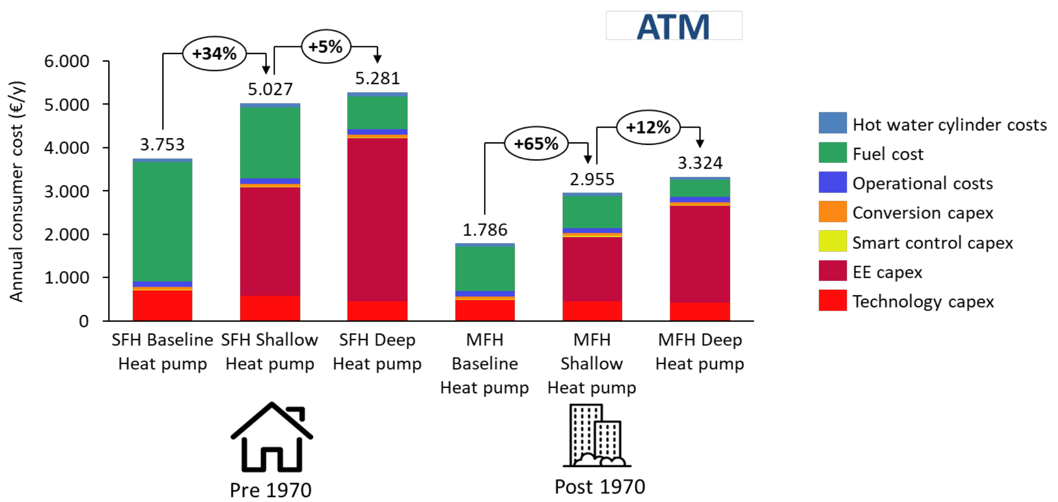

Figure 13 - Household level costs (€/y) and savings of energy efficiency in typical archetypes in mountain climate.

Although energy efficiency measures may not be cost effective at an individual building level, the installation of these efficiency measures brings about cost savings to the entire energy system. These savings depend on the type of renewable heating system deployed but are likely to be at least €0,4bn per year, the exact figures are shown in Figure 14. It is important to note that for the system to realise the full savings from energy efficiency rollout, policy support will be required to remove the significant upfront cost of energy efficiency from households such that they are incentivized to invest in reducing their dwelling's heating demand.

Energy efficiency upgrades require significant capital outlay depending on the size and age of the home and the level of retrofit. Figure 15 shows the upfront cost of energy efficiency retrofit in the typical archetypes. The total annual expenditure on energy efficiency measures would be €2,5bn in the baseline scenario, and €2,9bn in the efficient scenario.

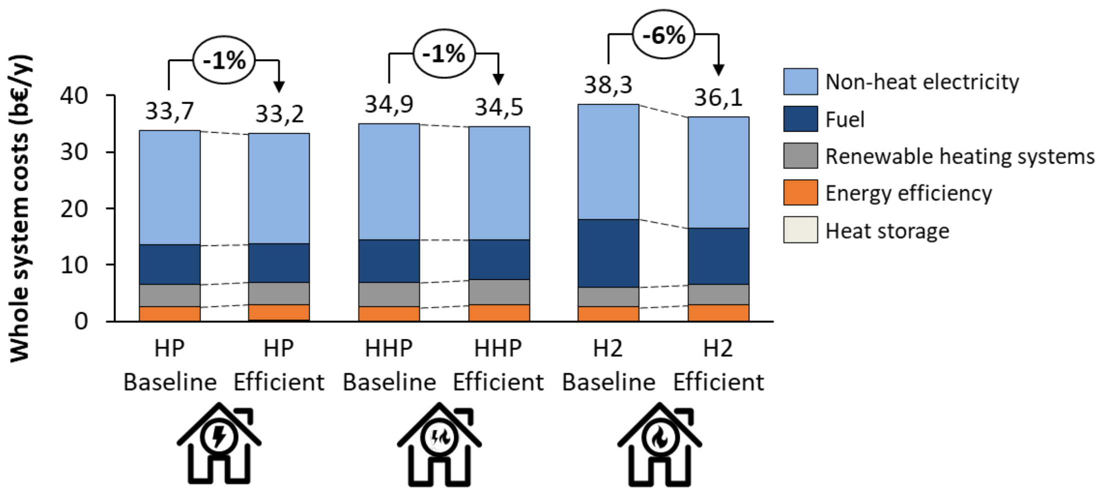

Figure 14 - The system cost saving from the efficient scenario in Austria.

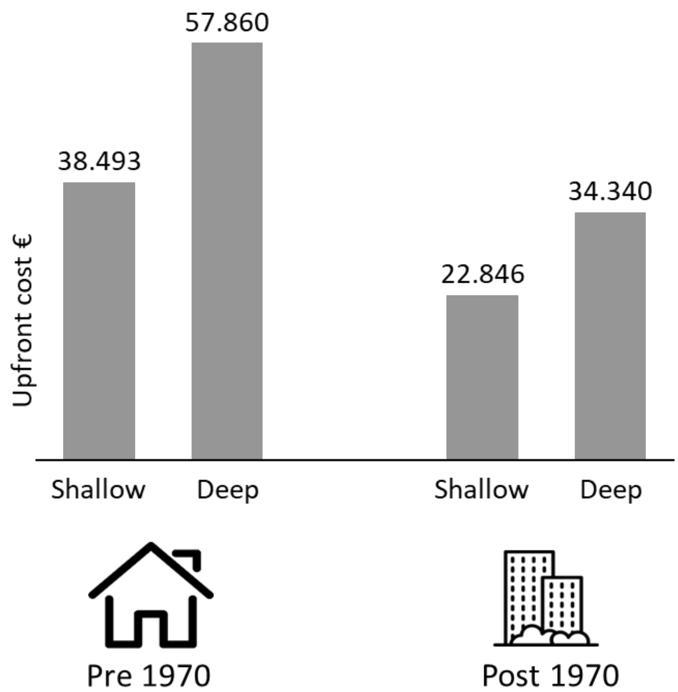

Figure 15 - Upfront cost of energy efficiency packages in Austria.

3 Consumer costs of low carbon heating options in 2040

The cost of heating systems to consumers has two parts. There is an upfront capital cost (capex) that is incurred when the heating system is replaced and there is an ongoing cost of fuel and maintenance. This section shows the total cost of heating made up of both of those components, and then looks at each component individually. All costs presented in this study exclude subsidies and taxes.

3.1 Total cost of heating for consumers

The total cost of heating for consumers is found by summing the annualised capital cost, at a 5% discount rate with a 15-year technology lifetime, with the annual operating cost. Heating systems could have a 20-year lifetime in practice, but the principle here is to use the same lifetime for annualisation for all systems capex. A 20 years lifetime would favour heat pumps and other systems with a large capex, as it would be annualised over 20 instead of 15 years. This represents the total cost for a consumer in each year of heating their dwelling with that technology. The results presented below assume that the archetypes had a counterfactual gas boiler and all costs for converting to the new heating system are reflected in the “conversion” costs. This comparison shows that heating dwellings with heat pumps, biomass boilers, and district heating is the cheapest option for consumers in key archetypes in valley climates. In mountain climates, biomass boilers and district heating are still the cheapest options, with hybrid heat pumps becoming cheaper than heat pumps because they benefit from higher heat pumps efficiency because they use their hydrogen boiler component in times of low temperature where heat pump efficiency is low. A high rollout of hydrogen boilers relative to a rollout of heat pumps could leave consumers paying between 40-50% more for their heat. Since the cheapest overall options, heat pumps and biomass boilers, come at a significant upfront cost premium compared to hydrogen boilers and counterfactual heating technologies, it is important that government provides adequate support to consumers to switch their heating through incentives and financial products that address these high upfront costs in order for consumers to achieve the possible savings.

While ground-source heat pumps were not explicitly modelled in this study, it is expected that their annualised cost of heating could be similar to that of air-source heat pumps in mountain climates. This is because they have a higher capex for the ground work, but benefit from much higher efficiency during the winter months and therefore lower fuel costs.

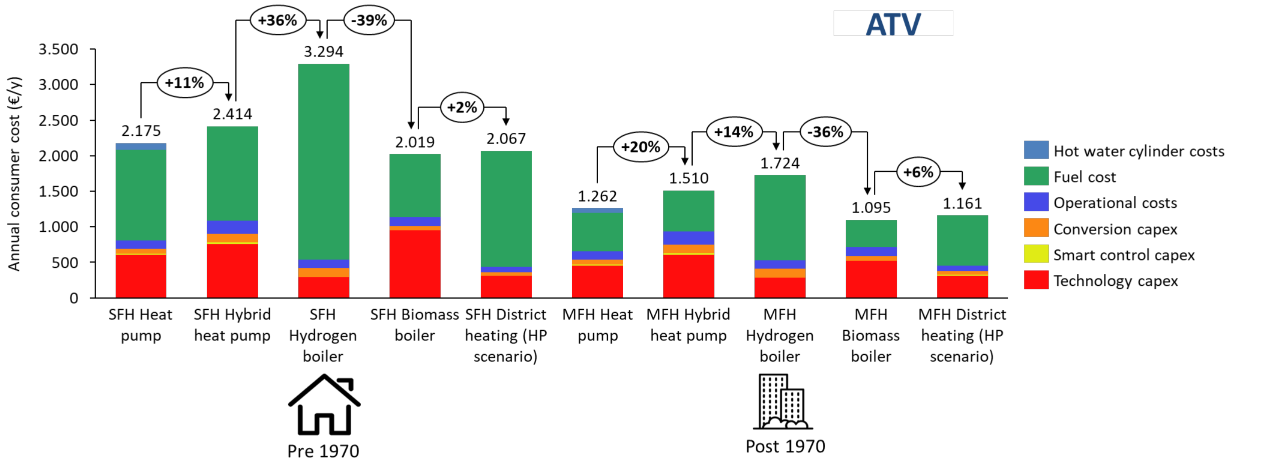

Figure 16 - Annual consumer cost of heat with the main technology in each scenario in valley climate.

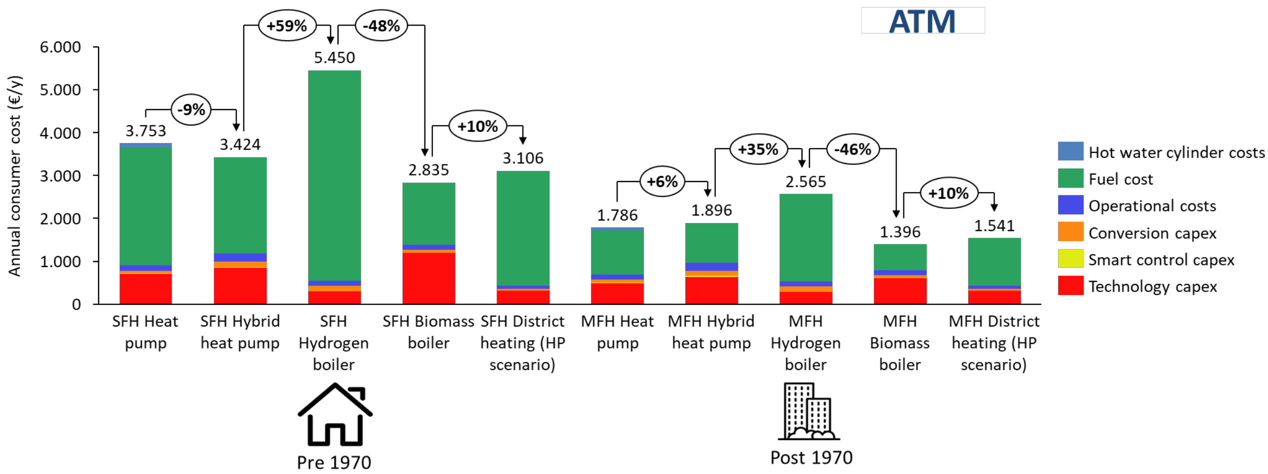

Figure 17 - Annual consumer cost of heat with the main technology in each scenario in mountain climate.

Despite biomass boilers leading to the cheapest heating costs in this study, there are several limitations to it:

1. Unlike other heating systems, the higher the number of biomass boilers, the more expensive they become. This is because their feedstocks have a range of costs and the cheaper ones will be used first, leaving additional new consumers to pay potentially significantly higher costs for their biomass fuel
2. Biomass boilers are a mature technology and do not benefit from economies of scales like innovative technologies
3. A critical aspect of biomass is its CO2 content. Biomass needs to be sourced sustainably and conform to key standards to ensure that it is a low carbon technology and not contributing to CO2 emissions like other fossil fuels
4. Using biomass boilers in residential homes is limited to having a large amount of space for storing the biomass feedstock. It makes this technology particularly unsuitable for MFH and small SFH even where biomass boilers would be economically advantageous.

5. Additionally, delivery of biomass feedstock to the homes and from the storage area to the boiler can be challenging for people living in remote locations or without the ability to move large quantities of heavy feedstock around.

3.2 Ongoing costs of heating systems

Fuel costs are found from electricity system modelling based on the uptake of heating systems and energy efficiency for that scenario. The technologies considered here have different efficiencies of producing heat from their fuel, heat pumps can operate at 280% efficiency, whereas hydrogen boilers are 85% efficient. Since hydrogen is produced from electricity via electrolysis using hydrogen boilers to produce heat typically uses 4.5x as much electricity as producing the heat with a heat pump. Due to this the operational costs of hydrogen systems can be over 2x as large as those of heat pump systems. This means although hydrogen can be cheaper than electricity per kWh the additional consumption outweighs this. Hydrogen is also likely to be more expensive than gas is today (2021 figure, before the gas crisis) for consumers. Figure 18 and Figure 19 show the annual running costs for the different heating systems in the main archetypes.

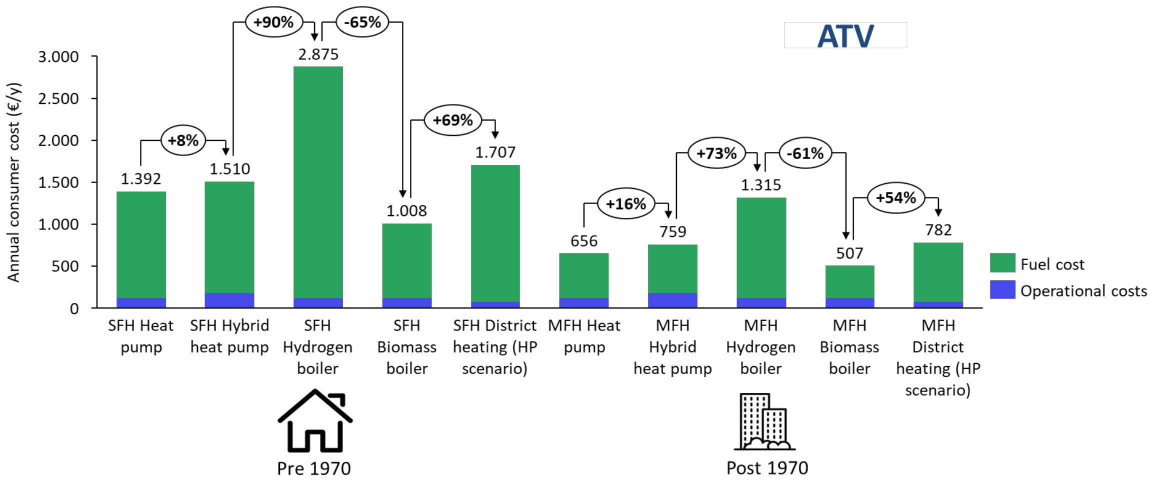

Figure 18 - Annual running costs of different heating systems in valley climate.

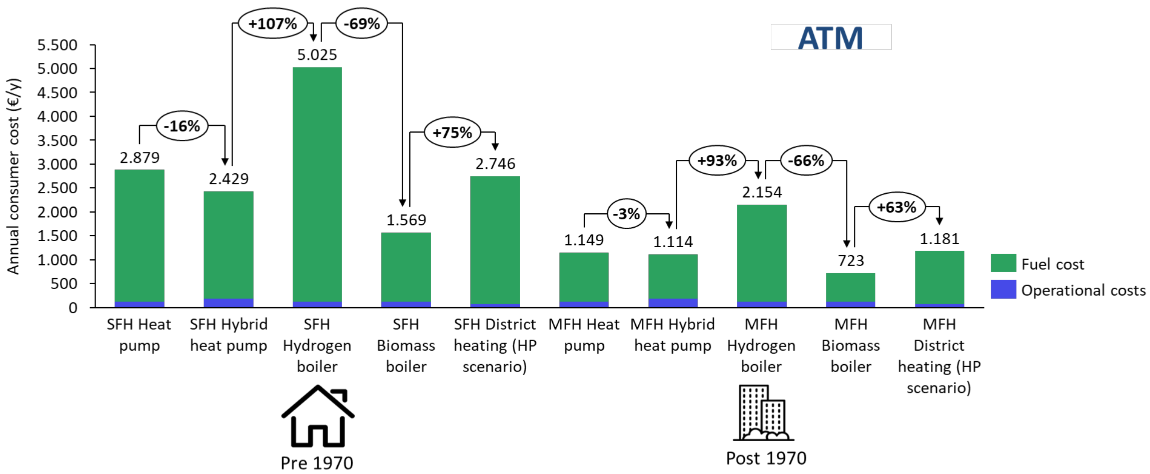

Figure 19 - Annual running costs of different heating systems in mountain climate.

3.3 Capital cost of heating systems

Capital costs are found from the Element Energy database of heating system costs and include the cost of the heating system as well as the cost of hot water cylinders and smart controllers where appropriate. Hydrogen boilers have the lowest capital cost of the heating systems considered; hybrid heat pumps have the highest capital cost.

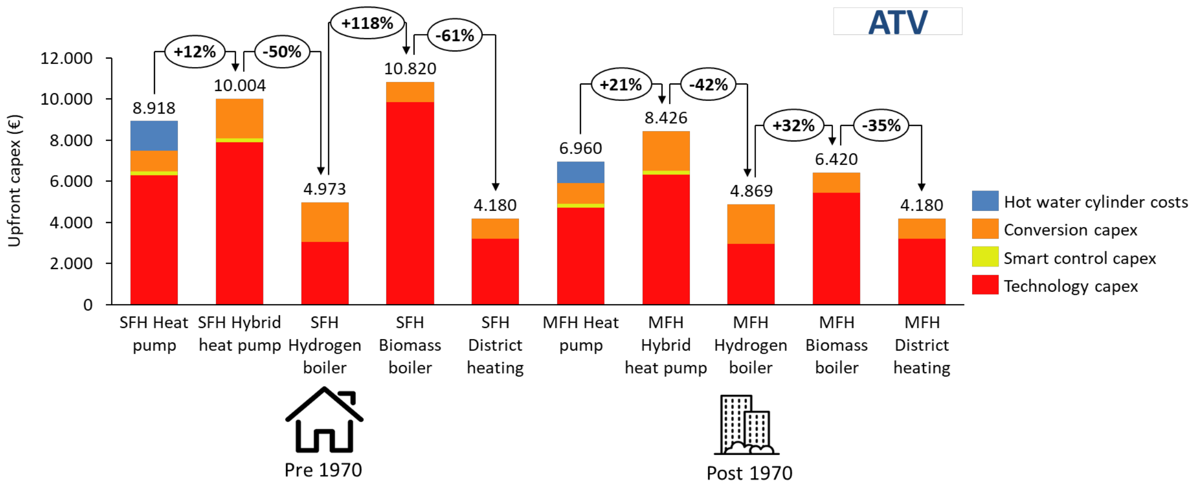

Figure 20 - Capital costs of different heating systems for typical archetypes in valley climate.

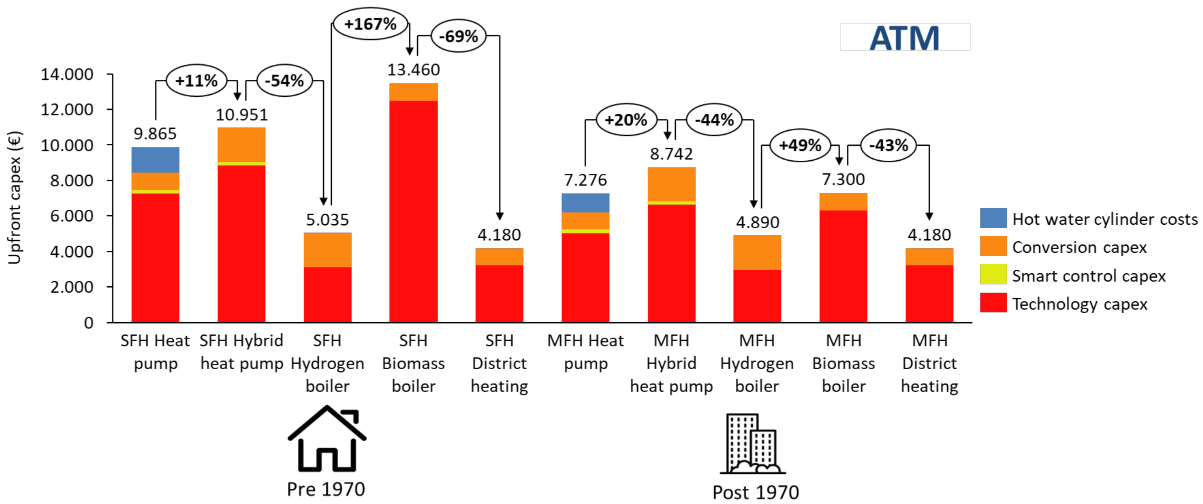

Figure 21 - Capital costs of different heating systems for typical archetypes in mountain climate.

4 Benefit from smart and responsive low carbon heating

Two system operation scenarios are presented in this study, the **Baseline-Passive** scenario involves passive operation of the energy system to meet demand, and the **Efficient-Smart** or **Flexible** scenario involves a higher rate of energy efficiency and operation of the energy system in a flexible way such that demand is changed to better match supply of power. Each of these two scenarios has been run with the three different technology deployment levels, so in each case the impact of smart system operation can be quantified. In all scenarios smart operation of electric vehicle charging is assumed.

4.1 Energy system benefit of smart operation

When heat pumps are operated in a smart way, they act to move demand away from the peak, this is achieved by pre-heating houses with high thermal mass relative to their heat loss rate, or by storing thermal energy in a phase change heat battery. We assume that by 2040, 50% of buildings with heat pumps that cannot be flexible through their thermal mass purchase a thermal battery. This allows a greater proportion of buildings to offer flexibility services, without implying an unrealistic rate of deep retrofit.

When heating is operated flexibly, the total demand for heating is unchanged, but the profile of electricity use is less “peaky”. The lower peaks mean that the total required capacity of electricity generation can be lower and less upgrade to higher capacity electricity networks is required, reducing the cost of the electricity system. In addition to the peak reduction, flexibility also allows demand to be better matched to when there is high generation of renewable technologies, this means those technologies with zero marginal cost have higher load factors and less thermal generation is required decreasing the system cost. Figure 22 shows the nationwide electricity demand over a typical winter week in 2040 in the scenario with high uptake of heat pumps. Under smart operation, heat demand is removed away from the peak, increasing demand at other times of day. This decreases the peak system demand and means less network capacity is required. In addition, heat demand can be moved into times where variable renewable electricity is available, reducing both the cost of electricity production and its carbon content. The model first moves demand that is flexible based on thermal mass, and then moves the demand that is flexible based on installing additional thermal storage, Figure 22 shows the change in the demand profile after the thermal mass flexibility (“building demand side response - DSR”) and thermal storage are applied, the majority of flexibility comes from additional thermal storage.

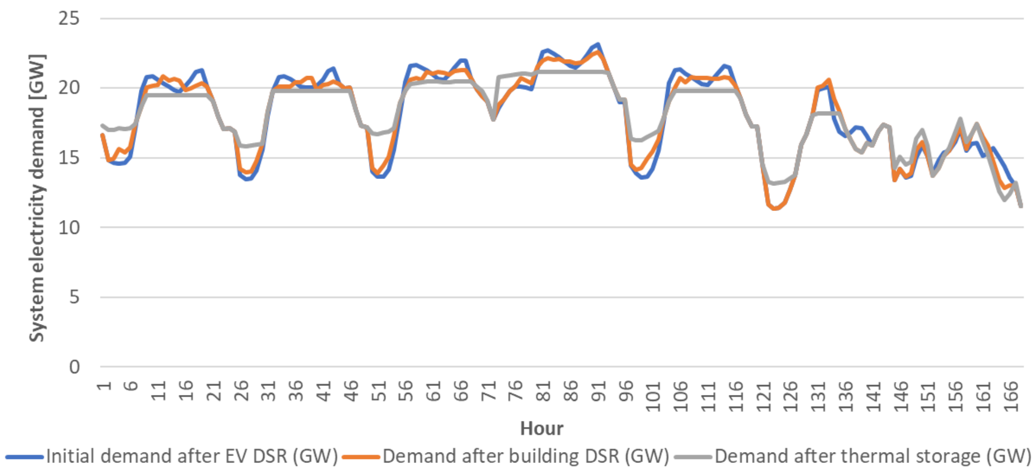

Figure 22 - Example of total electricity demand in Austria under the heat pump scenario with passive and smart heating system operation.

District heating also provides flexibility to the system through use of larger-scale thermal storage (typically in the form of stored hot water). This allows the peaks and troughs of heating demand from buildings on a district heat network to be mitigated locally so the loads on the wider energy system are minimised. In the flexible case hydrogen is considered to be produced by collocated renewables and curtailment so does not impact the wider electricity system relative to the baseline scenario where it is produced by grid connected electrolysers.

4.2 Costs and savings of flexibility for consumers

The total cost of the energy system, and therefore the energy costs faced by consumers, is reduced when heating systems are operated flexibly. The level of savings seen by different types of consumers will depend on the policies, tariff design, incentives for flexibility, taxation systems and market structures created to enable and incentivise smart operation of domestic heating. The cost savings may be passed on to the consumers that provide flexibility services, or they may be socialised across all electricity consumption. In practice, a mix of these two options is likely. While consumers may be incentivised to participate in DSR through Time-of-use electricity tariffs or through regular discounts on bills, these incentives may be less than the total system cost savings.

The range of different annual heating costs that could be seen by consumers in the smart and flexible heat pump scenario relative to the baseline passive scenario is shown in Figure 23 and Figure 24. The dashed bars show the range of different fuel costs that consumers might pay in different circumstances. If the benefits of flexibility are fully socialised, larger homes may save around €40-100/y, with flats saving about €20-35/y.

If savings are directed towards the households providing flexibility, large flexible households as much as €600/y over the baseline case, depending on how they provide flexibility. Similarly, flexible flats may save up to €250/y. If all savings are passed along to households providing flexibility, those unable to operate flexibly will have fuel bills unchanged from the passive case.

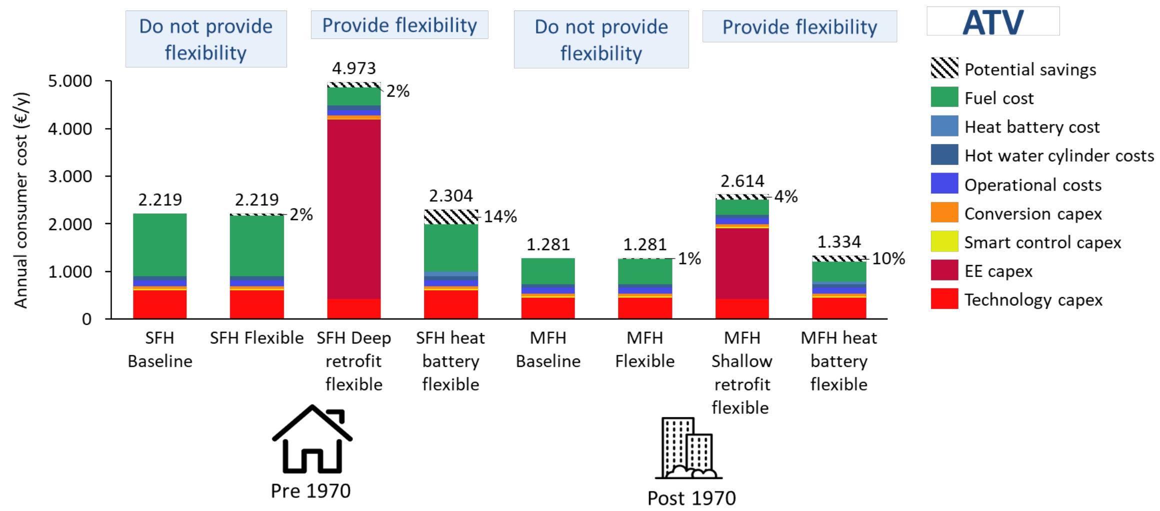

Figure 23 - The range of total consumer costs (€/y) possible in the flexible scenario in valley climate.

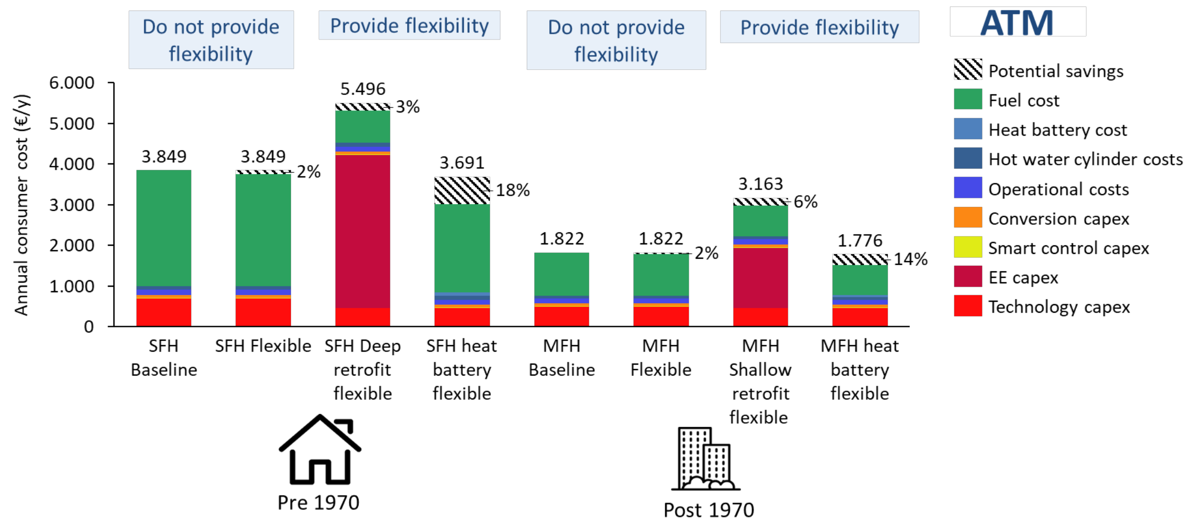

Figure 24 - The range of total consumer costs (€/y) possible in the flexible scenario in mountain climate.

In older single-family homes, all consumers are better off with a flexible energy system, whether they purchase an energy efficiency retrofit or heat battery to provide flexibility or not. Whereas in newer multi-family homes it is more difficult for consumers to see a saving on an individual level. For example, the post-1970 multi-family home in Figure 23 which has undergone a deep retrofit has higher total costs than the same dwelling in the passive baseline scenario, despite providing benefits to the wider energy system. It is therefore likely that policy support will be needed so consumer providing system flexibility do not pay higher costs overall. These supports may take the form of grants or other subsidies for energy efficiency measures, or enhanced payments for flexibility services.

4.3 System level savings from flexibility

This section considers savings at the system level from operating heating systems in a flexible way. This includes both the upfront cost of achieving flexibility and the final fuel savings resulting from the flexibility. Figure 14 shows the full system costs for each technology deployment scenario in both the baseline and efficient flexible cases. Across all scenarios the system cost is less in the flexible scenario compared to the baseline scenario. The efficient heat pump case has the lowest full system costs, considering only the heat sector and not the non-heat electricity, the heat pump scenario is €1.3bn cheaper per year than the hybrid heat pump scenario which is the next cheapest.

When considering the components of the fuel cost which decrease in the flexible case, the biggest decreases are from lower electricity generation costs where the lower peaks mean less investment in generation is required. The biggest savings come from the hydrogen scenario where making dedicated renewables that produce hydrogen at high load factors is significantly more cost effective than using grid connected electrolysers for hydrogen production.

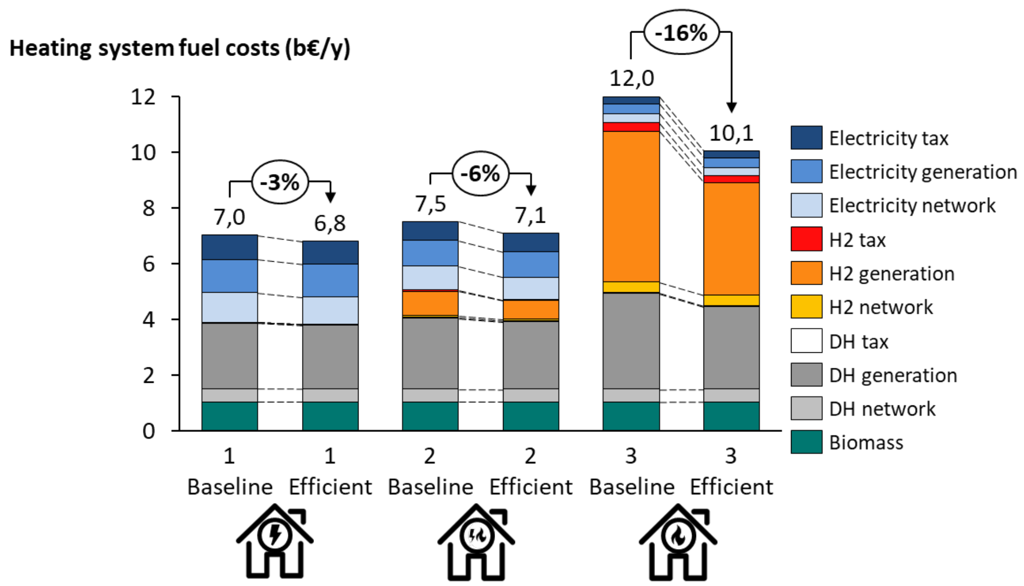

Figure 25 - Fuel cost savings from operating the electricity system in a flexible way (costs shown from system perspective).

When the energy system is operated flexibly consumers will see a difference in their fuel bill. Some of the benefits of flexibility are likely to be passed on to the consumers that provide the flexibility, but some of the benefit is also likely to be socialised across all consumers. Since there is high uncertainty around how these savings will be shared in 2040 we show a range of possible savings for each consumer based on the maximum and minimum possible savings that they could be given by the system. Figure 26 shows the range of different costs that might be given to consumers in the Efficient-Smart scenario, the first and second bars represent the range of costs that a dwelling that doesn't provide flexibility might have, and the second and third bars show the range of costs that a consumer that does provide flexibility may have. In the extreme case of the third bar, all savings from flexibility are passed on to consumers who provide flexibility, and so consumers not providing flexibility would see the baseline electricity cost shown in the left-hand bar.

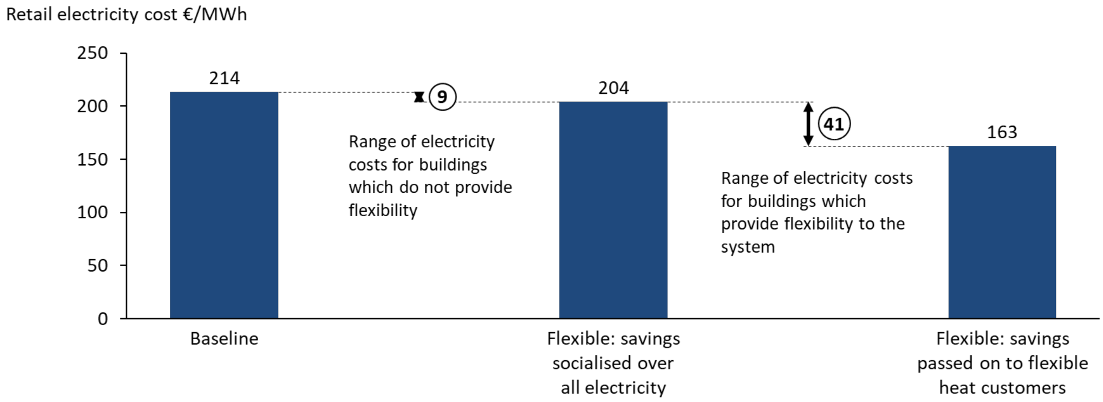

Figure 26 - The range of different fuel costs available to consumers in Austria.

5 Consumer costs of low carbon district heating

District heating in Austria is modelled at existing deployment rate, with 28% of domestic dwellings connected. The heat sources used by district heating are varied with the technology scenarios, as shown in Figure 27, with the further assumption that district heating is fully decarbonised by 2040. This means that gas, oil, and coal-fired systems (including combined heat and power) are not modelled as it is expected that these will be replaced with lower carbon alternatives. District heating systems can help accelerate decarbonisation since it is easier to replace a few large heat generators than the heat generators in many different dwellings. Although not modelled in this study, waste heat, geothermal, and solar thermal can be used as a cost-effective heat source for heat networks and should be considered where available. Waste heat is already used to a large extent in Austria and there is limited scope to increase its use further.

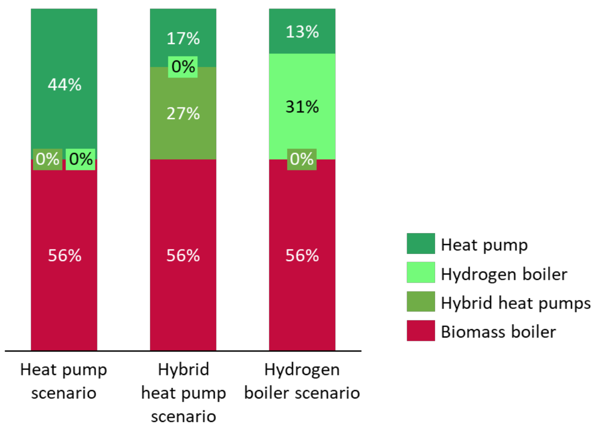

Figure 27 - Heat sources assumed for district heat in each technology scenario

While decarbonising district heating will bring benefits in terms of lower carbon emissions, it is important that adequate regulation is put in place to protect consumers on district heating networks. Because district heating is inherently a monopoly supply, consumers are at higher risk of high costs and poorly performing systems, and relatively less recourse to address these issues.

5.1 Cost of district heating networks for consumers

District heating networks are likely to have lower costs for consumers on average to the typical building level technology in each scenario. This stems mostly from the assumption that district heating networks use 50% biomass, which has a very low fuel cost of 0.045€/kWh. However, the cost of any heat network is highly dependent on the local area in which it is installed and so drawing exact comparisons between district heating and building level technologies is difficult. This analysis shows however that heat networks are likely to be a good option for consumers, particularly since their ease of decarbonisation is higher than building level technologies. In addition to that they are a cost-effective way to help multi-family homes provide flexible heating, since installing a deep retrofit to provide flexibility is unlikely to lead to cost savings relative to the baseline.

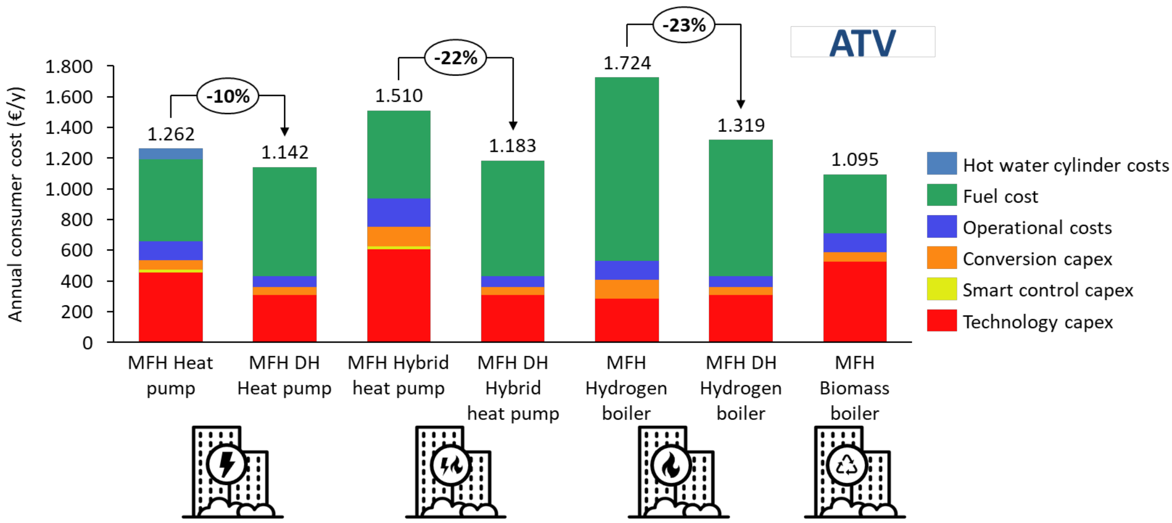

Figure 28 - District heating and building level technology cost for consumers, district heating plant and network costs are included in the fuel cost in valley climate.

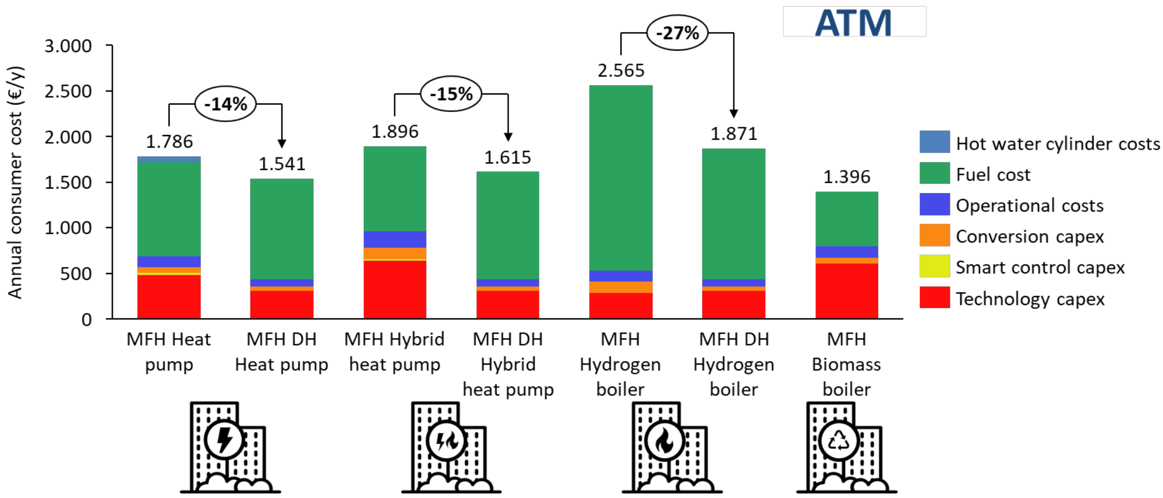

Figure 29 - District heating and building level technology cost for consumers, district heating plant and network costs are included in the fuel cost in mountain climate.

6 Conclusion

As in most European countries, fossil fuels play a significant role in domestic heating and in electricity generation in Austria today. Across the economy, electricity and heating contribute about 13% of Austria's carbon emissions[4]. Recent steps to reduce emissions include adoption of the EU's 2030 target for 55% reduction in carbon emissions from 1990 levels roadmap. These commitments will need to be supported by sector-specific policy supporting the energy transition. Over 45% of Austrian homes are heated with fossil fuels, including about 20% heated with oil[5]. By 2040, a significant shift towards renewable heating sources will be required to fulfil Austrian commitments towards net zero emissions in 2040.

The analysis presented above indicates that electrification of heat via heat pumps is likely to be the most affordable for consumers in the long run. Although heat pumps have a higher upfront cost than hydrogen boilers, the high running costs of hydrogen boilers result in a lifetime cost of heat over 40-50% higher than that offered by heat pumps. Policy support in the form of grants or low-cost loans enabling consumers to cover the initial capital cost of heat pumps will result in significant savings across the energy system. District heating and biomass boilers can be cost competitive with other low carbon heating technologies. Decarbonising existing networks is likely to be more cost effective than a conversion to low carbon heat solutions at individual building level.

Building fabric efficiency is a key enabler of a smart, cost-effective energy system in future. As shown above, energy efficiency retrofits in Austria could reduce demand for heating by 5% (3 TWh) by 2040 relative to today. Raising the ambition for energy efficiency deployment beyond 2% of dwellings per year contributes to system-wide savings of €0,5bn (1% of total energy system costs) despite the additional expenditure of €0,4bn on efficiency measures. This means that for each €1 spent on energy efficiency measures and smart operation, system costs are reduced by €1.25. Again, consumers may need to be supported in adopting energy efficiency in order for the system-wide savings to be realised. Smart and responsive operation of heating systems could reduce electricity costs by €10 to €50 per MWh. Households providing flexibility services may see yearly savings of between €100/year and €700/year, depending on home size and energy demand if appropriate rewards for flexible operation are in place.

[4] EU Parliament Briefing, Climate Action in Austria, 2021, https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/696186/EPRS_BRI(2021)696186_EN.pdf

[5] EntraNZE European Buildings database, https://www.entranze.eu/pub/pub-data