

# **INTRO**

The climate crisis means we need to rethink how we heat our homes, moving away from gas to more efficient solutions. Gas boilers, which are used by millions of consumers across Europe, are both polluting and leave us exposed to major price fluctuations. As we've seen in recent months, this can have a major impact on consumers' energy bills. So, what will be the most affordable alternative for consumers to sustainably heat their homes? And therefore, what solutions should upcoming EU and national legislative revisions promote?

To answer these questions, consumers organisations in Italy (Altroconsumo), Czech Republic (dTest), Poland (Federacja Konsumentow), Spain (OCU) and BEUC commissioned a study fromeconomic analysis firm, Element Energy.

The study estimates the cost of heating the two most typical homes (a house and an apartment) in those countries by using electric heat pumps, hybrid electric-hydrogen heat pumps and hydrogen boilers in the period 2025-2040. This period was chosen as it is when legislation on residential heating that is being revised or will shortly be revised will enter into force and as 15 to 20 years is the average lifetime of a heating appliance.

The cost of heating is calculated by considering the total cost of ownership of the different appliances. It includes the cost of energy generation, the cost of operating energy networks and make the appropriate upgrades, the cost of insulating the buildings and the cost of purchasing and installing the appliances.

# **KEY FINDINGS**



Electric heat pumps are the most affordable option for consumers to decarbonise their heating. In high density areas, district heating powered by heat pumps is also competitive, but consumer rights must be improved to match those in electricity. Hydrogen boilers and hybrid heat pumps (hydrogen/electric) are the most expensive option for consumers. Hydrogen will be far more expensive than gas is today.



In cold climates, major home energy efficiency improvements deliver significant financial benefits to consumers, reducing consumption and helping to reduce energy bills. This applies in all four countries, helping to keep homes warm in winter. In warm climates, shading (e.g. the use of blinds) can decrease consumption and improve comfort.



'Smart heating' (e.g. when it's cheaper at off-peak times) with heat pumps will reduce consumers' heating costs by up to 25% compared to conventional heating. This is because consumers using electricity smartly reduces the need for investments in electricity grids. The savings have the potential to reduce grid charges on consumers' energy bills.



If national governments roll out ambitious home renovation programmes, allowing many consumers to improve the energy efficiency of their homes, this could also mean lower grid tariffs (and energy bills) for all if savings are passed on to consumers.



To be able to reap the benefits of lower energy bills, consumers will need financial support (affordable and green loans and/or grants) to help with the high up-front investment to purchase a heat pump and pay for energy efficiency improvements.

# POLICY RECOMMENDATIONS

01

EU and national policies should support a switch to electric heat pumps as it will be the most costeffective heating solution for consumers. They should not support reliance on hydrogen in the residential heating sector, as it will never be a costeffective option

Consumers relying on gas for heating should not be switched to hydrogen as a result of EU and national policies. The European Commission and national governments should prioritise the roll out of individual electric heat pumps and, in urban areas, district heating with fully electric or with hybrid hydrogen/electric heat pumps.

For this reason, the upcoming Gas Package should not set a target for blending hydrogen into existing gas networks. Similarly, national governments should not aim to decarbonise heating by blending hydrogen in the gas networks.

— O2 ——

National governments and local authorities should financially support consumers to switch to electric heat pumps and where needed to improve the energy efficiency of their homes. To that end, EU and national governments should also guarantee consumers' access to finance and ensure consumer protections for credit

Switching to heat pumps and improving energy efficiency brings significant financial savings for consumers and the energy system, but up-front costs can represent a barrier for many consumers.

Countries should provide grants of up to 100% of the initial investment needed for vulnerable consumers to make the switch.

Consumers should also have access to affordable green mortgages/loans and on-bill schemes. Member States should also introduce guarantee funds to reduce the risk of providing loans or mortgages, so that banks can offer better interest rates to consumers. At the same time, financial services regulations should require banks to be responsible when lending money and EU should foresee a cap on the total cost of credit for green mortgages/loans under the Consumer Credit and Mortgage Credit Directives.

03

Governments should ensure that all consumers have access to trusted, tailored advice, and to a skilled workforce

Consumers often struggle to find reliable professionals to undertake renovation works or replace their heating appliance or who could advise them on these works.

The Energy Efficiency Directive should require countries to set up one-stop shops to advise consumers on renovation works or heating appliances, and on where to find skilled workers or financial support. Consumers should be advised according to their individual situations as, for example, homes in colder climates require more insulation than homes in warmer climates.

The Renewable Energy Directive and the Energy Efficiency Directive should require that the workforce specialised in carrying out these works is available to all consumers.

04 —

Governments and regulators should ensure that consumers have access to tariffs and to financial rewards, giving them incentives to heat their homes smartly and benefit of the reduction in the cost of operating electricity networks

As smart heating (e.g. operating heat pumps at off-peak times) will help reduce the cost of managing electricity networks, these benefits should be passed on to consumers in the form of financial incentives. This will be increasingly important as the share of wind and solar power in the electricity mix is expected to increase. Flexibility on the demand side will greatly help reducing the cost borne by electricity networks to balance supply and demand and will hence reduce consumers' network tariffs.

Countries should swiftly implement the measures in the Electricity Directive that give such financial incentives to consumers to use energy outside peak times (i.e. allowing them to sign up for dynamic electricity price contracts).

#### Ecodesign rules should not force consumers who need to purchase a gas boiler to buy a hydrogenready one

In the next decade, consumers whose gas boilers break down may still need to replace them with a new one and may not be able to switch immediately to a heat pump. There are discussions on requiring all gas boilers on sale to be able to function with hydrogen under the Ecodesign Directive. Hydrogen may never become a reality for consumers, hence this functionality may never be useful for them and may only come at a premium. Hence, the new Ecodesign rules should not require all gas boilers on the market to be hydrogen-ready.



#### CZECH REPUBLIC



#### Heating appliance

Heat pumps will be the cheapest heating option for consumers in the Czech Republic. The total cost of ownership of hydrogen boilers in this period would be 65-80% higher.

The reason is that despite the higher up-front cost of heat pumps, the running cost of hydrogen boilers is typically more than double that of heat pumps in the Czech Republic. The price of hydrogen can be lower than the price of electricity, but the efficiency of hydrogen boilers is much lower, so more fuel is required.

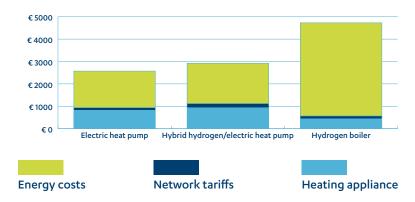
#### Home renovation

Home renovation measures pay back in the Czech Republic within 30 years, which is their average lifespan. Deeper renovations are more cost effective in single family homes than they are in apartment buildings, where a medium renovation can already bring significant monetary benefits. The reason is that less energy is required to heat an apartment. Hence, making additional investment in deeper renovation would not bring significant extra energy consumption (and bill) reductions. Improving energy efficiency in homes would also reduce the cost of operating electricity networks, and hence network tariffs on consumers' bills.

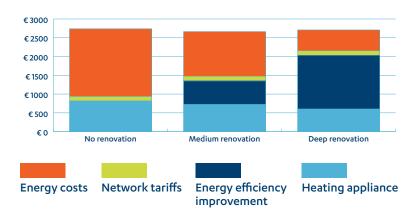
#### District heating

In urban areas, in the same period, renewable electricity-based district heating will have similar costs for consumers as individual heat pumps. However, hydrogen-based district heating would be 30% more expensive for consumers than district heating with fully electric or hybrid hydrogen/electric heat pumps.

Annual cost of heating a single family home in the Czech Republic in the period 2025-2040 with different heating systems



Annual cost of heating a single family home in Czech Republic in the period 2025-2040 with a heat pump, with different levels of energy efficiency improvements









#### Heating appliance

Similarly, as with the other countries, the best and cheapest heating option for Spanish consumers, would be an electric heat pump. The total cost of ownership of hydrogen boilers would be 60% more expensive for consumers than for electric heat pumps in the period 2025-2040. It needs to be noted that while heat pumps will be able to also deliver cooling during the summer, hydrogen boilers will not and consumers would need to purchase a separate appliance, further increasing their expenditure for energy.

#### Home renovation

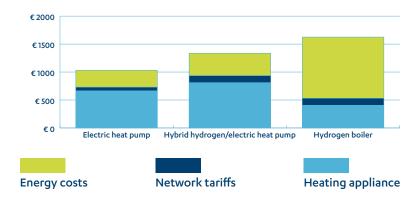
Bill savings from energy efficiency improvements in Spain, however, would often not be sufficient to recover the initial investments over the lifetime of such interventions due to milder winter and hence less heating needs, even when savings on summer cooling costs are factored in. Deep retrofits are much more expensive for consumers over the lifetime of the intervention than not carrying out any energy efficiency measures, due to high costs in Spain linked to higher labour costs.

Shallow retrofits lead to slightly higher annual costs (+18%) but also offer other non-monetary benefits, such as increased comfort. However, if many consumers adopt such measures, this will lead to a significant reduction in electricity grid

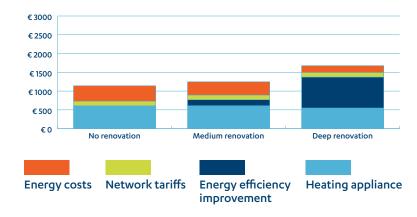
#### District heating

District heating networks could deliver heat at an affordable cost to consumers living in urban areas, which is 3% cheaper than using an electric heat pump. However, rolling out district heating to rural areas would not be cost-competitive with individual solutions.

# Annual cost of heating an apartment in Spain in the period 2025-2040 with different heating systems



Annual cost of heating an apartment in Spain with a heat pump in the period 2025-2040, with different levels of energy efficiency improvements



costs (~€1bn/year), due to lower consumer demand and their ability to use energy smartly. Hence public support for energy efficiency improvements is important to help consumers reap their benefits.







#### Heating appliance

In Italy, the cheapest individual heating option for consumers from over the 2025-2040 period would be an electric heat pump. Hydrogen boilers would be 90-140% more expensive than electric heat pumps over their lifetime, while hybrid hydrogen-electric heat pumps would typically be 35% more expensive than fully electric. It needs to be noted that while heat pumps will be able to also deliver cooling during the summer, hydrogen boilers will not and consumers would need to purchase a separate appliance, further increasing their expenditure for energy.

#### Home renovation

Improving the energy efficiency of homes in Italy would allow consumers to make savings by using less energy for heating and by using heat pumps flexibly. This would reduce electricity grid costs by 4% and flexibility would allow consumers to save up to 31% in their electricity bills.

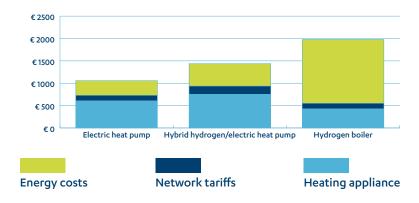
However, public support is needed to help consumers retrofit their homes due to the significant up-front costs, which often do not have a payback period over their lifetimes. This is due to higher labour costs and milder winters which reduce heating needs.

While medium efficiency measures could be more cost-effective in multi-unit buildings, as

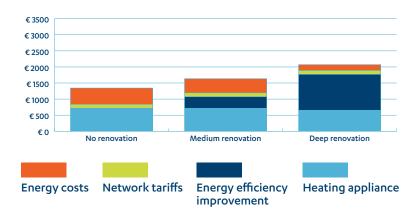
#### District heating

District heating with electric or hybrid electric/ hydrogen heat pumps would have similar costs for consumers as individual heat pumps and hence could be an affordable solution in urban areas, while hydrogen-based district heating would typically be 50% more expensive.

# Annual cost of heating an apartment in Italy in the period 2025-2040 with different heating systems



Annual cost of heating an apartment in Italy with a heat pump in the period 2025-2040, with different levels of energy efficiency improvements



they would allow consumers to cut energy needs and operate their heat pumps smartly without being too financially burdensome, deep retrofits should be encouraged in single family homes.







#### Heating appliance

Electric heat pumps would be the cheapest way to decarbonise heat for consumers in Poland. Typically, hybrid heat pumps would be 12-24% more expensive and hydrogen boilers 63-95% more expensive than electric heat pumps over their lifetime.

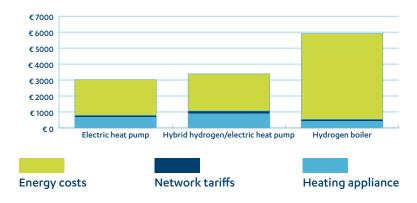
#### Home renovation

Energy efficiency improvements would help consumers make big savings on their energy bills (20%), with the cost of investment paying for itself within the works' lifespan.

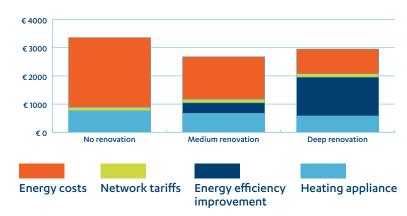
#### District heating

Renewable electricity-based district heating networks could heat consumers' homes in urban areas at a similar cost to individual heat pumps. District heating with hydrogen boilers would be approximately 40% more expensive for consumers than district heating with electric heat pumps or hybrid hydrogen/electric heat pumps.

Annual cost of heating a single family home in Poland in the period 2025-2040 with different heating systems



Annual cost of heating a single family home in Poland with a heat pump in the period 2025-2040, with different levels of energy efficiency improvements





# CONCLUSION

The study shows that, although the cost of heating our homes may increase in the future as we decarbonise our energy, consumers will continue being able to heat their homes affordably and can do so sustainably if EU and national policies focus on proven and cost-effective solutions, such as heat pumps. They should not focus on promises, such as hydrogen, that may never materialise and, even if they do, would be very expensive for consumers.

In addition, a switch away from gas boilers to heat pumps powered with electricity that is increasingly produced with wind and solar power will also mean more stability, as we will be less exposed to volatility in global gas markets, which has led to very high energy bills in recent months. Improving the thermal insulation of our homes will also contribute to reducing our energy bills.

efficiency of our homes is a quite expensive investment, government support will be essential to ensure that all consumers, including the most vulnerable, are able to reap the benefits of these measures.

In addition, we should not forget that the transition in the heating sector will bring a wider range of benefits than monetary savings alone. Well insulated homes will not only also help with improving the air quality of our cities, but it will also bring important benefits in terms of adequate thermal comfort and health to consumers, as they will be warmer during the winter and cooler during the summer.

Hence, BEUC calls on EU and national policymakers to

speed up the decarbonisation of the heating and buildings, reducing our energy bills. prioritising cost-efficient energy efficiency improvements in homes and the deployment of heat pumps. This will benefit Clearly, as switching to a heat pump and improving the energy both the environment and consumers.

















# Consumer cost of heat decarbonisation: executive summary graphs

#### **BEUC and ECF**



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#### **Poland**

#### **Key messages**

Impact of ambitious energy efficiency deployment in PL

Consumer costs of electrification vs hydrogen

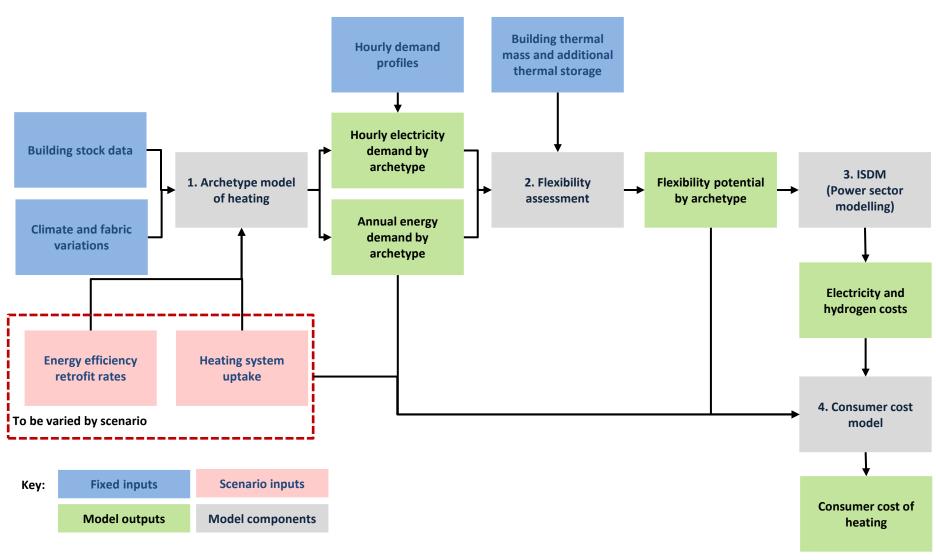
Benefit of smart and flexible operation

#### **Key messages for Poland**

- Heat pumps are the cheapest way to decarbonise heat for consumers, they are typically 12% cheaper than Hybrid heat pumps and 95% cheaper than hydrogen boilers
- Operating the energy system flexibly lowers the total energy system cost by 3% in a high heat pump scenario, this saving can be
  passed on to consumers
- Installing energy efficiency can provide cost savings to consumers in some cases, and also comes with additional benefits
- Installing additional thermal storage to provide system flexibility is cost effective for the system and so consumers should be rewarded for providing this service to the energy system
- District heating is of comparable cost to building level heating systems, but provides flexibility and is easier to decarbonise, so decarbonising existing district heating networks has significant consumer benefit

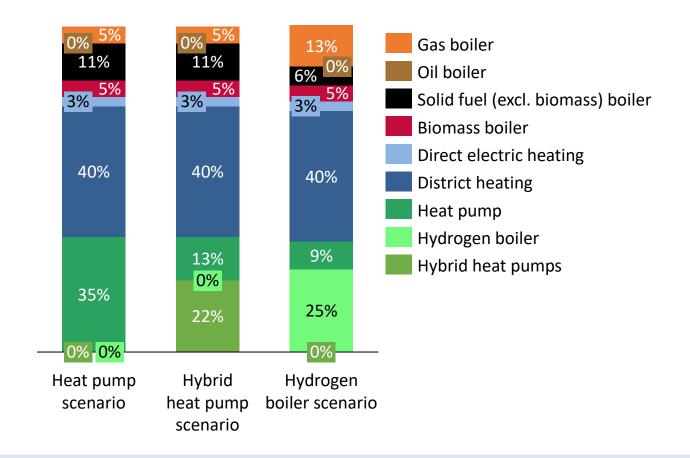
#### Overview of modelling methodology

- 1. The archetype stock model calculates the heat demand and final energy consumption on an annual and hourly basis for domestic dwellings in Spain. The outputs are generated at the building level and at the country-level (i.e. including all buildings). Nondomestic buildings are included in the national demand although they are addressed with less detail than the residential stock.
- 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 Spain's energy system throughout 2040. The ISDM predicts the retail costs of electricity and green hydrogen.
- The upfront and ongoing costs of heating are calculated by the consumer cost model for the selected Spanish building archetypes.



## **Technology mix**





## **Agenda**

Key messages

Impact of ambitious energy efficiency deployment in PL

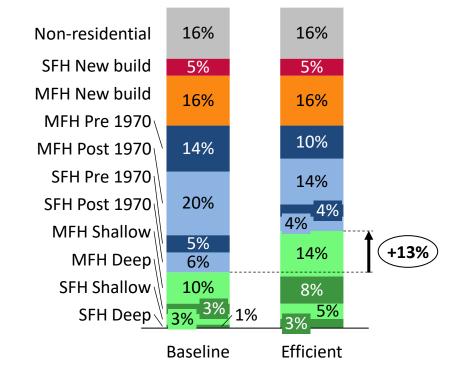
Consumer costs of electrification vs hydrogen

Benefit of smart and flexible operation

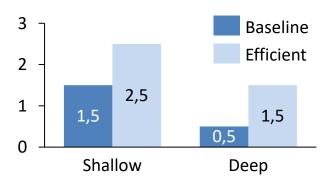
#### **Energy efficiency scenarios**

- 2 scenarios analysed
- Current renovation rate applied to 2025
- Higher rates below applied 2025-2040
- Baseline scenarios at 2% renovations per year is already ambitious

- 17% of homes renovated in Baseline scenario
- Rising to 30% in the Efficient scenario



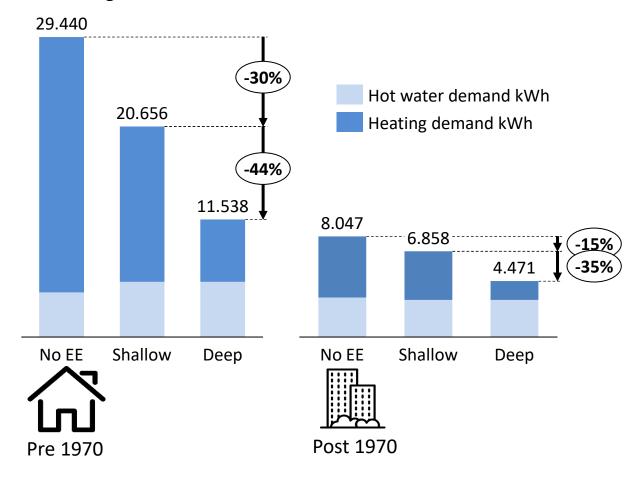
#### Annual renovation rate (%)



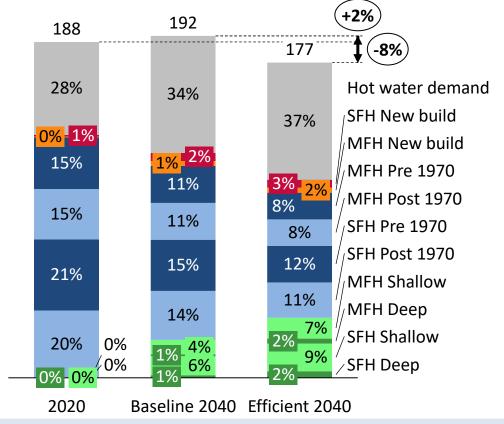
#### **Heat demand savings**



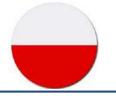
 Savings in heat demand depend on size and age of the dwelling as well as level of retrofit



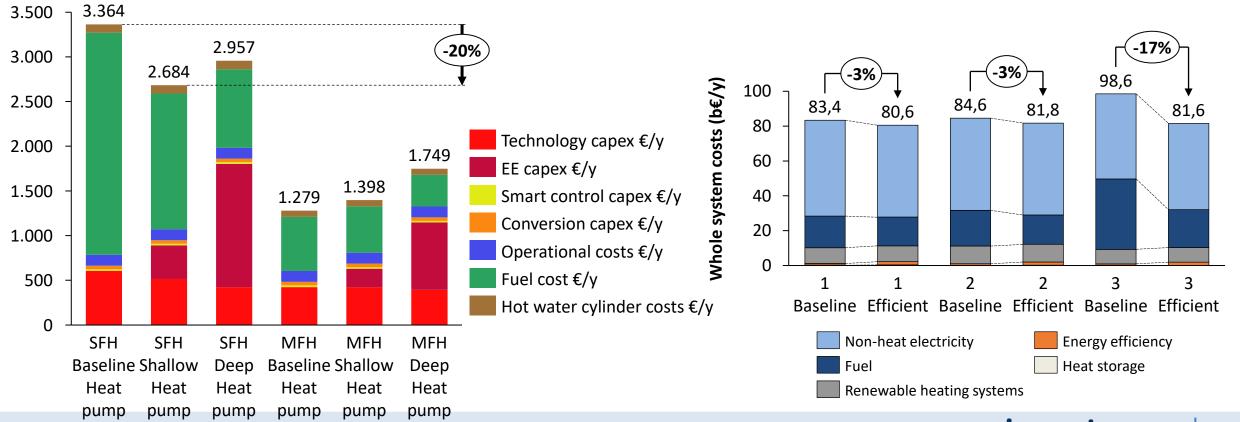
- Total heat demand increase by 4 TWh in Baseline scenario, and decreases by 11 TWh saving in Efficient scenario.
- 8% reduction between Baseline and Efficient scenarios.



## Energy efficiency provides direct savings in older less efficient dwellings.



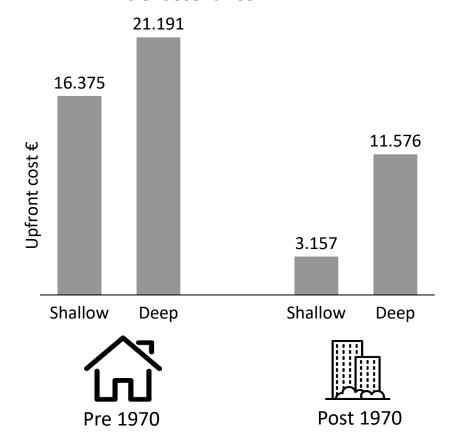
- Consumers can save 20% in large old homes by installing a shallow package, but they will not achieve the same savings in newer smaller multi family homes where installing ee increases the cost of heat for consumers.
- Installation of energy efficiency measures enables cost savings to the entire energy system.
- Savings depend on the type of renewable heating system most commonly deployed, but are likely to be at least €2.8 bn per year.
- Policy support is needed to achieve these high rates of deployment due to the significant upfront cost to households.



## **Costs and savings of energy efficiency measures**



- Energy efficiency upgrades require significant capital outlay, again depending on the size and age of the home and level of retrofit.
- Total outlay of €0.9bn/y in Baseline and €1.9bn/y in Efficient scenarios.



## **Agenda**

Key messages

Impact of ambitious energy efficiency deployment in PL

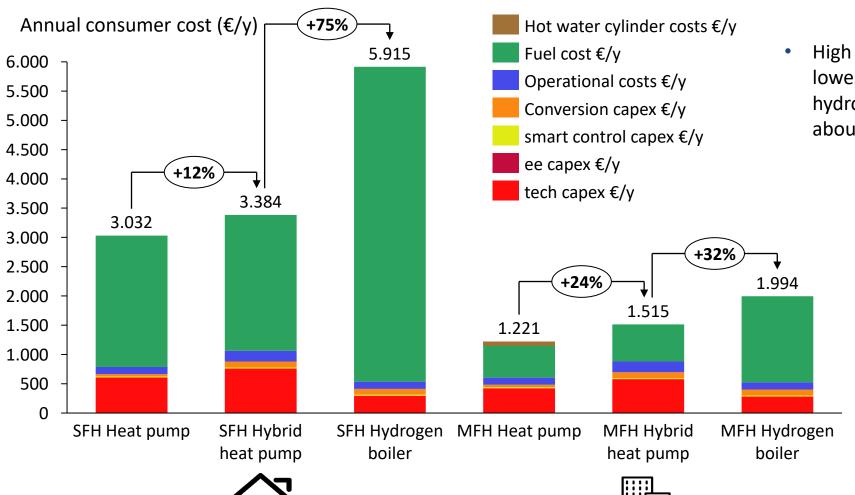
**Consumer costs of electrification vs hydrogen** 

Benefit of smart and flexible operation

# Heat pumps are less costly for consumers than hydrogen, with hybrid heat pumps in

Post 1970





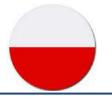
Pre 1970

between

 High prevalence of heat pumps will lead to the lowest costs of heating for consumers, with hydrogen boilers leading to additional costs of about 2x per unit of heat

	Heat pump	Hybrid heat pump	Hydrogen boiler
Heat cost €/MWh pre 1970 SFH	103	115	201
Heat cost €/MWh post 1970 MFH	152	188	248

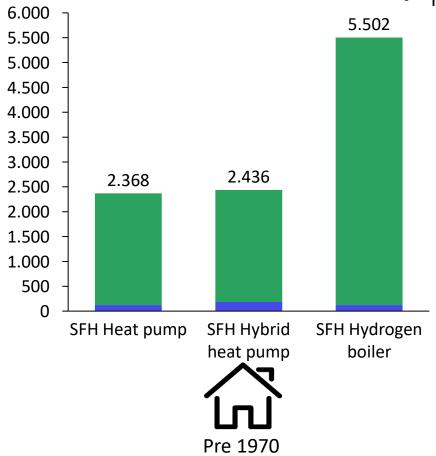
#### Hydrogen boilers have significantly higher running costs than heat pump systems



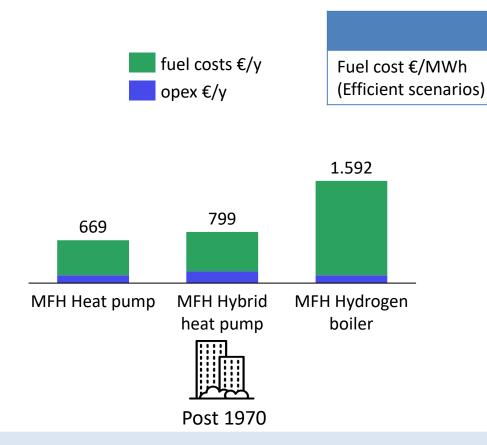
Hydrogen

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- Hydrogen boilers typically cost 2.3x as much to run as a heat pump system
- This is because the efficiency of hydrogen boilers is lower, so more fuel is required
- Hydrogen can be cheaper than electricity, but not enough to outweigh the higher consumption
- Hydrogen will be more expensive than gas is today



Annual running costs €



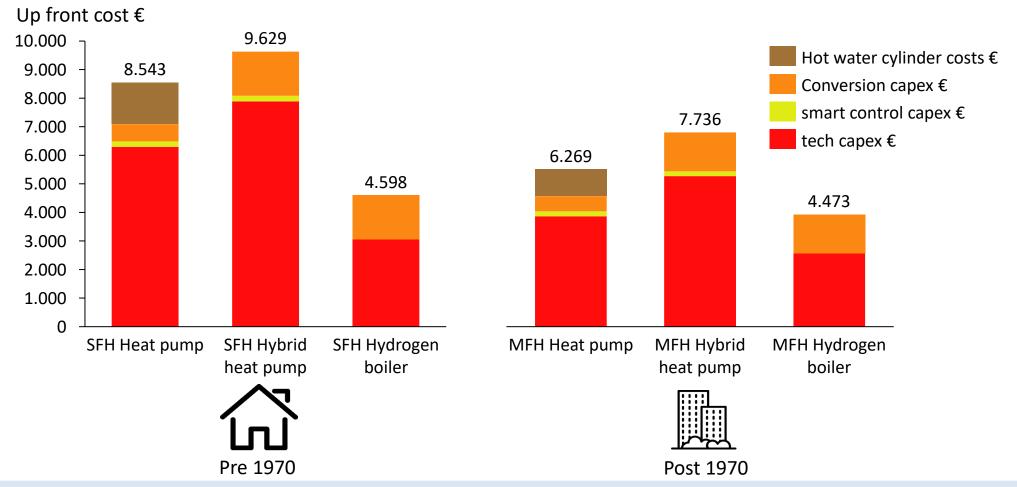
**Electricity** 

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# Hydrogen boilers have lower capex than heat pump systems, with hybrid systems most expensive initially



- Hydrogen boilers have the lowest up front cost for consumers out of the three options considered and hybrid heat pumps have the highest up front cost
- In a pre 1970 SFH hydrogen boilers have 46% lower up front cost than heat pumps



## **Agenda**

Key messages

Impact of ambitious energy efficiency deployment in PL

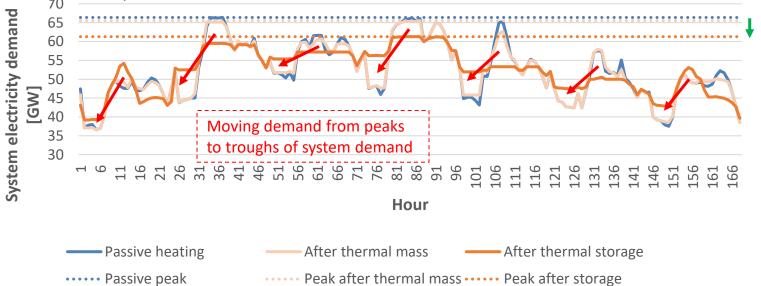
Consumer costs of electrification vs hydrogen

Benefit of smart and flexible operation

#### How does smart operation of heating help the energy system?

- Uncontrolled operation of heat pumps leads to a high peak demand of the overall electricity system
- Utilising the **flexibility** provided by thermal storage and thermal mass, smart operation of heat pumps moves demand from hours of high demand to hours of low demand (**from peaks to troughs**, see graph below)
- This **reduces** the peak demand of the system and thus the required **network capacity**.
- In our models smart heat pumps are also operated to move their demand to hours of high generation from variable renewable energy sources<sup>1</sup>, to **reduce curtailment** of the electricity they generate and the amount of **dispatchable** generation **capacity** required to ensure security of supply.
- Thermal storage provides a much higher degree of flexibility than thermal mass (see below chart showing total system demand with and without flexibility from smart heating over a period of one week)

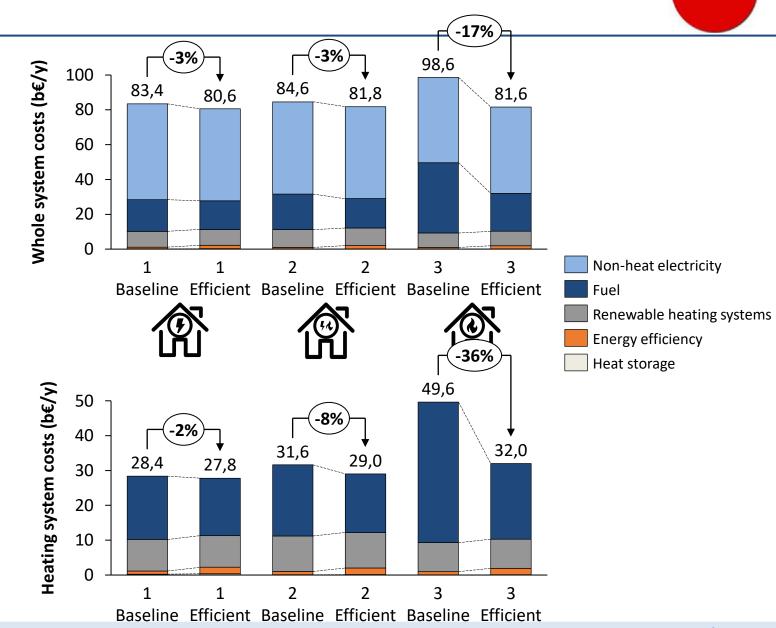
• System peak demand drops from 65.5 MW with passive heating to 64.5 MW when high efficiency buildings are operated flexibly. Flexibility from thermal storage in buildings lowers peak demand further to 61.3 MW.



Peak system
demand is reduced
leading to lower
network capacity
requirements

# In the Czech Republic, the whole system costs are always lower in the efficient compared to the baseline scenario

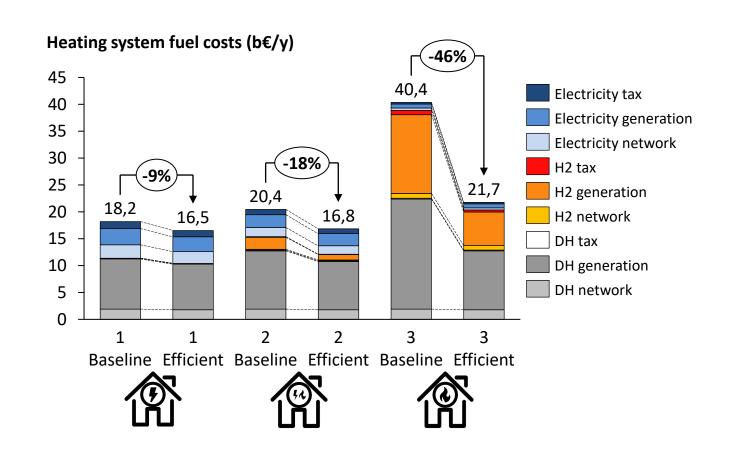
- Across all technology scenarios, the whole system costs decrease in the efficient case compared to the baseline. This effect is most significant in the hydrogen-led scenario.
- In the baseline, the heat pump-led scenario has the lowest whole system costs, with 16% lower costs than the hydrogen-led scenario (83 compared to € 99 b/y).
- In the efficient case, the total system costs are similar across all scenarios with the heat pump case being fractionally the lowest.
- When the system benefits are only shared across the heat sector the heat pump case has 1.2b€/y lower costs than the next cheapest scenario.
- The costs shown are from the system perspective, rather than the consumer perspective.



## In the Czech Republic, significant system cost savings are made by using flexibility



- The heating system fuel costs are significantly lower in the efficient scenarios relative to the baseline case.
- The majority of the savings come from lower electricity generation costs.
- The costs shown are from the system perspective, rather than the consumer perspective.



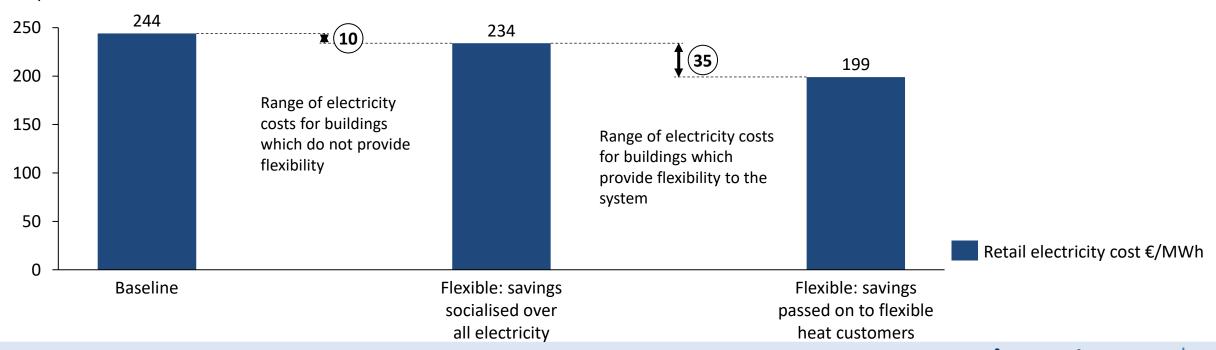
#### System savings from flexibility can be shared in different ways with consumer



- Both consumers who provide flexibility and those who don't can benefit from system flexibility
- Fuel cost savings could be distributed in different ways:

€/MWh

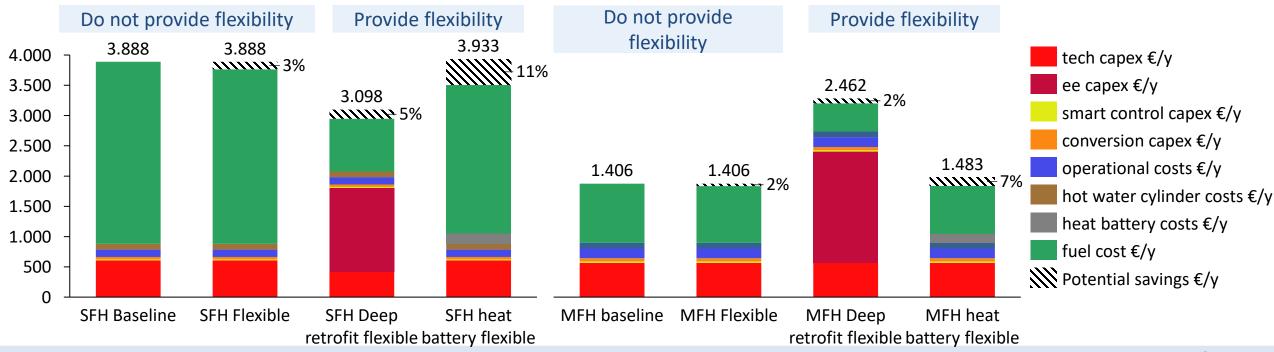
- Savings could be passed on to consumers who provide flexibility, e.g. with time-of-use tariffs or payments for reducing demand at peak times
- Savings could be socialised over all heating electricity demand
- The range of possible savings are demonstrated via a minimum and maximum fuel cost for each building type with the real savings likely to fall somewhere between the two limits



## Providing flexibility can lead to cost savings for consumers in the heat pump scenario



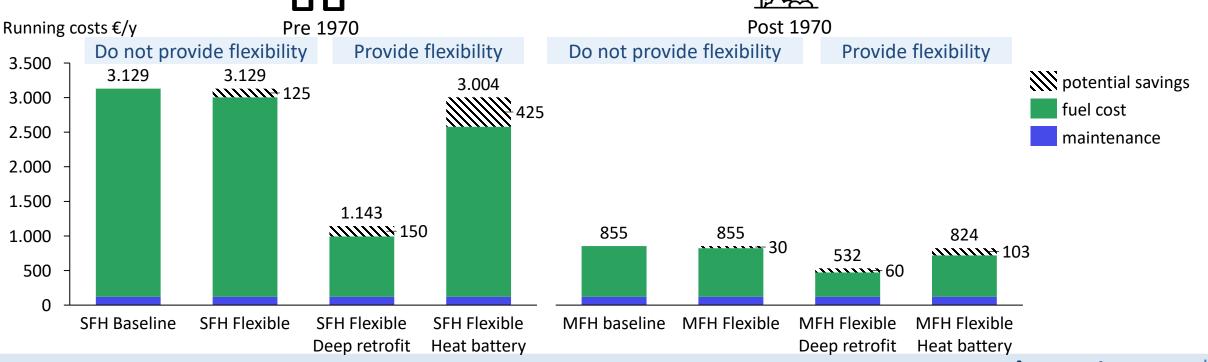
- Both consumers who provide flexibility and those who don't can benefit from system flexibility
- The dashed bars show the range of different fuel costs that consumers might pay in different circumstances, the minimum and maximum fuel costs that these represent are shown on the previous slides
- In SFH there are always system savings from flexibility relative to the baseline, but in MFH grants for EE or heat batteries may be needed in so that flexibility savings can be passed onto consumers



## Heat pump running costs in different households will depend on how flexibility is rewarded

- The dashed bars show the range of different fuel costs that consumers might pay in different circumstances, the minimum and maximum fuel costs that these represent are shown on the previous slide
- If the benefits are fully socialised, larger homes may save around €100/y, with flats saving about €25/y
- If savings are directed towards the households providing flexibility, large flexible households may save a further €380/y, for total savings of €480/y over the Baseline case
- Similarly, flexible flats may save up to €125/y

Buildings which have been retrofit may see reduced savings due to their reduced energy demand – it is important policy and the market
mechanisms for flexibility are <u>designed</u> to incentivise energy efficiency retrofit



## **Agenda**

Key messages

Impact of ambitious energy efficiency deployment in PL

Consumer costs of electrification vs hydrogen

Benefit of smart and flexible operation

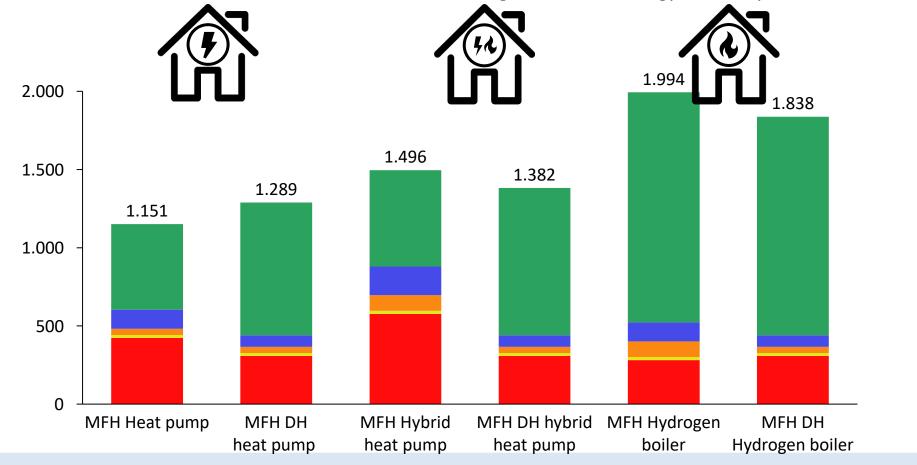
#### **HPs are also cheaper for DH than H2**

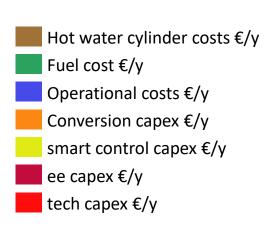
- Gas and oil CHPs will have to phased out
- DH can aid/accelerate decarbonisation because it's easier to replace fewer larger heat generators
- Waste heat can be very cost effective
- Some waste heat can be used directly, other waste heat will require temperature increase with heat pumps
- We have not assumed significant waste heat usage in the current analysis
- Further comments on consumer protections to be added in text

## District heating has similar costs for consumers but provides more system flexibility



- Heat pumps are the most cost effective way of decarbonising existing heat networks
- District heating costs around the same or less than building level heating depending on the scenario, and can be a cost effective way to provide system flexibility, especially in multi family homes
- Trends shown below would be consistent with higher levels of energy efficiency.





## **Czech Republic**

#### **Key messages**

Impact of ambitious energy efficiency deployment in CZ

Consumer costs of electrification vs hydrogen

Benefit of smart and flexible operation

#### **Key messages for Czech Republic**

- Heat pumps are the cheapest way to decarbonise heat for consumers, they are typically 14% cheaper than Hybrid heat pumps and 83% cheaper than hydrogen boilers
- Operating the energy system flexibly lowers the total energy system cost by 4% in a high heat pump scenario, this saving can be passed on to consumers
- Installing energy efficiency can provide cost savings to consumers in some cases, and also comes with additional benefits
- Installing additional thermal storage to provide system flexibility is cost effective for the system and so consumers should be rewarded for providing this service to the energy system
- District heating is of comparable cost to building level heating systems, but provides flexibility and is easier to decarbonise, so decarbonising existing district heating networks has significant consumer benefit

## **Agenda**

Key messages

Impact of ambitious energy efficiency deployment in CZ

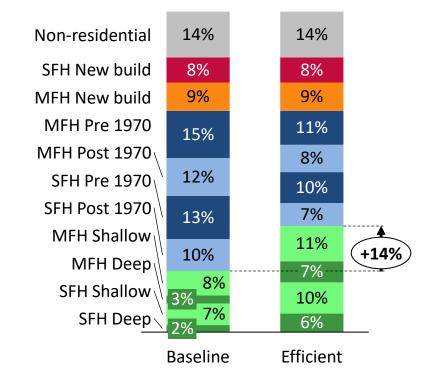
Consumer costs of electrification vs hydrogen

Benefit of smart and flexible operation

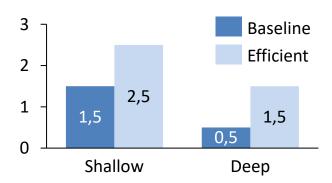
#### **Energy efficiency scenarios**

- 2 scenarios analysed
- Current renovation rate applied to 2025
- Higher rates below applied 2025-2040
- Baseline scenarios at 2% renovations per year is already ambitious

- 20% of homes renovated in Baseline scenario
- Rising to 34% in the Efficient scenario



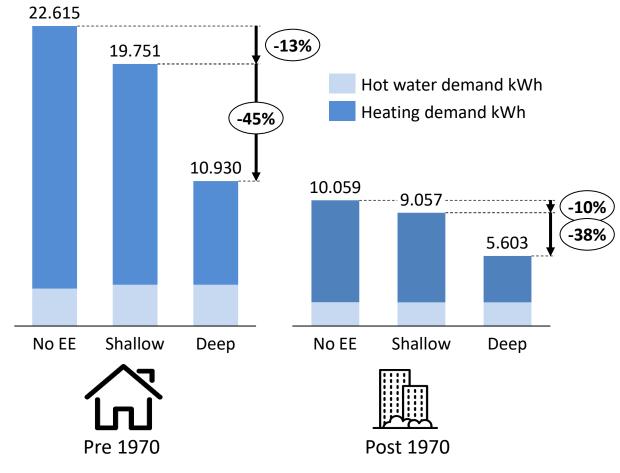
#### Annual renovation rate (%)



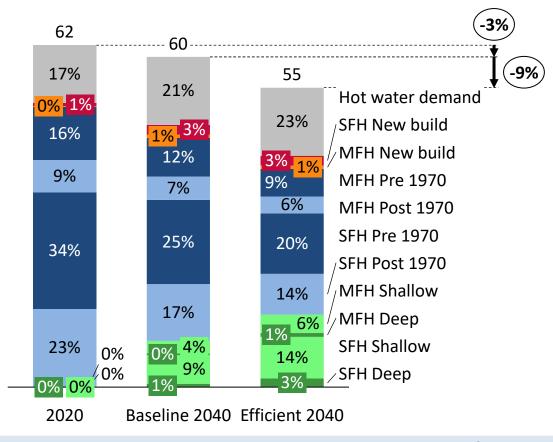
#### **Heat demand savings**



 Savings in heat demand depend on size and age of the dwelling as well as level of retrofit



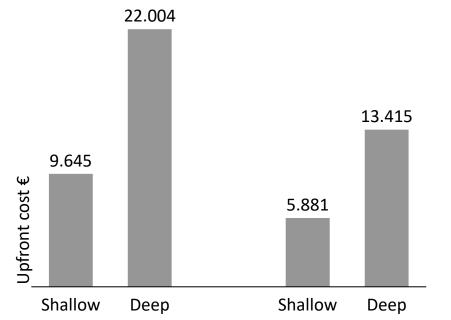
- Total heat demand savings of 2 TWh in Baseline scenario, with further 5 TWh in Efficient scenario.
- 9% reduction between Baseline and Efficient scenarios.



#### Costs and savings of energy efficiency measures



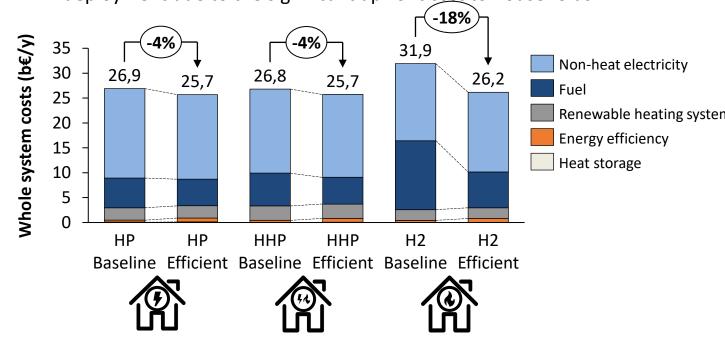
- Energy efficiency upgrades require significant capital outlay, again depending on the size and age of the home and level of retrofit.
- Total outlay of €0.4bn/y in Baseline and €0.8bn/y in Efficient scenarios.







- Installation of energy efficiency measures enables cost savings to the entire energy system.
- Savings depend on the type of renewable heating system most commonly deployed, but are likely to be at least €1,2 bn per year.
- Policy support is needed to achieve these high rates of deployment due to the significant upfront cost to households.



### **Agenda**

Key messages

Impact of ambitious energy efficiency deployment in CZ

Consumer costs of electrification vs hydrogen

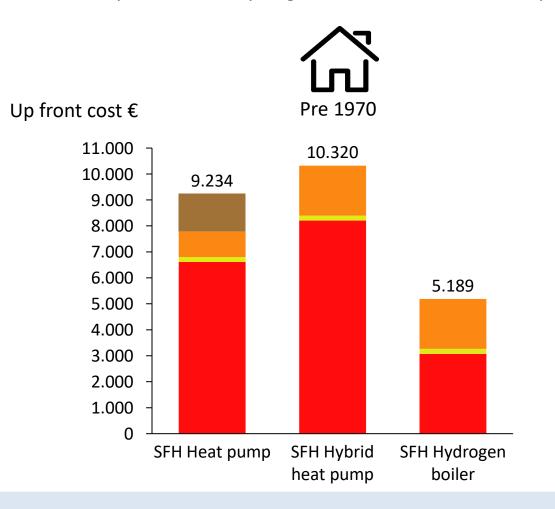
Benefit of smart and flexible operation

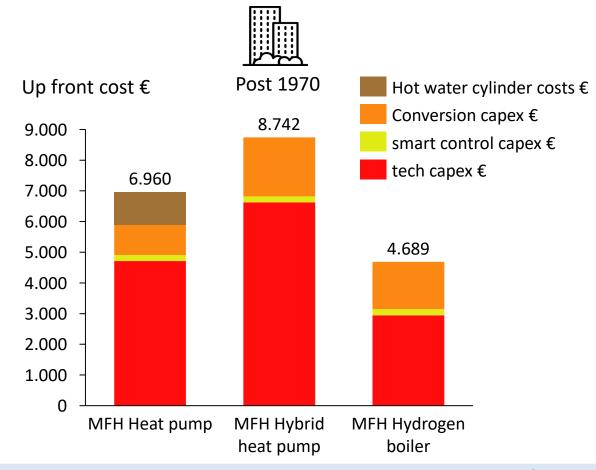
Costs of district heating

# Hydrogen boilers have lower capex than heat pump systems, with hybrid systems most expensive initially



- Hydrogen boilers have the lowest up front cost for consumers out of the three options considered and hybrid heat pumps have the highest up front cost
- In a pre 1970 SFH hydrogen boilers have 44% lower up front cost than heat pumps

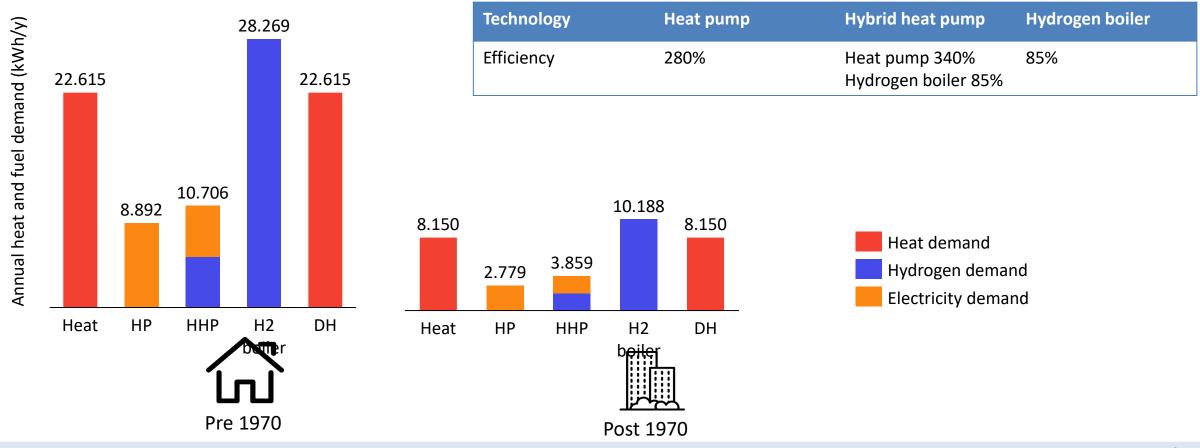




# The fuel demand for HPs is considerably below that for H2 boilers in all archetypes due to system efficiencies



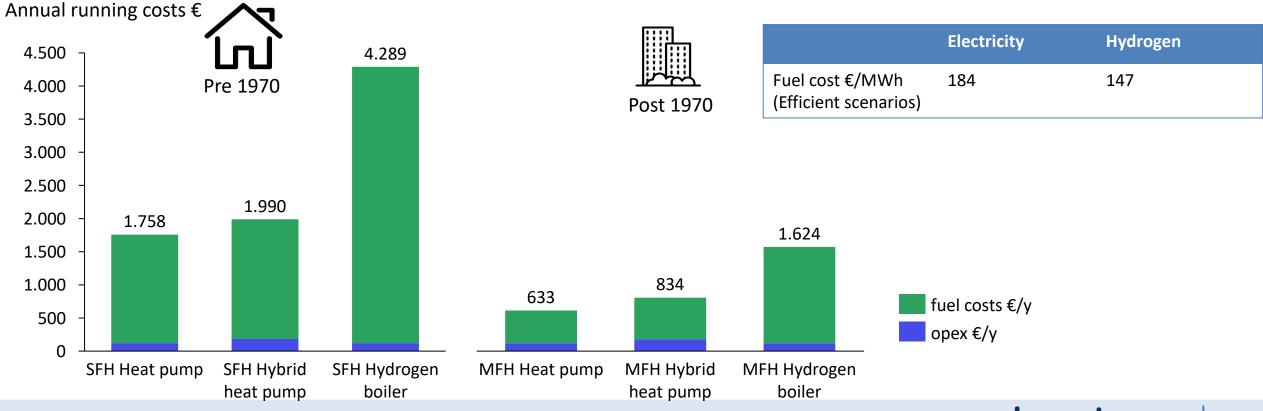
- Heat pumps have the highest efficiency of the technologies considered and so use the least fuel to provide heat
- Using hydrogen boilers typically requires 4.5x as much electricity as using a heat pump, assuming the hydrogen is made via electrolysis



#### Hydrogen boilers have significantly higher running costs than heat pump systems



- Hydrogen boilers typically cost 2.5x as much to run as a heat pump system
- This is because the efficiency of hydrogen boilers is lower, so more fuel is required
- Hydrogen can be cheaper than electricity, but not enough to outweigh the higher consumption
- Hydrogen will be more expensive than gas is today

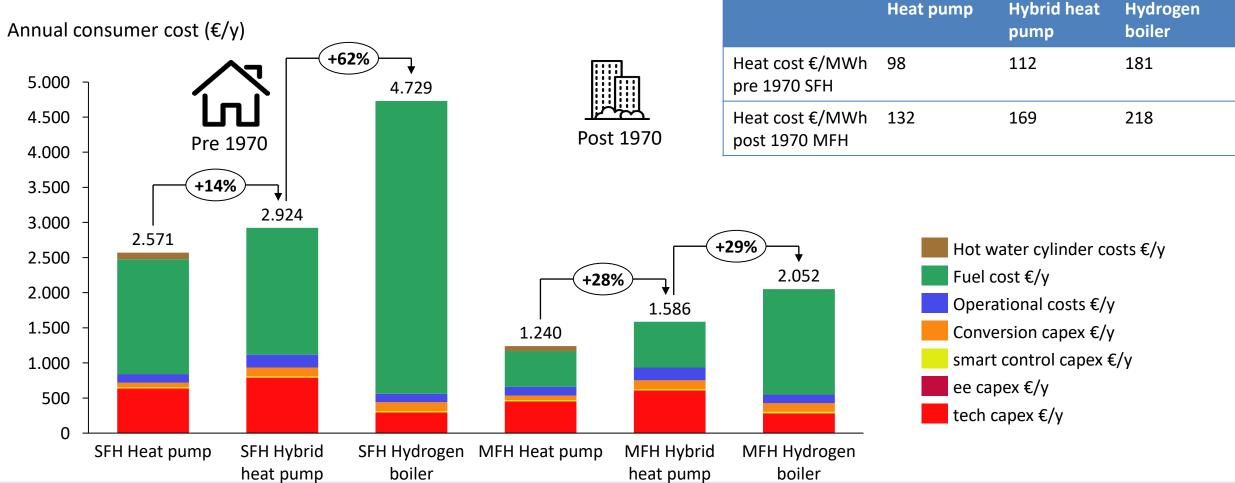


## Heat pumps are less costly for consumers than hydrogen, with hybrid heat pumps in between



High prevalence of heat pumps will lead to the lowest costs of heating for consumers, with hydrogen boilers leading to

additional costs of about 1.8x per unit of heat



### **Agenda**

#### Key messages

Impact of ambitious energy efficiency deployment in CZ

Consumer costs of electrification vs hydrogen

Benefit of smart and flexible operation

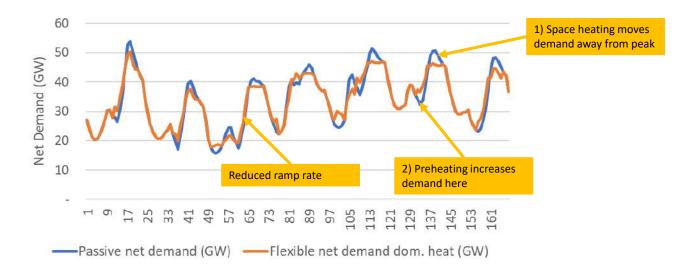
Costs of district heating

# In the Smart/Efficient scenario, heating systems thermal comfort to occupants while also responding to the needs of the energy system

		Baseline – Passive	Efficient – Smart
Energy efficiency	(A) B)	• 2% per annum renovation rate (2025-2040)	• 4% per annum renovation rate (2025-2040)
Heating operation		<ul> <li>Passive operation to supply building heat demand</li> <li>Static electricity tariffs</li> </ul>	<ul> <li>Smart operation and interaction with energy system</li> <li>Incentives for dynamic operation of heating</li> </ul>
HPs	•	Usage profile based on heat demand	<ul> <li>Flexible usage profile supplying heat while mitigating system impacts</li> <li>Improved energy efficiency increases opportunities for flexible operation</li> </ul>
HHPs	44	Boiler operated to supply building peak heat demand	Boiler operated to mitigate system impacts and to supply building peak heat demand
GH <sub>2</sub>		Hydrogen <b>generated and stored</b> to supply heat demands	<ul> <li>Hydrogen generated and stored to supply heat demands and mitigate system impacts</li> <li>Increased energy efficiency reduces heat demand</li> </ul>
DH		Energy plant and thermal storage used to supply heat demands	<ul> <li>Energy plant and thermal storage used to supply heat demands and mitigate system impacts</li> </ul>

#### How does smart operation of heating help the energy system?

- Smart operation of heat pumps acts to move demand away from the peak demand
- This means the total installed capacity of electricity generation can be lower, and less upgrade to higher capacity networks is required
- In addition the use of technologies can better map to periods of excess demand of renewable generation leading to higher load factors of these technologies and less thermal generation
- Example plot, to be updated with data from CZ:

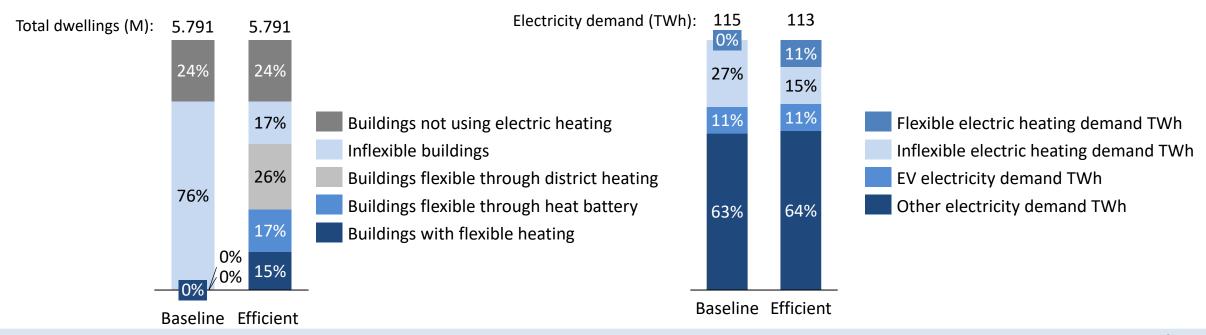


# Flexible electricity demand makes up a large fraction of heating electricity demand, but a smaller fraction of total electricity demand



#### Flexible stock and heating demand in the Heat pump scenario

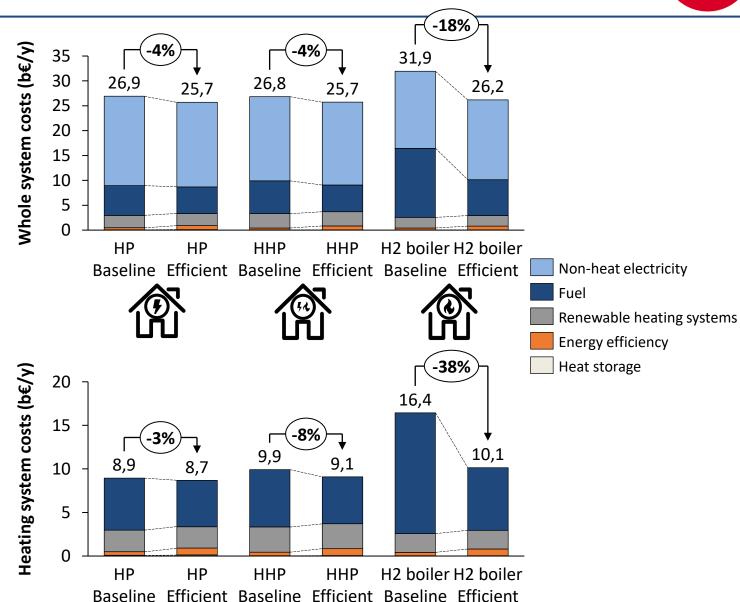
- In dwellings in Czechia consumers can provide flexibility via thermal mass by undergoing a deep retrofit, or consumers can install a heat battery to provide flexibility via thermal storage
- In the Baseline scenario flexibility is only provided via electric vehicle charging
- In the Efficient scenario flexibility is provided via electric vehicle charging, district heating, and flexible operation of buildings
  using building thermal mass and thermal storage
- In the heat pump scenario 58% of the building stock provides flexibility to the system via heating



## In the Czech Republic, the whole system costs are always lower in the efficient compared to the baseline scenario



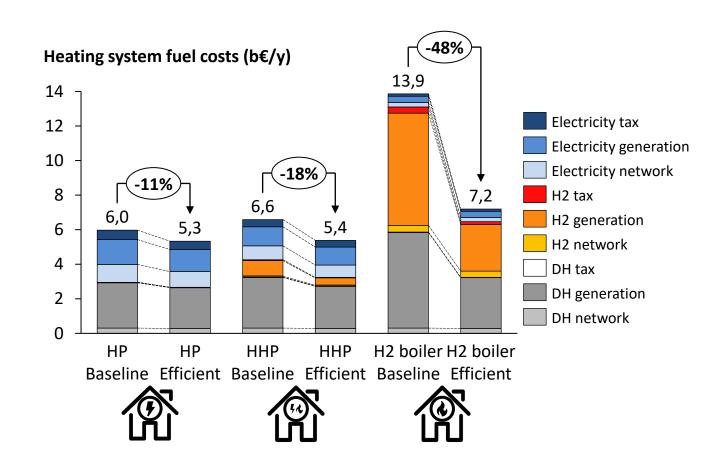
- Across all technology scenarios, the whole system costs decrease in the efficient case compared to the baseline. This effect is most significant in the hydrogen-led scenario.
- In the baseline, the heat pump-led scenario
  has the lowest whole system costs, with 40%
  lower costs than the hydrogen-led scenario (26
  compared to € 36 b/y).
- In the efficient case, the total system costs are similar across all scenarios with the heat pump case being fractionally the lowest.
- When the system benefits are only shared across the heat sector the heat pump case has 0.4b€/y lower costs than the next cheapest scenario.
- The costs shown are from the system perspective, rather than the consumer perspective.



#### In the Czech Republic, significant system cost savings are made by using flexibility



- The heating system fuel costs are significantly lower in the efficient scenarios relative to the baseline case.
- The majority of the savings come from lower electricity generation costs.
- The costs shown are from the system perspective, rather than the consumer perspective.



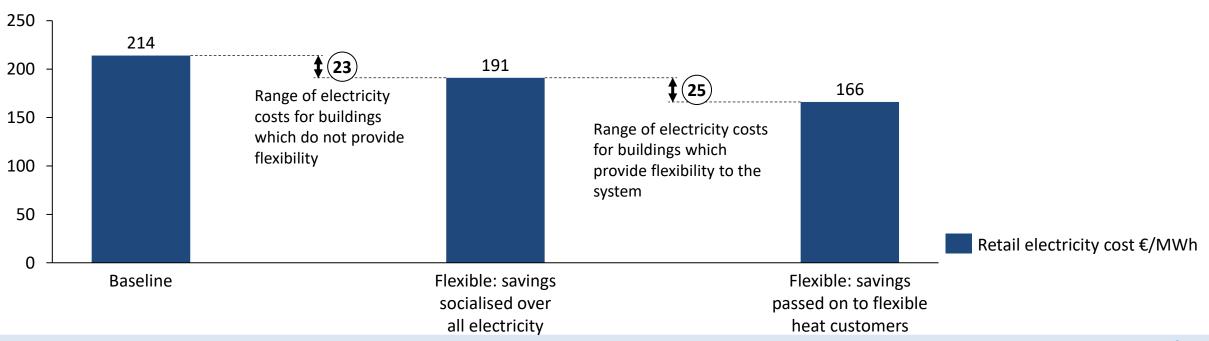
### System savings from flexibility can be shared in different ways with consumer



- Both consumers who provide flexibility and those who don't can benefit from system flexibility
- Fuel cost savings could be distributed in different ways:

€/MWh

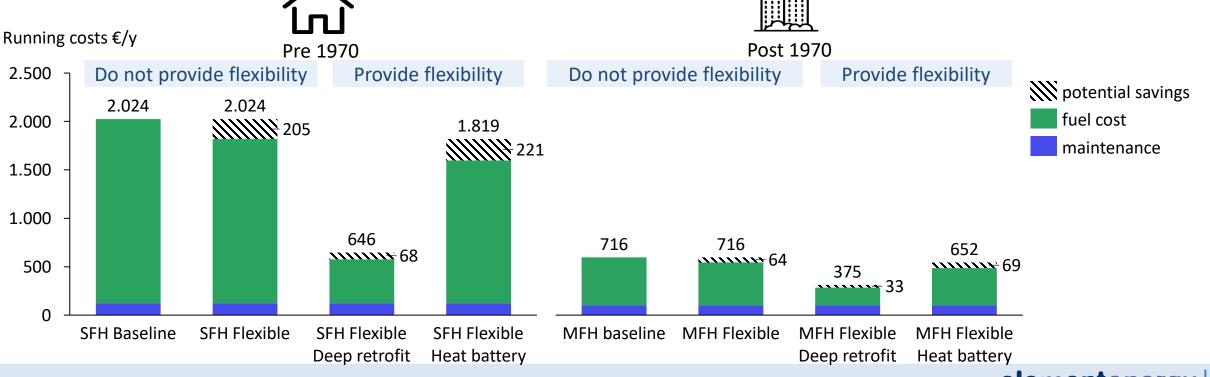
- Savings could be passed on to consumers who provide flexibility, e.g. with time-of-use tariffs or payments for reducing demand at peak times
- Savings could be socialised over all heating electricity demand
- The range of possible savings are demonstrated via a minimum and maximum fuel cost for each building type with the real savings likely to fall somewhere between the two limits



## Heat pump running costs in different households will depend on how flexibility is rewarded



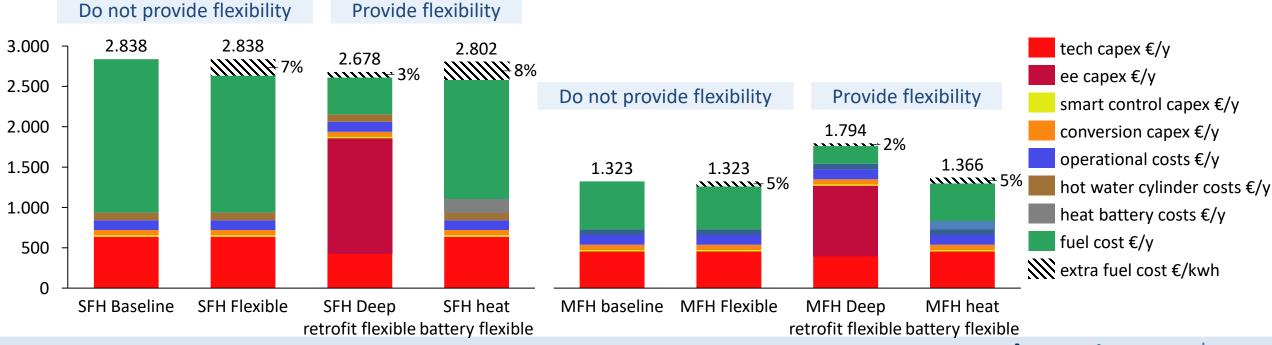
- The dashed bars show the range of different fuel costs that consumers might pay in different circumstances, the minimum and maximum fuel costs that these represent are shown on the previous slide
- If the benefits are fully socialised, larger homes may save around €200/y, with flats saving about €65/y
- If savings are directed towards the households providing flexibility, large flexible households may save a further €220/y, for total savings of €420/y over the Baseline case
- Similarly, flexible flats may save up to €130/h
- Buildings which have been retrofit may see reduced savings due to their reduced energy demand it is important policy and the market mechanisms for flexibility are designed to incentivise energy efficiency retrofit



#### Providing flexibility can lead to cost savings for consumers in the heat pump scenario



- Both consumers who provide flexibility and those who don't can benefit from system flexibility
- The dashed bars show the range of different fuel costs that consumers might pay in different circumstances, the minimum and maximum fuel costs that these represent are shown on the previous slides
- In SFH there are always system savings from flexibility relative to the baseline, but in MFH grants for EE or heat batteries may
  be needed in so that flexibility savings can be passed onto consumers



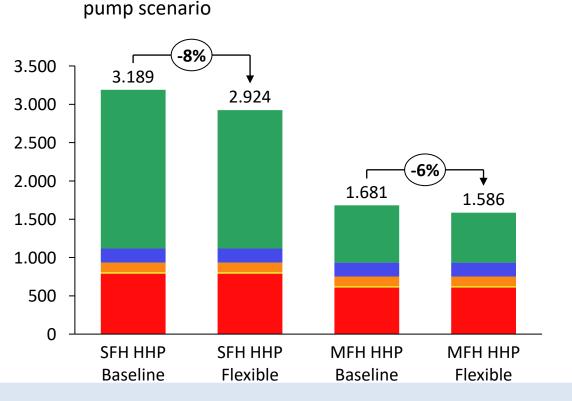
## In the hybrid heat pump and hydrogen scenarios providing flexibility can lead to savings for consumers

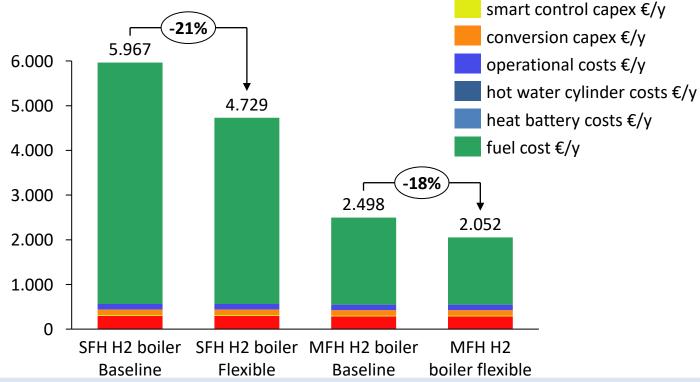


- There are more significant savings for consumers to be made from flexibility in the hybrid heat pump and hydrogen scenarios
- This is because operating electrolysers flexibly brings more system benefit than flexible operation of heat pumps

Operating hybrid heat pumps flexibly could help consumers save up to 8% on their total cost of heating, and operating electrolysers flexibly to produce hydrogen could save consumers up to 21% relative to the baseline

Even with flexibility, the annual costs to consumers are higher with these technologies than in the heat





tech capex €/y

ee capex €/y

### **Agenda**

#### Key messages

Impact of ambitious energy efficiency deployment in CZ

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**Costs of district heating** 

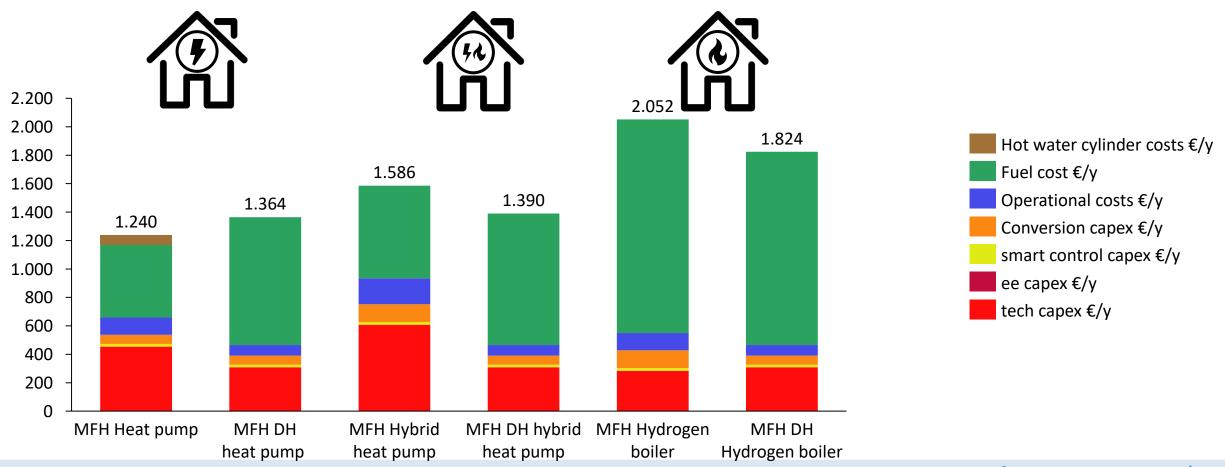
#### **HPs are also cheaper for DH than H2**

- Gas and oil CHPs will have to phased out
- DH can aid/accelerate decarbonisation because it's easier to replace fewer larger heat generators
- Waste heat can be very cost effective
- Some waste heat can be used directly, other waste heat will require temperature increase with heat pumps
- We have not assumed significant waste heat usage in the current analysis
- Further comments on consumer protections to be added in text

### District heating has similar costs for consumers but provides more system flexibility



- Heat pumps are the most cost effective way of decarbonising existing heat networks
- District heating costs around the same or less than building level heating depending on the scenario, and can be a cost effective way to provide system flexibility, especially in multi family homes



### **Spain**

#### Key messages

Intro & method

Energy efficiency deployment in ES

Consumer costs of electrification vs hydrogen

Benefit of smart and flexible operation

Costs of district heating

#### **Key messages for Spain**



- Heat pumps are the cheapest way to decarbonise heat for consumers, they are typically 30% cheaper than Hybrid heat pumps and 60% cheaper than hydrogen boilers.
- Operating the energy system flexibly lowers the total energy system cost by 1% in a high heat pump scenario, this saving can be
  passed on to consumers.
- Installing energy efficiency can increase costs for consumers in the average dwelling due to a relatively low annual heating demand, but can provide system-wide savings due to increasing the proportion of buildings that can operate their heating flexibly.
- Installing additional thermal storage to provide system flexibility is cost effective for the system and so consumers should be rewarded for providing this service to the energy system.
- District heating in both high and low DH rollout scenarios is of comparable cost to building level heating systems, but provides a
  higher level of system flexibility and can be to decarbonise.
- New district heating networks should be designed and constructed to be low carbon from the start.

### **Agenda**

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#### Intro & method

Energy efficiency deployment in ES

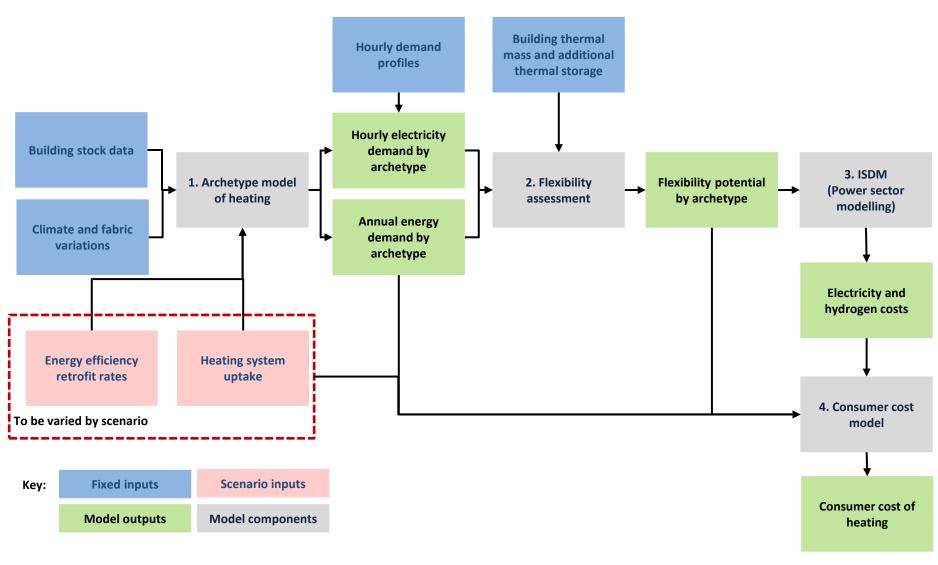
Consumer costs of electrification vs hydrogen

Benefit of smart and flexible operation

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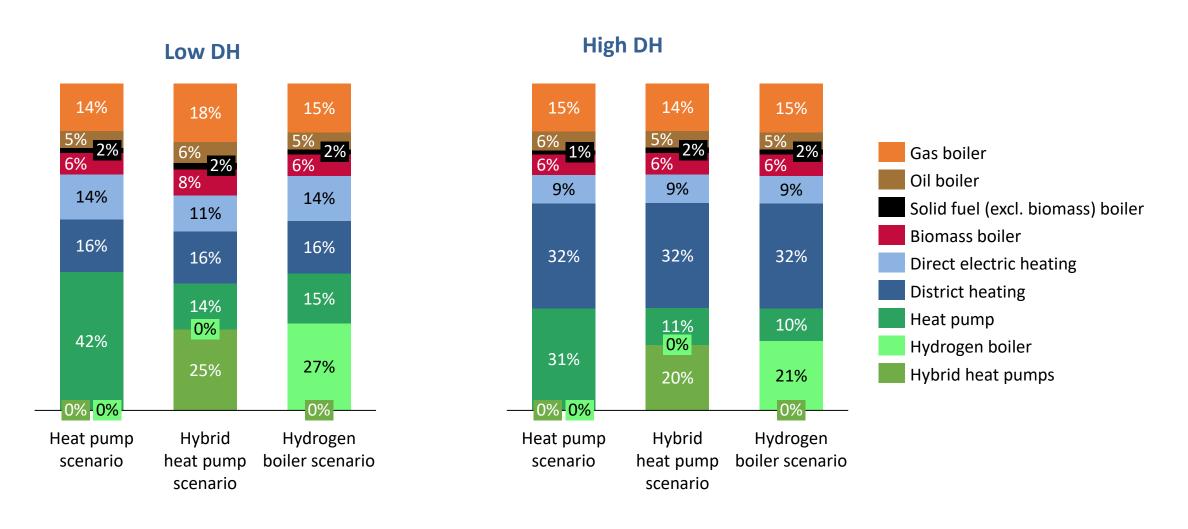
#### Overview of modelling methodology

- 1. The archetype stock model calculates the heat demand and final energy consumption on an annual and hourly basis for domestic dwellings in Spain. The outputs are generated at the building level and at the country-level (i.e. including all buildings). Nondomestic buildings are included in the national demand although they are addressed with less detail than the residential stock.
- 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 Spain's energy system throughout 2040. The ISDM predicts the retail costs of electricity and green hydrogen.
- The upfront and ongoing costs of heating are calculated by the consumer cost model for the selected Spanish building archetypes.



#### **Technology mix in Spain**





### **Agenda**

Key messages

Intro & method

#### **Energy efficiency deployment in ES**

Consumer costs of electrification vs hydrogen

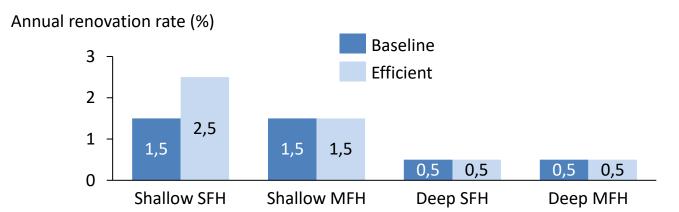
Benefit of smart and flexible operation

Costs of district heating

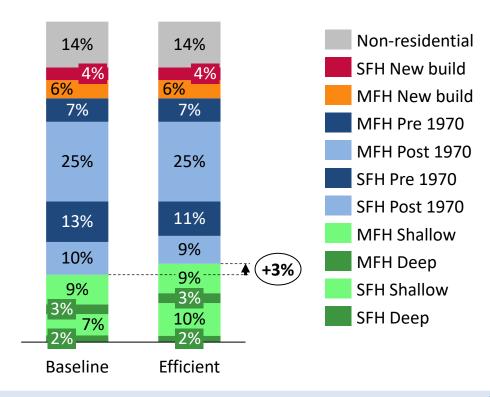
#### **Energy efficiency scenarios**



- 2 scenarios analysed
- Current renovation rate applied to 2025
- Higher rates below applied 2025-2040 higher rates chosen where additional retrofit benefits the system by providing flexibility
- Baseline scenarios at 2% renovations per year is already ambitious
- In the Efficient scenario, the rate of shallow renovations to SFH has been increased from 1.5% to 2.5% per year.
- With a shallow renovation, SFH can provide flexibility, when the building wasn't flexible previously.



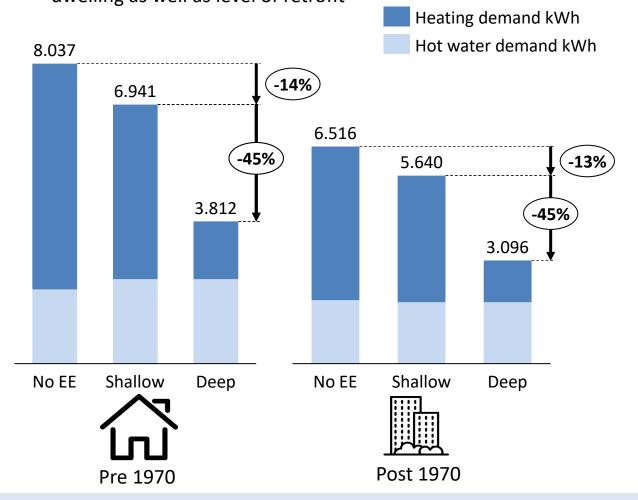
- 21% of homes renovated in Baseline scenario
- Rising to 24% in the Efficient scenario



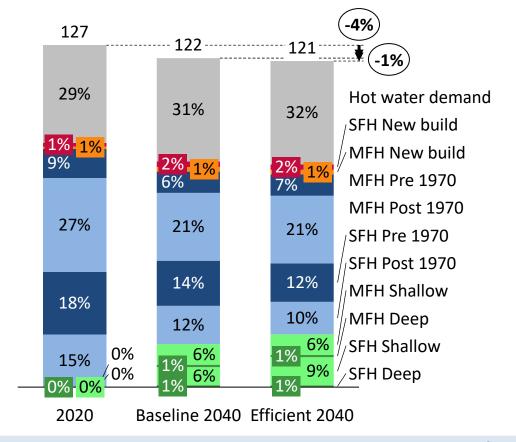
#### **Heat demand savings**



Savings in heat demand depend on size and age of the dwelling as well as level of retrofit



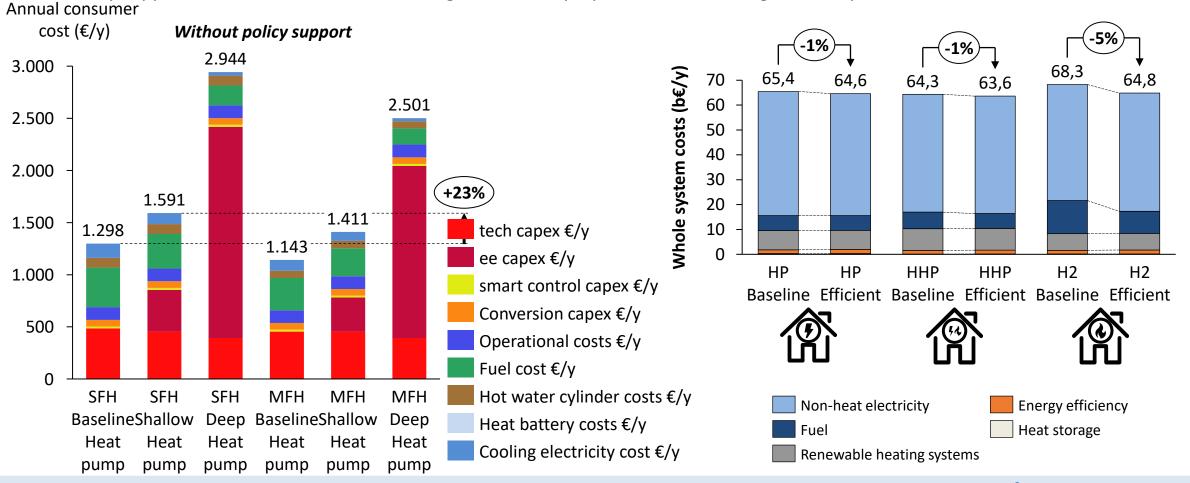
- Total heat demand savings of 5 TWh in Baseline scenario, with further 1 TWh in Efficient scenario.
- 1% reduction between Baseline and Efficient scenarios.



#### Costs and savings of energy efficiency measures



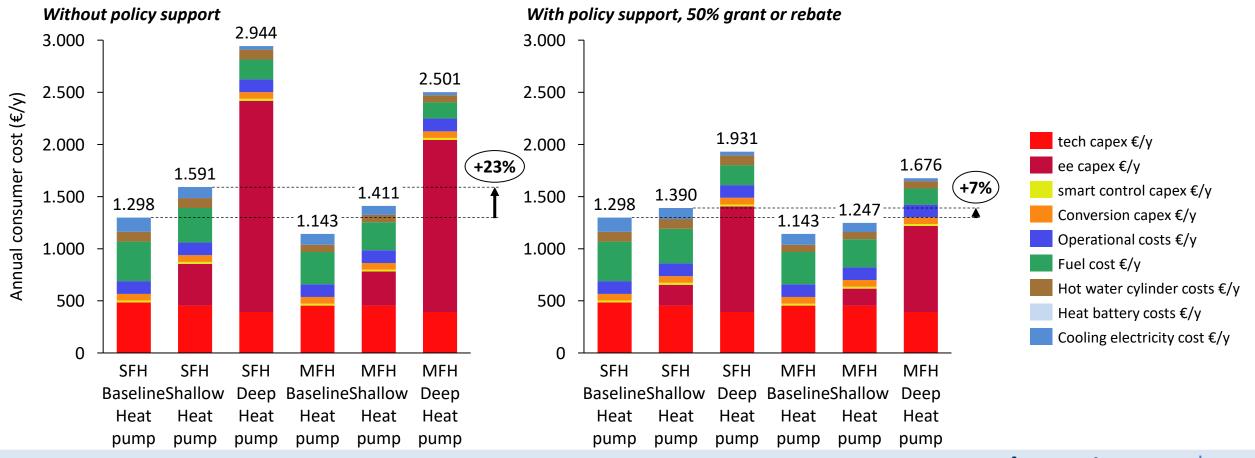
- Installation of energy efficiency measures enables cost savings to the entire energy system.
- Savings depend on the type of renewable heating system most commonly deployed, but are likely to be at least €0.8 bn per year.
- Policy support is needed to achieve these high rates of deployment due to the significant upfront cost to households.



#### Costs and savings of energy efficiency measures with policy support



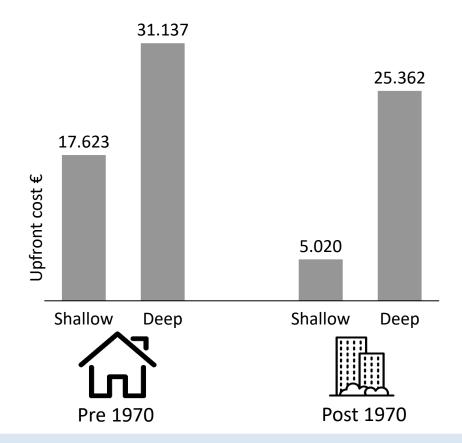
- Policy support is needed to achieve these high rates of deployment due to the significant upfront cost to households.
- With a 50% public subsidy, homes that adopt a shallow retrofit see changes to their annual cost of heating of less than 10%.



### **Costs of energy efficiency measures**



- Energy efficiency upgrades require significant capital outlay, again depending on the size and age of the home and level of retrofit.
- Total outlay of €1.5bn/y in Baseline and €1.6bn/y in Efficient scenarios.



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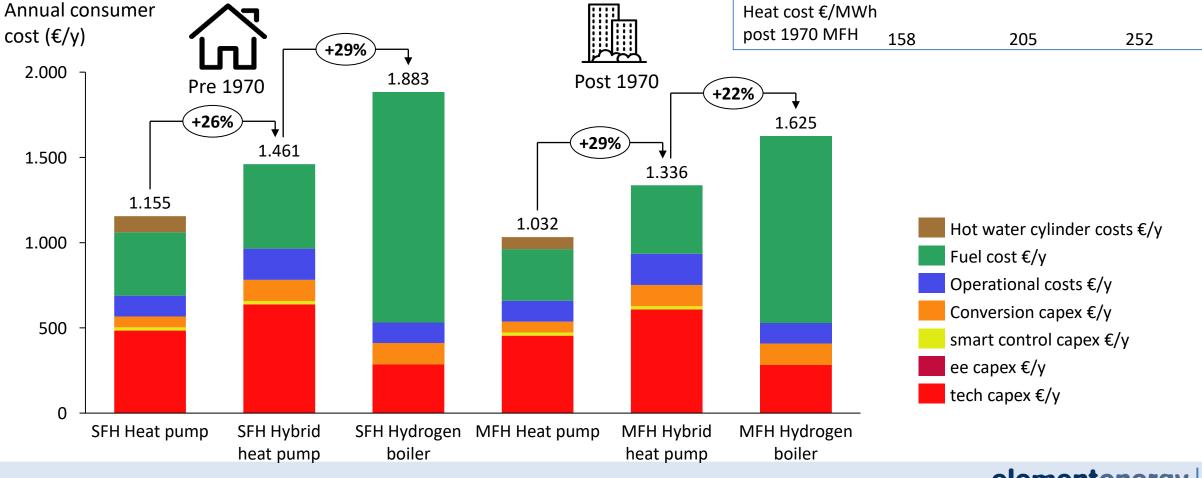
Costs of district heating

## Heat pumps are less costly for consumers than hydrogen, with hybrid heat pumps in between



 High prevalence of heat pumps will lead to the lowest costs of heating for consumers, with hydrogen boilers leading to additional costs of about 1.6x per unit of heat

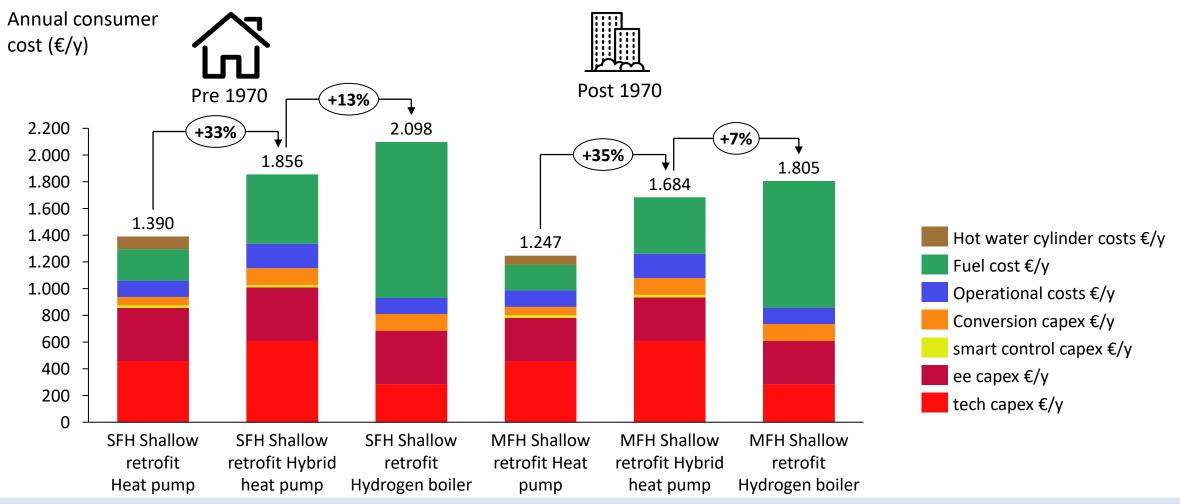
	Heat pump	Hybrid heat pump	Hydrogen boiler
Heat cost €/MWh pre 1970 SFH	144	182	237
Heat cost €/MWh post 1970 MFH	158	205	252



### With shallow packages heat pumps are the most cost effective technology for consumers



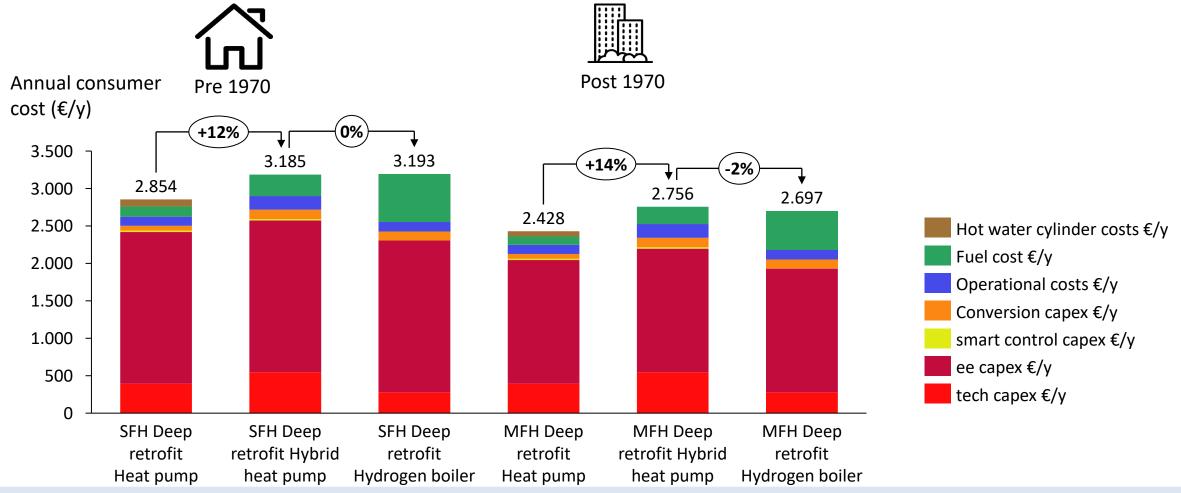
 With shallow packages installed heat pumps are still the most cost effective heating technology for consumers.



## Heat pumps are less costly for consumers than hydrogen, with hybrid heat pumps in between



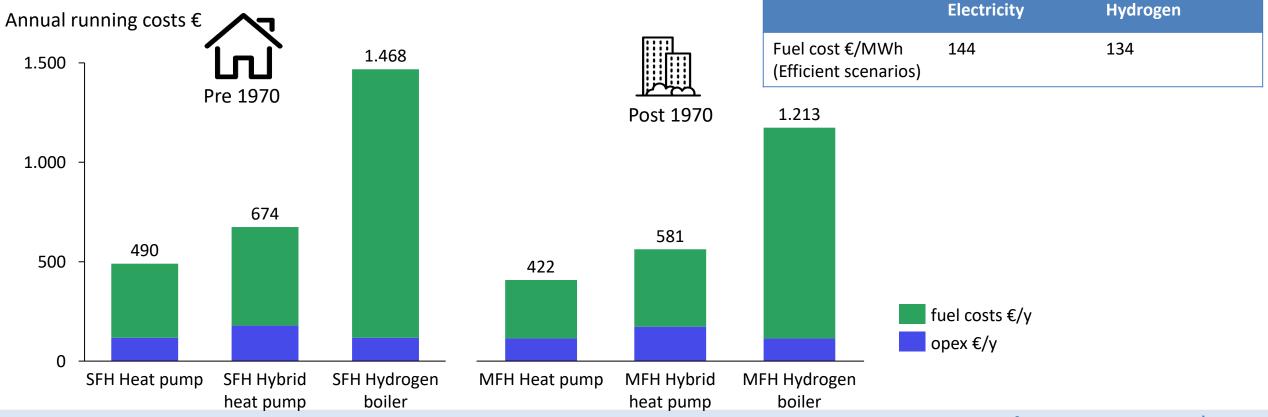
 With Deep packages heat pumps are still the most cost effective technology for consumers in both archetypes although the gap to hydrogen boilers is smaller in.



## Hydrogen boilers have significantly higher running costs than heat pump systems



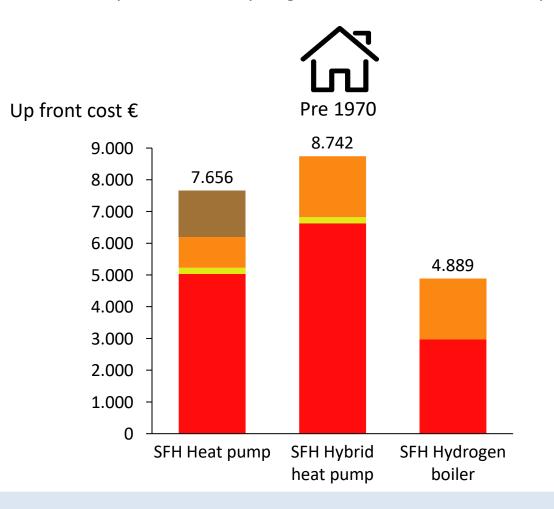
- Hydrogen boilers typically cost 3x as much to run as a heat pump system
- This is because the efficiency of hydrogen boilers is lower, so more fuel is required
- Hydrogen can be cheaper than electricity, but not enough to outweigh the higher consumption
- Hydrogen will be more expensive than gas is today

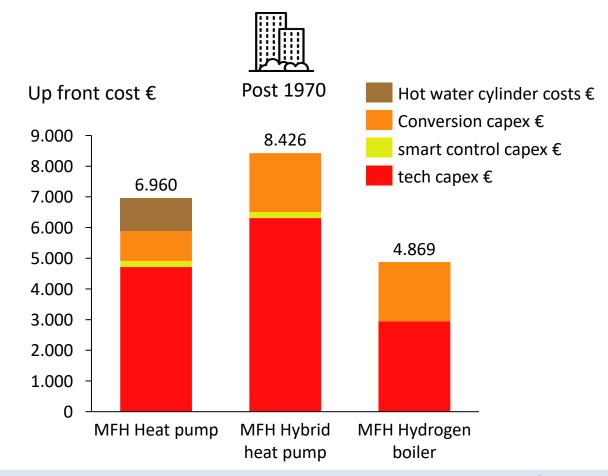


# Hydrogen boilers have lower capex than heat pump systems, with hybrid systems most expensive initially



- Hydrogen boilers have the lowest up front cost for consumers out of the three options considered and hybrid heat pumps have the highest up front cost
- In a pre 1970 SFH hydrogen boilers have 36% lower up front cost than heat pumps





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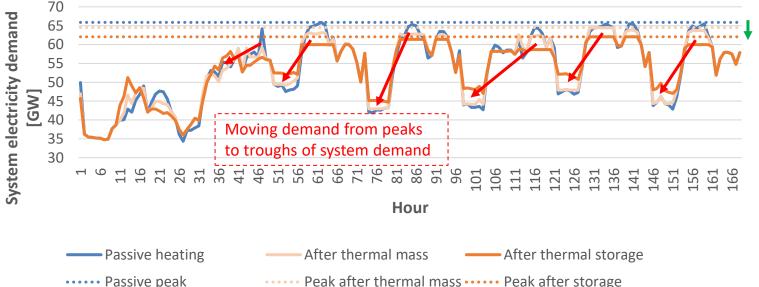
Consumer costs of electrification vs hydrogen

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Costs of district heating

## How does smart operation of heating help the energy system?

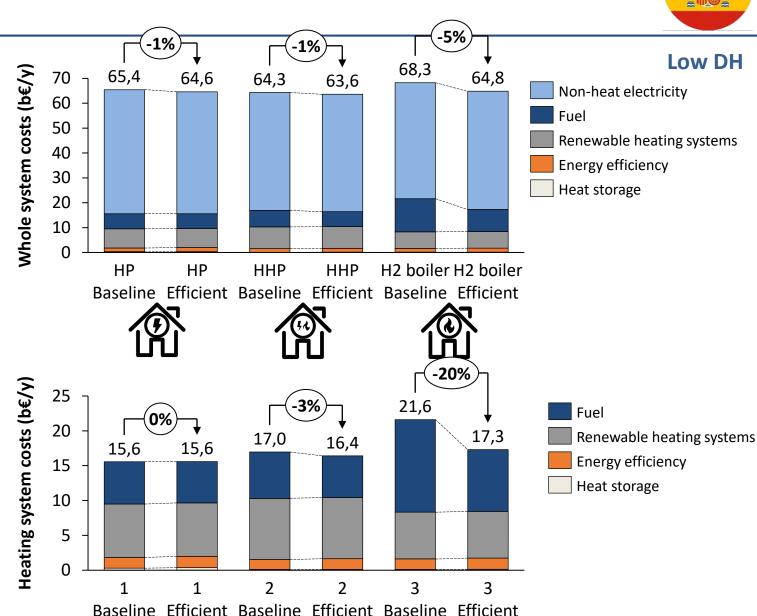
- Uncontrolled operation of heat pumps leads to a high peak demand of the overall electricity system
- Utilising the **flexibility** provided by thermal storage and building thermal mass, smart operation of heat pumps moves demand from hours of high demand to hours of low demand (**from peaks to troughs**, see graph below)
- This reduces the peak demand of the system and thus the required network capacity.
- In our models smart heat pumps are also operated to move their demand to hours of high generation from variable renewable energy sources<sup>1</sup>, to **reduce curtailment** of the electricity they generate and the amount of **dispatchable** generation **capacity** required to ensure security of supply.
- Thermal storage provides a much higher degree of flexibility than thermal mass (see below)
- System peak demand drops from 65.9 MW with passive heating to 64.5 MW when high efficiency buildings are operated flexibly. Flexibility from thermal storage in buildings lowers peak demand further to 62.0 MW.



Peak system
demand is reduced
leading to lower
network capacity
requirements

## Operating the system flexibly gives savings of up to 5%

- Across all technology scenarios, the whole system costs decrease in the Efficient-Smart case compared to the Baseline-Passive. This effect is most significant in the hydrogen-led scenario.
- This is due to a high energy efficiency cost and a mild climate, which means retrofitting buildings in Spain has a comparatively higher cost than in colder countries.
- The heating system costs reduce in the hybrid and hydrogen scenarios while staying constant in the heat pump scenario.
- Some incentives on energy efficiency uptake and smart heating operation will be needed to realise these system savings.
- The benefits brought by the additional flexibility from the renovation still always outweigh the costs of energy efficiency.

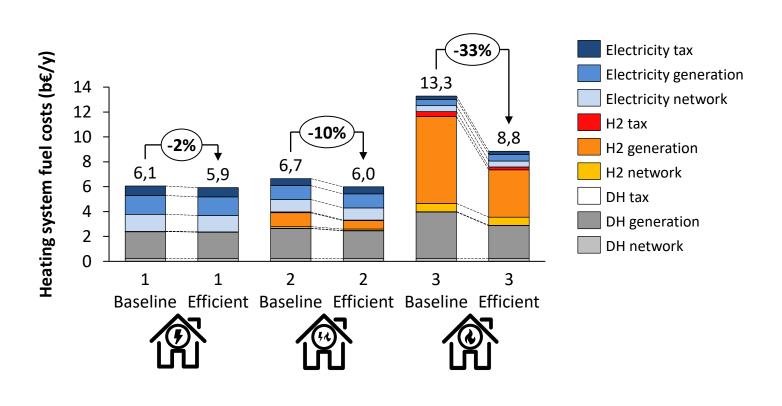


## In Spain, significant hydrogen fuel savings are made in the flexible scenario compared to the baseline



#### **Low DH**

- The "fuel" category has been broken down in its subcomponents to show more detail of how they differ across the various scenarios.
- The fuel subcomponents reported here have been assigned based on the final use technology.
- For example, if electricity is used in a heat pump, it will be logged under electricity. If it is used for generating hydrogen, then used in a hydrogen boiler, it will be logged under hydrogen. If the electricity-generated hydrogen is then used to generate DH heat, it is logged as DH.
- As seen previously, the large decrease in fuel costs in scenario 3 is due to significant hydrogen cost savings in the flexible compared to the baseline case.



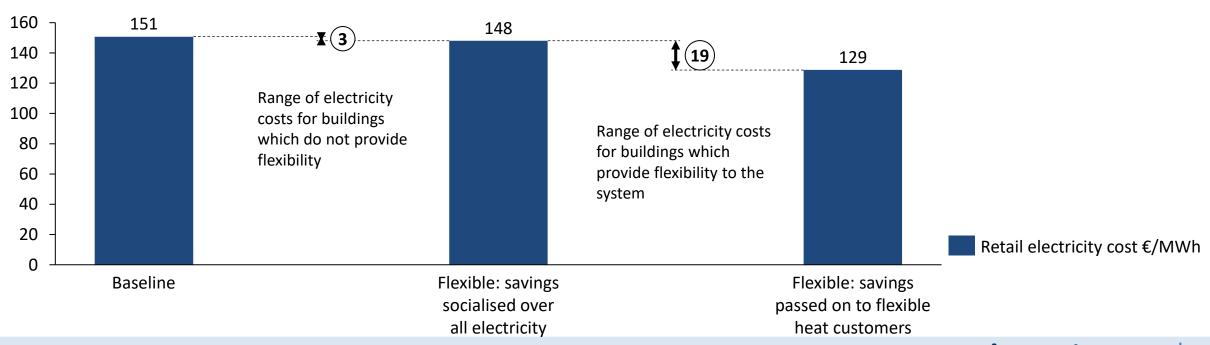
## System savings from flexibility can be shared in different ways with consumer



- Both consumers who provide flexibility and those who don't, can benefit from system flexibility
- Fuel cost savings could be distributed in different ways:

€/MWh

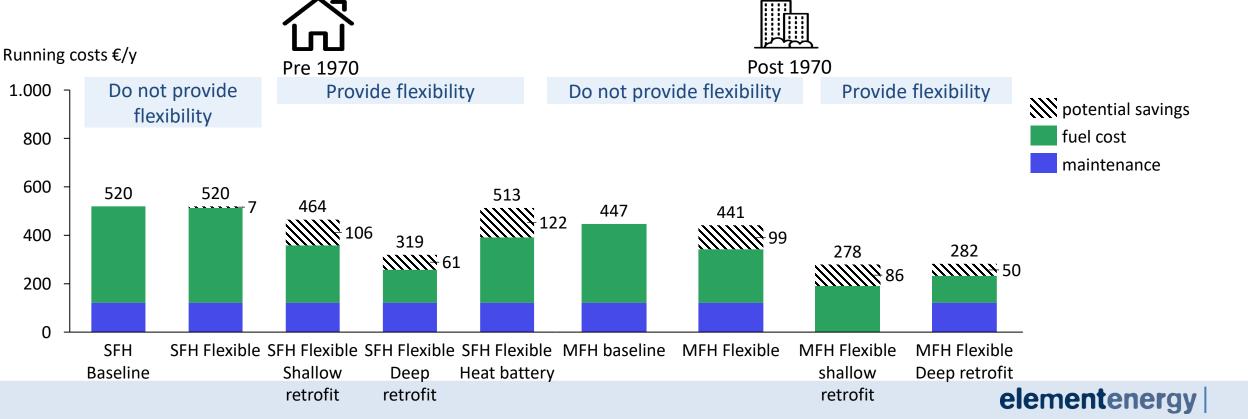
- Savings could be passed on to consumers who provide flexibility, e.g. with time-of-use tariffs or payments for reducing demand at peak times
- Savings could be socialised over all heating electricity demand
- The range of possible savings are demonstrated via a minimum and maximum fuel cost for each building type with the real savings likely to fall somewhere between the two limits



## Heat pump running costs in different households will depend on how flexibility is rewarded



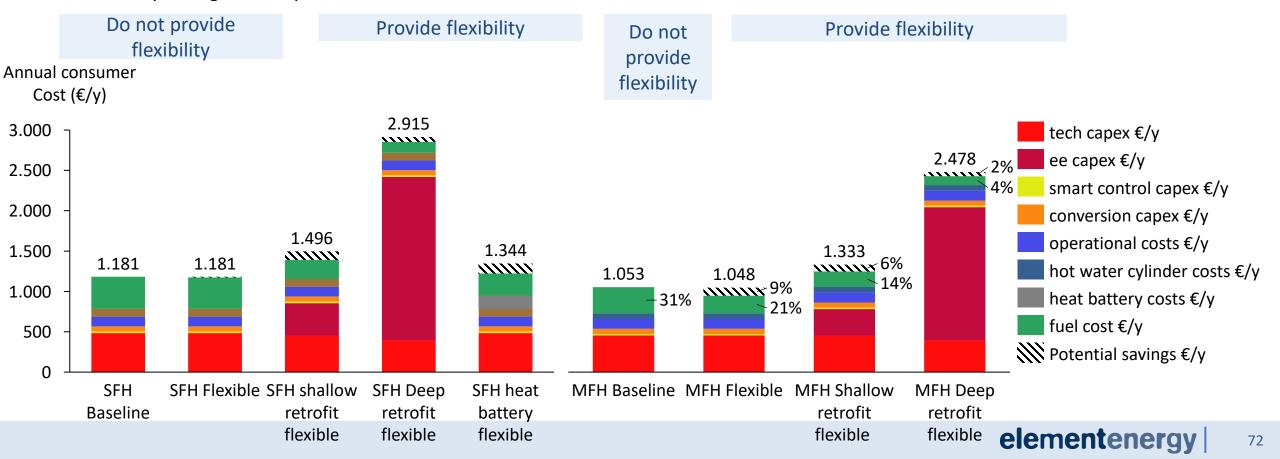
- The dashed bars show the range of different fuel costs that consumers might pay in different circumstances, the minimum and maximum fuel
  costs that these represent are shown on the previous slide
- If the benefits are fully socialised, larger homes and flats may save around €7/y
- If savings are directed towards the households providing flexibility, large flexible households may save a further €122/y, for total savings of €129/y over the Baseline case
- Similarly, flexible flats may save up to €99/y
- Buildings which have been retrofit may see reduced savings due to their reduced energy demand it is important policy and the market mechanisms for flexibility are designed to incentivise energy efficiency retrofit



## Providing flexibility can lead to cost savings for consumers in the heat pump scenario



- Both consumers who provide flexibility and those who don't can benefit from system flexibility
- The dashed bars show the range of different fuel costs that consumers might pay in different circumstances, the minimum and maximum fuel costs that these represent are shown on the previous slides
- Since there is not a saving from providing flexibility in every case grants for EE or heat batteries may be needed in so that flexibility savings can be passed onto consumers



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**Costs of district heating** 

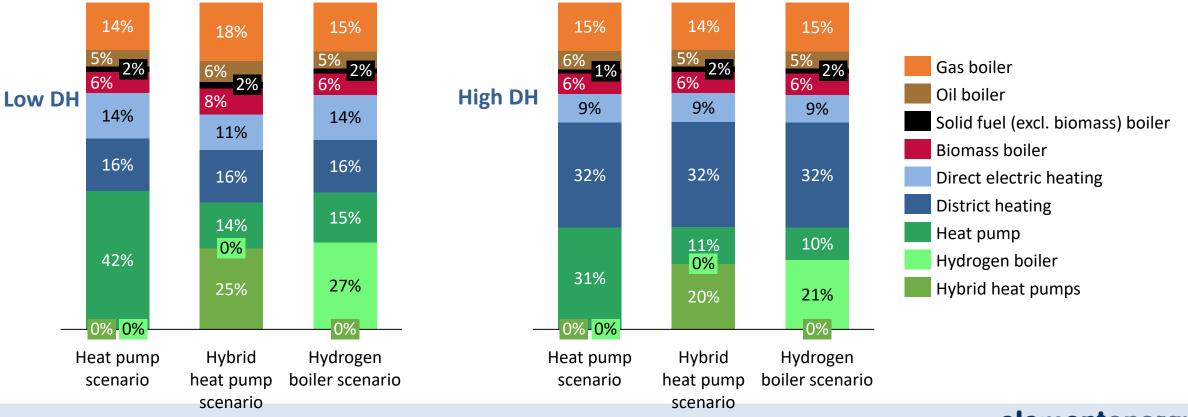
## We consider a sensitivity with increase DH uptake in Spain – 32% of homes vs 16% in the central case

- Benefits/pitfalls of DH
  - Consumer issues
  - Greater flexibility
  - Technology agnostic
  - Less in-home disruption, although higher public realm disruption
  - Requires coordination and funding for implementation
- DH should be built to be low carbon from the start
- Existing DH will need to be supported to transition to low carbon technologies
- Waste heat can be very cost effective
- Some waste heat can be used directly, other waste heat will require temperature increase with heat pumps
- We have not assumed significant waste heat usage in the current analysis
- Further comments on consumer protections to be added in text

## Heating system uptake under low and high DH scenarios

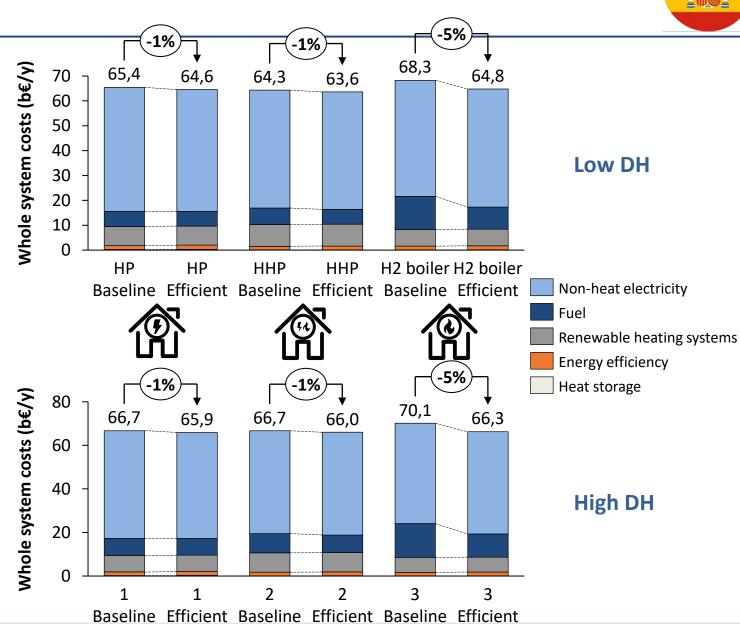


- The heat sources used in DH depend on the technology scenario.
- Extending DH uptake to 32% involves construction of DH in areas that are less heat-dense. These are likely to be in smaller cities and large towns, while in the low DH case DH will be more concentrated in large cities.



# In Spain, a lower DH uptake leads to a reduction in whole system costs as DH is only taken up where most cost-effective

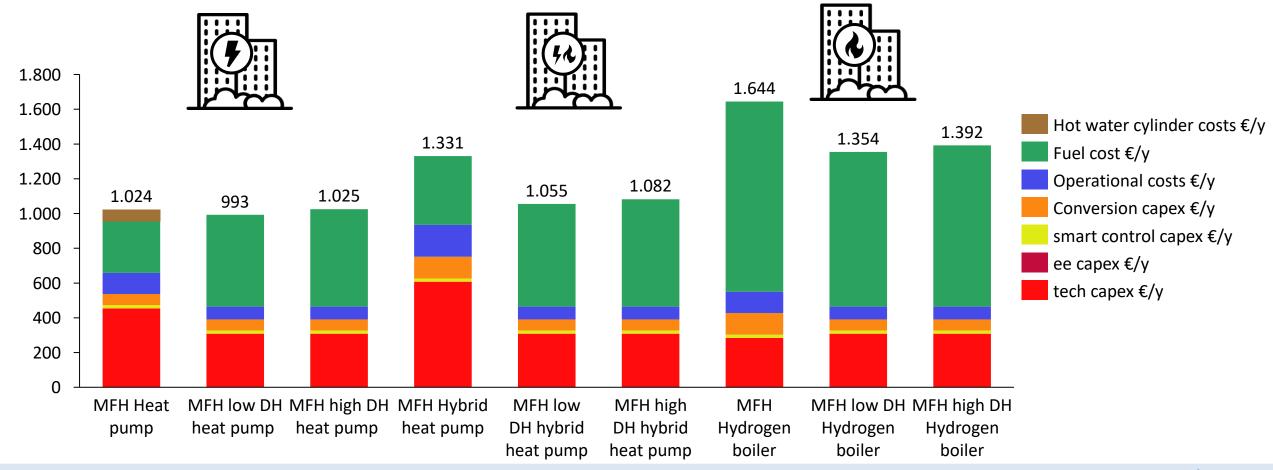
- The results reported in this slide show the whole system cost difference between the higher and lower DH uptake in ES.
- The main difference between the higher and lower DH penetration scenarios in Spain is a decrease in total costs in the lower DH uptake case.
- This is because DH is assume to be taken first where it is most economical. Therefore, DH added only in the higher DH scenario will be less cost effective that that added in both scenarios
- It leads to an overall whole system cost increase as it is also more expensive than other heating systems alternatives.



## District heating has similar costs for consumers but provides more system flexibility



- Heat pumps provide the most cost effective heat source for decarbonised heat networks.
- District heating costs around the same or less than building level heating depending on the scenario, and can be a cost effective
  way to provide system flexibility, especially in multi family homes.
- Trends shown below would be consistent with higher levels of energy efficiency.



## Italy

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## Key messages for Italy



- Heat pumps are the cheapest way to decarbonise heat for consumers, they are typically 35% cheaper than Hybrid heat pumps and 142% cheaper than hydrogen boilers
- Operating the energy system flexibly lowers the total energy system cost by 4% in a high heat pump scenario, this saving can be
  passed on to consumers
- Installing energy efficiency can increase costs for consumers in the average dwelling due to a relatively low annual heating demand, but can provide system-wide savings due to additional flexible stock
- Installing additional thermal storage to provide system flexibility is cost effective for the system and so consumers should be rewarded for providing this service to the energy system
- District heating is of comparable cost to building level heating systems, but provides flexibility and is easier to decarbonise, so decarbonising existing district heating networks has significant consumer benefit

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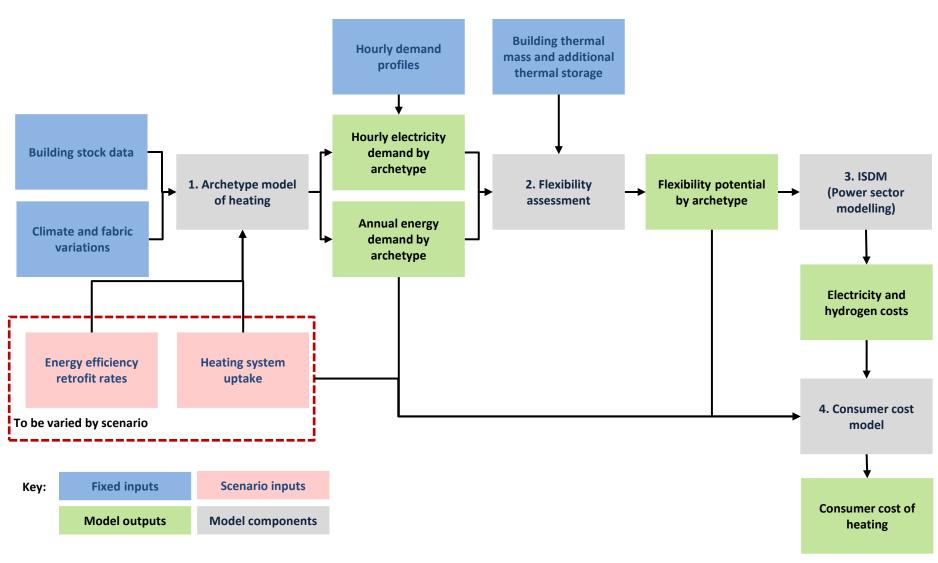
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For technical annex

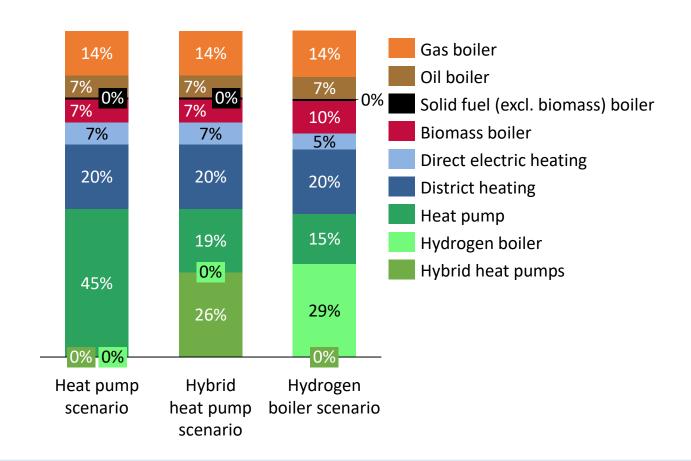
## Overview of modelling methodology

- 1. The archetype stock model calculates the heat demand and final energy consumption on an annual and hourly basis for domestic dwellings in Spain. The outputs are generated at the building level and at the country-level (i.e. including all buildings). Nondomestic buildings are included in the national demand although they are addressed with less detail than the residential stock.
- 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 Spain's energy system throughout 2040. The ISDM predicts the retail costs of electricity and green hydrogen.
- The upfront and ongoing costs of heating are calculated by the consumer cost model for the selected Spanish building archetypes.



## **Technology mix**





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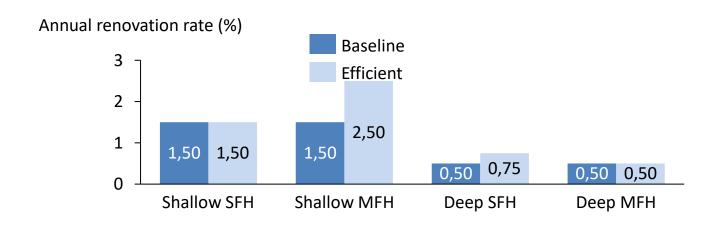
Benefit of smart and flexible operation

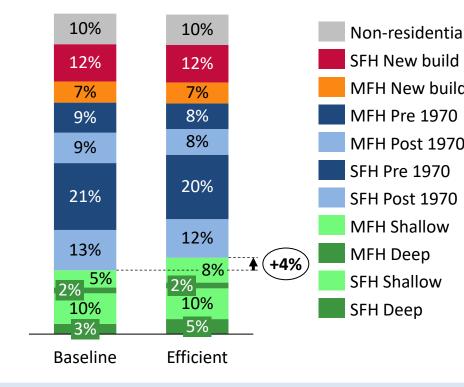
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## **Energy efficiency scenarios**

- 2 scenarios analysed
- Current renovation rate applied to 2025
- Higher rates below applied 2025-2040 higher rates chosen where additional retrofit benefits the system by providing flexibility
- Baseline scenarios at 2% renovations per year is already ambitious

- 20% of homes renovated in Baseline scenario
- Rising to 24% in the Efficient scenario

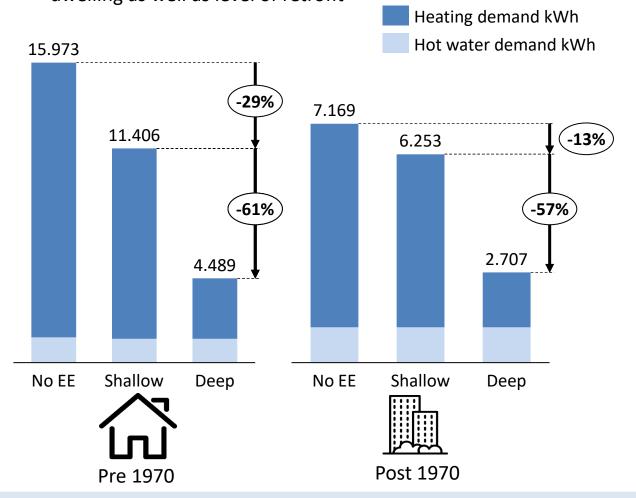




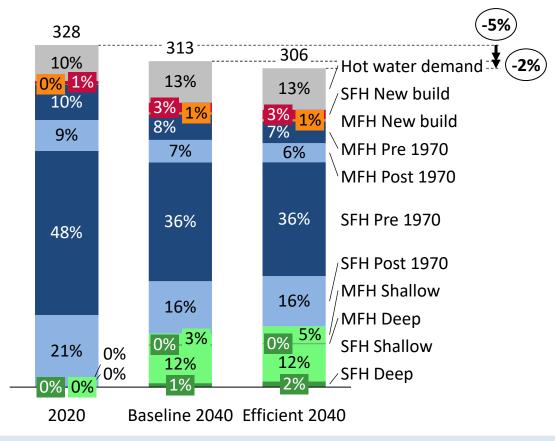
## **Heat demand savings**



 Savings in heat demand depend on size and age of the dwelling as well as level of retrofit



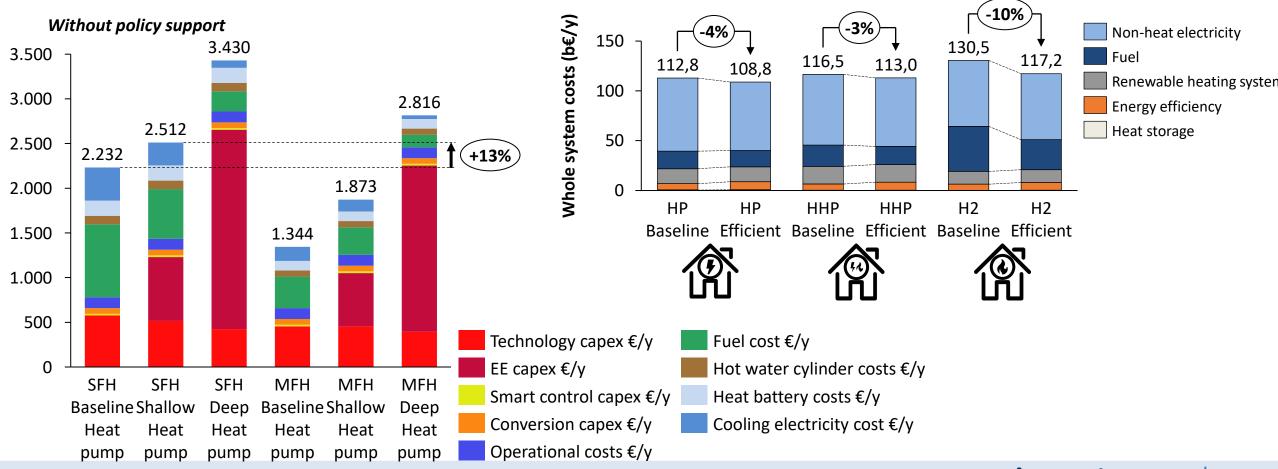
- Total heat demand savings of 15 TWh in Baseline scenario, with further 7 TWh in Efficient scenario.
- 2% reduction between Baseline and Efficient scenarios.



## **Costs and savings of energy efficiency measures**



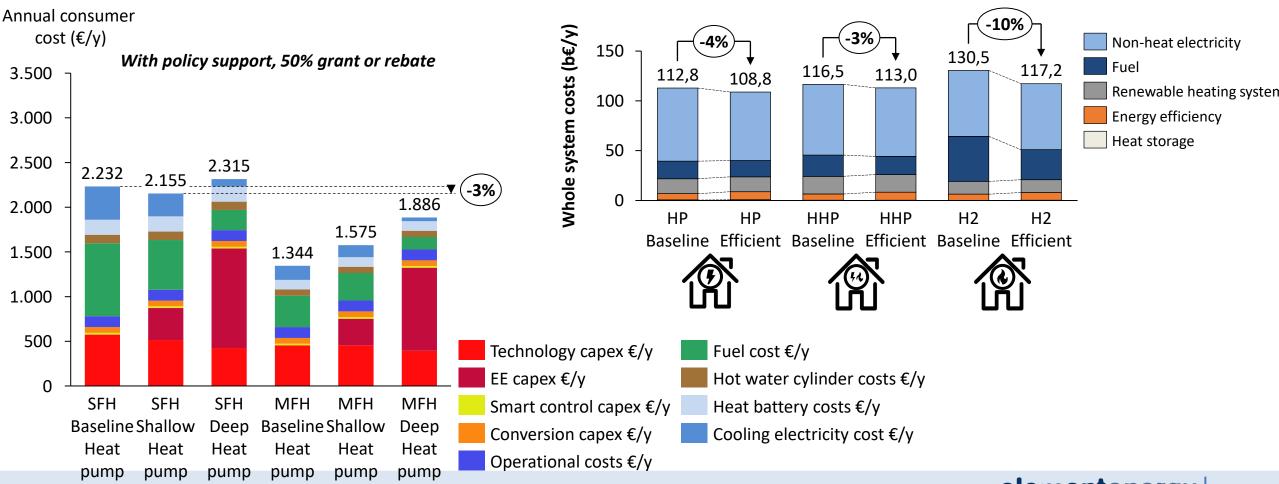
- Installation of energy efficiency measures enables cost savings to the entire energy system.
- Savings depend on the type of renewable heating system most commonly deployed, but are likely to be at least €4 bn per year.
- Policy support is needed to achieve these high rates of deployment due to the significant upfront cost to households.



## Costs and savings of energy efficiency measures with policy support



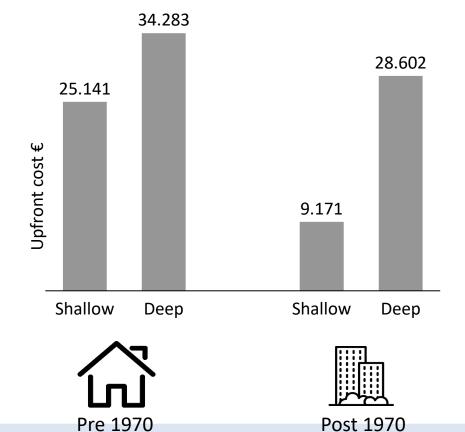
- Installation of energy efficiency measures enables cost savings to the entire energy system.
- Policy support is needed to achieve these high rates of deployment due to the significant upfront cost to households.
- With a 50% public subsidy, pre 1970 single family homes with a shallow retrofit see annual cost savings of about €80/y.



## **Cost of energy efficiency measures**



- Energy efficiency upgrades require significant capital outlay, again depending on the size and age of the home and level of retrofit.
- Total outlay of €6.3bn/y in Baseline and €8.0bn/y in Efficient scenarios.



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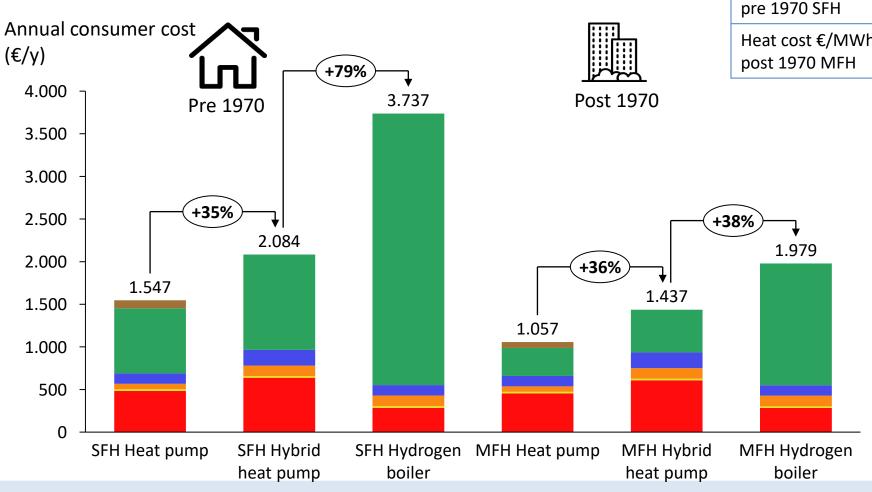
Costs of district heating

For technical annex

## Heat pumps are less costly for consumers than hydrogen, with hybrid heat pumps in between



 High prevalence of heat pumps will lead to the lowest costs of heating for consumers, with hydrogen boilers leading to additional costs of about 2.4x per unit of heat



	Heat pump	Hybrid heat pump	Hydrogen boiler
Heat cost €/MWh pre 1970 SFH	97	130	234
Heat cost €/MWh post 1970 MFH	147	200	276

Fuel cost €/y

ee capex €/y

tech capex €/y

Hot water cylinder costs €/y

Operational costs €/y

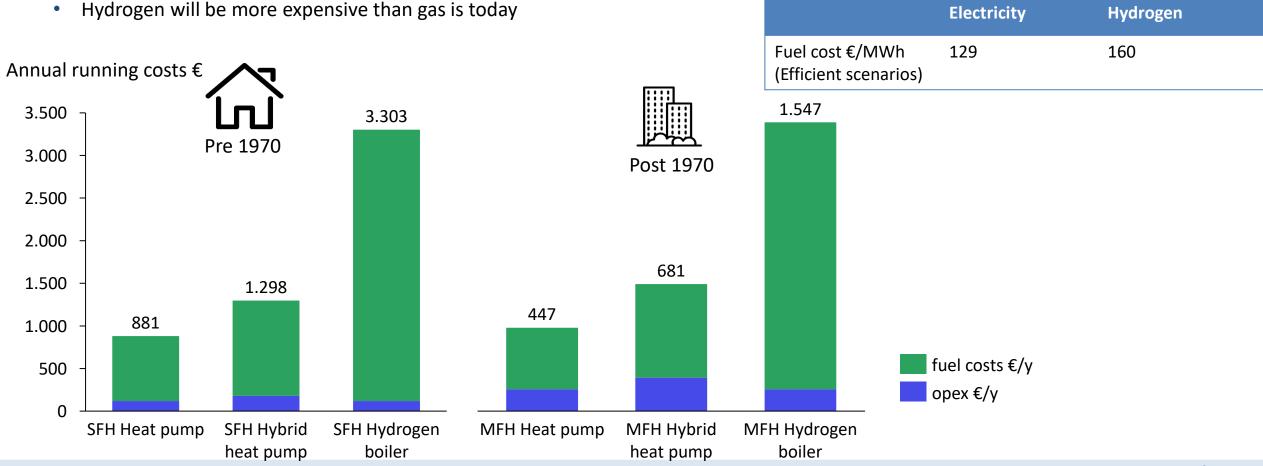
Conversion capex €/y

smart control capex €/y

## Hydrogen boilers have significantly higher running costs than heat pump systems



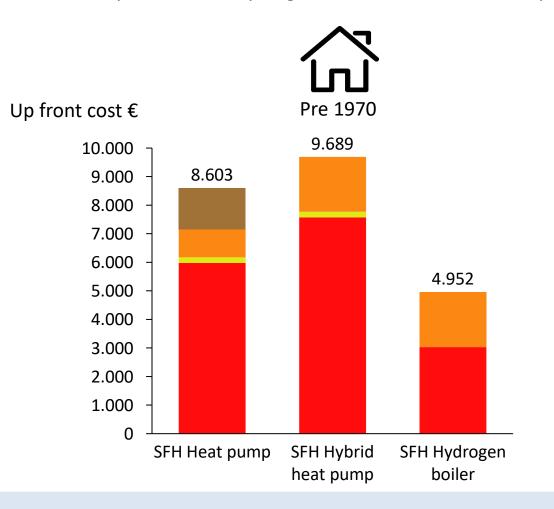
- Hydrogen boilers typically cost 3.75x as much to run as a heat pump system
- This is because the efficiency of hydrogen boilers is lower, so more fuel is required
- Hydrogen is also more expensive than electricity in Italy

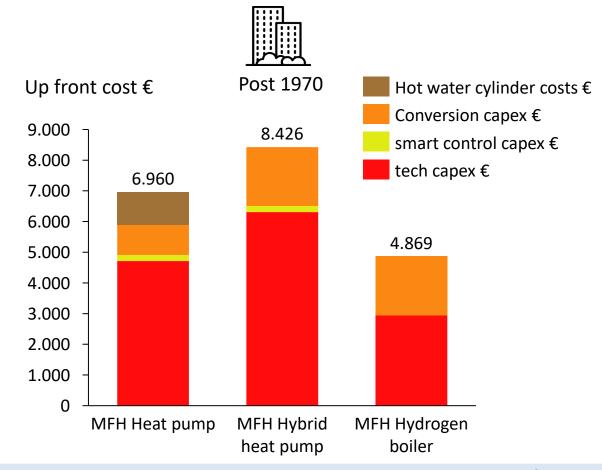


# Hydrogen boilers have lower capex than heat pump systems, with hybrid systems most expensive initially



- Hydrogen boilers have the lowest up front cost for consumers out of the three options considered and hybrid heat pumps have the highest up front cost
- In a pre 1970 SFH hydrogen boilers have 58% lower up front cost than heat pumps





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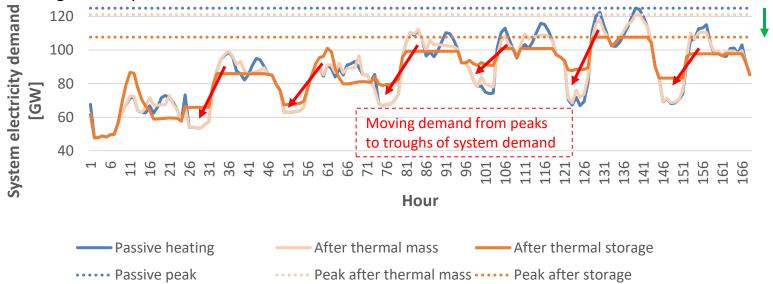
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## How does smart operation of heating help the energy system?

- Uncontrolled operation of heat pumps leads to a high peak demand of the overall electricity system
- Utilising the **flexibility** provided by thermal storage and thermal mass, smart operation of heat pumps moves demand from hours of high demand to hours of low demand (**from peaks to troughs**, see graph below)
- This reduces the peak demand of the system and thus the required network capacity.
- In our models smart heat pumps are also operated to move their demand to hours of high generation from variable renewable energy sources<sup>1</sup>,
  to reduce curtailment of the electricity they generate and the amount of dispatchable generation capacity required to ensure security of supply.
- Thermal storage provides a much higher degree of flexibility than thermal mass (see below chart showing total system demand with and without flexibility from smart heating over a period of one week).
- System peak demand drops from 125 MW with passive heating to 121.6 MW when high efficiency buildings are operated flexibly. Flexibility from thermal storage in buildings lowers peak demand further to 107.3 MW.

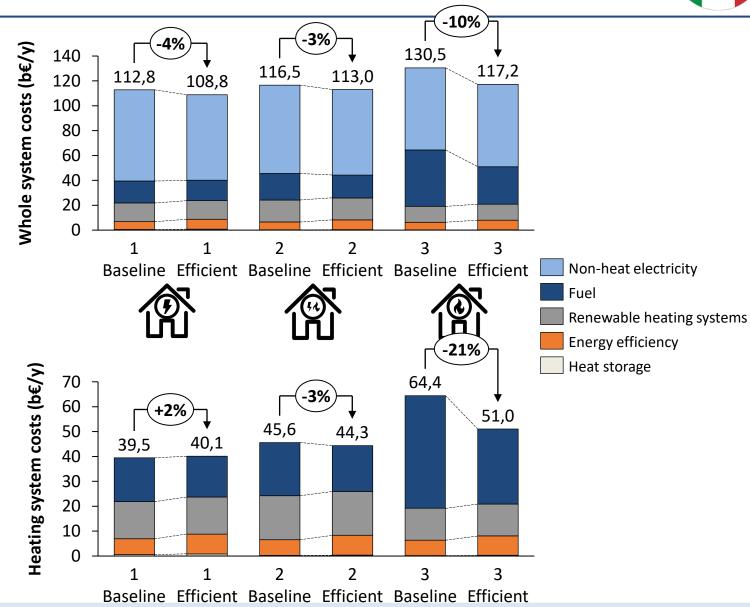


Peak system demand is reduced leading to lower network capacity requirements

## In Italy, the whole system costs are similar in all scenarios but the baseline hydrogen-led scenario



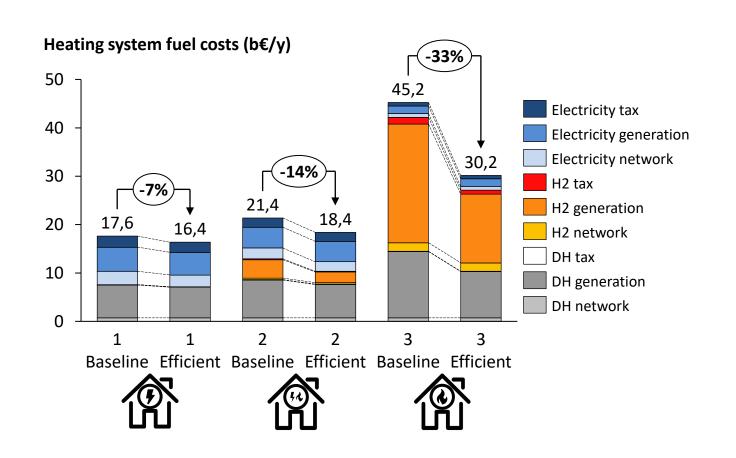
- Similarly to ES, the whole system costs always decrease in the efficient compared to the baseline scenario in Italy, and this is due to a lower efficient renovation rate compared to CZ and PL.
- As in ES, this is due to a high energy efficiency cost and a seasonal heat demand, which means retrofitting buildings in Italy has a comparatively higher cost than in CZ and PL.
- Savings are made through flexibility of the system, which leads to similar costs for the baseline and efficient scenarios in the heatpump and hybrid scenarios.
- The benefits brought by the additional flexibility from the renovation still always outweigh the costs of energy efficiency.
- In the hydrogen scenario, the high fuel cost reduction leads to a significantly lower efficient cost compared to the baseline.



# In Italy, significant hydrogen fuel savings are made in the flexible scenario compared to the baseline



- As seen previously, the large decrease in fuel costs in scenario 3 is due to significant hydrogen cost savings in the flexible compared to the baseline case.
- In Italy, the fuel costs contribute to a higher fraction of the whole system costs compared to ES, and as a result, the decrease in fuel costs between the baseline and efficient scenarios are more closely aligned with that of CZ and PL.



## System savings from flexibility can be shared in different ways with consumer



- Both consumers who provide flexibility and those who don't can benefit from system flexibility
- Fuel cost savings could be distributed in different ways:

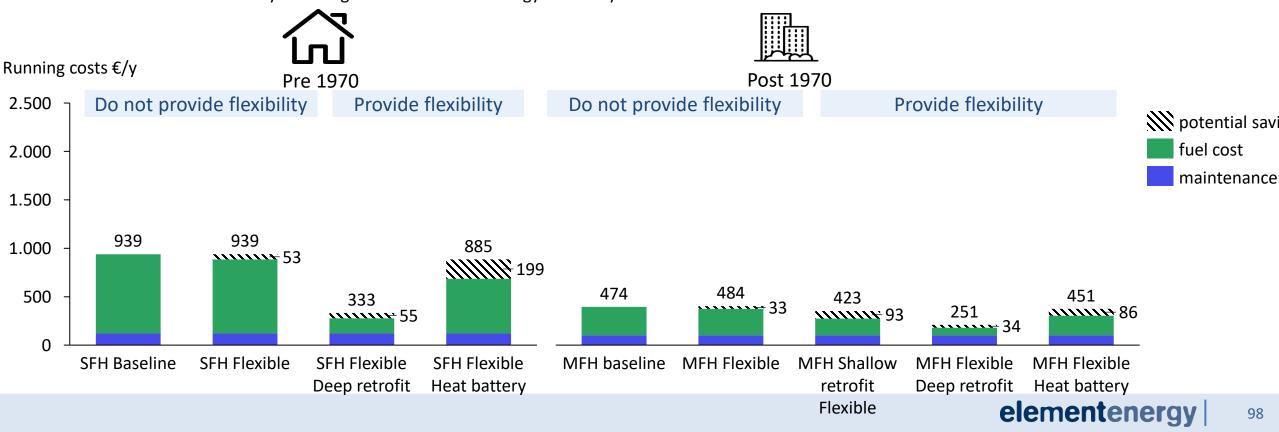
€/MWh

- Savings could be passed on to consumers who provide flexibility, e.g. with time-of-use tariffs or payments for reducing demand at peak times
- Savings could be socialised over all heating electricity demand
- The range of possible savings are demonstrated via a minimum and maximum fuel cost for each building type with the real savings likely to fall somewhere between the two limits

180 162 160 151 140 Range of electricity 112 120 costs for buildings 100 Range of electricity costs which do not provide for buildings which 80 flexibility provide flexibility to the 60 system 40 20 Retail electricity cost €/MWh 0 Flexible: savings Flexible: savings Baseline socialised over passed on to flexible all electricity heat customers

## Heat pump running costs in different households will depend on how flexibility is rewarded

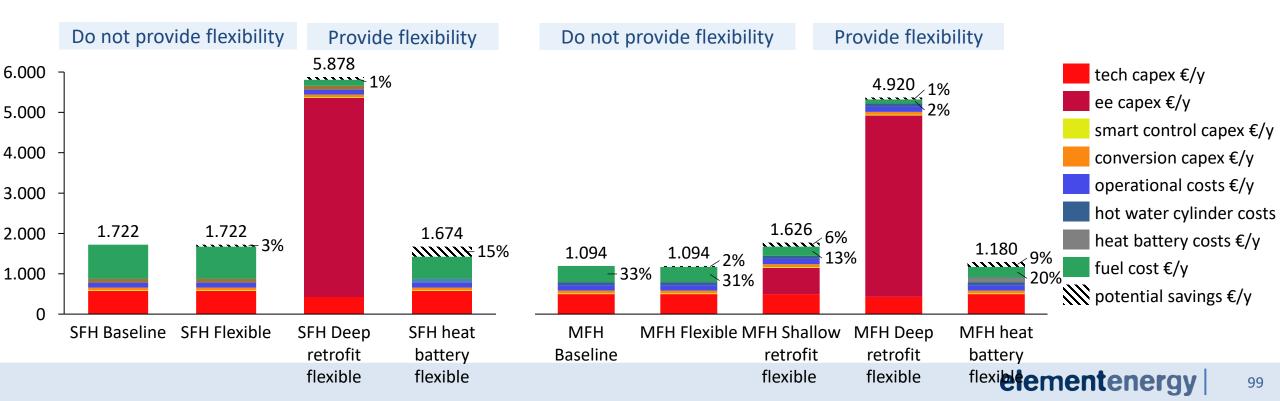
- The dashed bars show the range of different fuel costs that consumers might pay in different circumstances, the minimum and maximum fuel costs that these represent are shown on the previous slide
- If the benefits are fully socialised, larger homes may save around €50/y, with flats saving about €30/y
- If savings are directed towards the households providing flexibility, large flexible households may save a further €150/y, for total savings of €200/y over the Baseline case
- Similarly, flexible flats may save up to €85/h
- Buildings which have been retrofit may see reduced savings due to their reduced energy demand it is important policy and the market mechanisms for flexibility are designed to incentivise energy efficiency retrofit



## Providing flexibility can lead to cost savings for consumers in the heat pump scenario



- Both consumers who provide flexibility and those who don't can benefit from system flexibility
- The dashed bars show the range of different fuel costs that consumers might pay in different circumstances, the minimum and maximum fuel costs that these represent are shown on the previous slides
- In SFH there are always system savings from flexibility relative to the baseline, but in MFH grants for EE or heat batteries may be needed in so that flexibility savings can be passed onto consumers



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## HPs are also cheaper for DH than H2

- Gas and oil CHPs will have to phased out where they exist
- DH should be built to be low carbon from the start
- Waste heat can be very cost effective
- Some waste heat can be used directly, other waste heat will require temperature increase with heat pumps
- We have not assumed significant waste heat usage in the current analysis
- Further comments on consumer protections to be added in text

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- District heating costs around the same or less than building level heating depending on the scenario, and can be a cost effective way to provide system flexibility, especially in multi family homes
- Trends shown below would be consistent with higher levels of energy efficiency.

