BUILDING EUROPE'S NET-ZERO FUTURE

WHY THE TRANSITION TO ENERGY EFFICIENT AND ELECTRIFIED BUILDINGS STRENGTHENS EUROPE'S ECONOMY

WE ARE GRATEFUL TO THE FOLLOWING ORGANISATIONS FOR CONTRIBUTING THEIR EXPERTISE AND INSIGHT:

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This is a summary report produced and written by the European Climate Foundation and the European Alliance to Save Energy (EU-ASE), based on the Cambridge Econometrics report 'Modelling the socioeconomic impacts of zero carbon housing in Europe', which can be read on the Cambridge Econometrics website. For more information about this summary report, please contact Femke de Jong at *femke.dejong@europeanclimate.org.*

DISCLAIMER:

The stakeholders who contributed to this study shared the aim of establishing a constructive and transparent exchange of views on the data, assumptions and design of the scenarios used for modelling the impacts of decarbonising Europe's building stock. The objective was to evaluate the socio-economic impacts of different decarbonisation pathways for the residential building stock. Each stakeholder contributed their knowledge and vision on these issues. The information and conclusions in this report should not be treated as binding on the companies and organisations involved.

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EXECUTIVE SUMMARY

Europe can dramatically reduce its need to import gas from overseas, by undertaking a wave of climate-friendly renovations and heating upgrades that will also create many thousands of new jobs. This study explores various scenarios for reducing gas consumption in European buildings to hit the EU's climate goals and finds that doing so could cut annual spending on gas imports by €15 billion within a decade. The equivalent of a quarter of the EU's current gas imports from Russia can be saved by 2030 through renovating and electrifying Europe's residential buildings[1].

To meet the EU's climate objectives, the building sector will need to achieve 60% greenhouse gas (GHG) emissions reductions by 2030 and fully decarbonise by 2050. Unfortunately Europe is not on track: buildings still account for 40% of the EU's total energy consumption and 36% of CO_2 emissions.

To reverse the trend, the European Commission has launched the "Renovation Wave", a strategy aiming to upgrade the existing building stock, and has put forward several legislative proposals to improve buildings' energy efficiency and encourage heating fuel switching. These proposals are now being negotiated by the European Parliament and Member States.

This study, based on modelling by Cambridge Econometrics, assesses the socio-economic impacts of different scenarios to reach zero-emission in the residential building stock in the EU and the UK. The modelled scenarios show the climate, economic and social impacts of i) a large uptake of heat pumps (**Electrification**), ii) green hydrogen use (**Green Hydrogen**), and iii) a mix of both (**Mixed**), in individual heating systems and district heating networks. The modelled scenarios take into consideration the impact of a low and high annual energy renovation rate (1.5% and 3.5% respectively).

The study finds that the shift to electrified and highly efficient buildings will generate the largest socio-economic benefits for Europe. Heat pumps are a highly efficient heating technology, which reduces the energy bills of households and improves Europe's energy independence. A large deployment of heat pumps (both in individual heating systems and in district heating networks) and a high renovation rate can halve households' energy bills in 2050. The lowest-income households are expected to benefit the most from a switch to heat pumps. The uptake of heat pumps and energy renovations unlock spending on other goods and services produced in Europe, leading to more economic output and creating 1.2 million net additional jobs by 2050. The climate benefits are large too. As heat pumps are already available today, their high uptake allows the EU to meet its 2030 climate goals. This would not be feasible if green hydrogen is used for residential heating, as production and commercialisation are still one decade away.

The study finds that **relying on green hydrogen for heating is not projected to deliver similar socio-economic benefits.** Hydrogen boilers lead to higher energy bills as they are much less energy efficient than heat pumps, requiring up to six times more renewable electricity. Almost all middle-class and high-income households lose disposable income when domestic green hydrogen is used for heating. Importing cheaper green hydrogen in Europe could help control costs for consumers to a certain extent, however it will limit the development of a home-grown hydrogen production industry as well as increase Europe's spending and reliance on energy imports. In addition to higher energy costs for households, hydrogen boilers would have a negative impact on people's health because they release NOx emissions, significantly contributing to air pollution.

Finally, the study shows that relying on a mix of both hydrogen boilers and heat pumps to decarbonise heating delivers less benefits than the Electrification scenario. There is a clear relation between the deployment of heat pumps and socio-economic benefits in the scenarios; **the larger the uptake of heat pumps, the greater the socio-economic benefits**.

Across the scenarios analysed, making buildings more energy efficient is key to delivering socio-economic benefits for citizens. **The EU's Renovation Wave will boost employment and GDP growth in the short-term due to the large investment stimulus and will have a net beneficial impact for the economy.**

1 - The study shows that 1.45 EJ of gas can be saved in 2030 compared to 2022, compared to 5.5 EJ of natural gas being imported in the EU from Russia in 2020 (Eurostat, *https://ec.europa.eu/eurostat/statistics-explained/index.php?title=EU_imports_of_energy_products_-_recent_developments#Trend_in_extra_EU_imports_of_energy_products*, consulted on March 1, 2022).

According to the study, renovating Europe's building stock requires significant investments but comes with multiple socio-economic benefits. Increasing the renovation rate to 3.5% will halve the energy demand for heating by 2050. This will bring major benefits, including greater energy security. Using less energy to heat and cool buildings will lower Europe's reliance on imported fossil fuels and exposure to their price volatility. Additionally, households will benefit from lower energy bills which can help get households out of energy poverty.

In order to capitalise on the socio-economic benefits, **European decision makers need to put in place an enabling policy and financing framework** to speed up the transition to energy efficient and electrified buildings including:

- Legislative measures such as mandatory Minimum Energy Performance Standards to increase Europe's renovation rate and depth.
- A framework to enable vulnerable and low-income households to benefit from the transition, including financial support to address the high upfront investments of heat pumps, solar heat and renovations.
- Policies to accelerate the deployment of heat pumps, solar heat and clean district heating, to mandate the phase-out of fossil heating systems and to rebalance gas and electricity levies.
- Mechanisms to provide technical assistance, capacity building and training programs for a qualified workforce.

THE MAIN SOCIO-ECONOMIC BENEFITS OF THE TRANSITION TO EFFICIENT AND ELECTRIFIED BUILDINGS BY 2050

Figure 1: Illustration showing the main socio-economic benefits of the transition to efficient and electrified buildings by 2050, compared to the baseline

KEY FINDINGS

CLIMATE:

The scenarios relying on heat pumps are expected to decarbonise quicker than those relying on green hydrogen for heating. Heat pumps are a mature technology that can be diffused earlier than novel hydrogen boilers. **Only the scenario with a high renovation rate and a large uptake of heat pumps (both in individual heating systems and in district heating networks) can reduce greenhouse gas emissions in line with what is required to meet the EU's 2030 climate target.**

HEALTH:

A scenario in which heat pumps become the dominant heating technology would cut NOx emissions from heating from around 330,000 tonnes per year now to less than 27,000 tonnes by 2050, or a more than tenfold decrease. This will help cut air pollution from NOx, which currently causes 40,400 premature deaths in the EU[2]. On the contrary, **using green hydrogen for heating will increase air pollution from NOx compared to electrification**, since hydrogen boilers emit NOx while heat pumps do not.

ENERGY BILLS:

The average energy bill for heating can be cut in half by 2050 when buildings are renovated and heat pumps become the dominant heating technology. Relying on domestic green hydrogen will lead to energy bills that are higher than in the baseline.

TOTAL COST OF OWNERSHIP:

For the consumer, **heat pumps, district heating and solar thermal are cost competitive options** due to reduced energy spending, **while green hydrogen boilers are the most expensive technology** due to high energy costs. The total cost of ownership of heat pumps is likely to converge towards that of condensing gas boilers by 2028. Introducing a carbon price for heating fuels will lead to heat pumps becoming cost competitive immediately.

DISTRIBUTIONAL IMPACTS:

The lowest income households are expected to benefit the most from a switch to heat pumps. Low-income groups spend a greater proportion of their income on energy and the use of highly efficient heat pumps will lower their energy expenditure. **In the scenarios relying on domestically produced green hydrogen, almost all middle-class and high-income groups lose disposable income** due to increased energy costs. Importing hydrogen at lower prices reduces the negative impact somewhat but it limits the development of a home-grown green hydrogen production industry and increases Europe's spending on energy imports, prolonging Europe's energy dependency on third countries.

ECONOMY:

The transition to a zero-carbon building stock leads to an increase in GDP. **Electrifying the heat supply and lowering the need for heating through renovations shows the most favourable GDP impacts, leading to a 0.8% increase in annual GDP in 2030 and a 1% increase by 2050.** A transition to green hydrogen heating and a lower renovation rate will lead to smaller GDP impacts.

EMPLOYMENT:

Renovating Europe's building stock and electrifying the heating supply will help create 1.2 million net additional jobs by 2050. Most jobs are created in the construction sector and in the power sector, while jobs will be lost in fossil fuel related industries. Relying on green hydrogen heating and low energy efficiency is projected to lead to net additional jobs, but ten times less than in the case of electrification with high energy efficiency.

ENERGY IMPORTS:

Europe could cut its annual spending on gas imports by €15 billion in 2030 and €43 billion in 2050. Increasing the energy renovation rate and electrifying heat supply will therefore help reduce Europe's vulnerability to volatile fossil fuel prices and increase Europe's energy security and independence from energy imports.

2 - European Environment Agency, Air Quality in Europe 2021 *https://www.eea.europa.eu/publications/air-quality-in-europe-2021/health-impacts-of-air-pollution* (consulted on February 10, 2022)

INTRODUCTION

The building sector will need to completely decarbonise by 2050 and reduce its emissions by 60% by 2030 to meet Europe's climate commitments. This is not the path that Europe's buildings are on at the moment.

Buildings - such as houses, schools, hospitals, offices - still account for 40% of the EU's energy consumption and 36% of the EU's energy-related greenhouse gas emissions. At the moment, energy inefficient buildings are not renovated fast enough and Europe meets most of its heating demand with fossil fuels, with gas boilers being the most used heating technology.

To reverse the trend, the EU has launched a strategy to upgrade the existing building stock: the "Renovation Wave". The European Commission, as part of this effort, has put forward several legislative proposals to improve buildings' energy efficiency and encourage the switch to renewable heating. These proposals will be negotiated with the European Parliament and Member States before becoming law. Additionally, the UK government outlined in the Heat and Building Strategy its plans to significantly cut carbon emissions from the UK's 30 million homes and workplaces.

There are several pathways to zero-carbon buildings, but not all of them deliver the same advantages for Europe's society. To help inform the decision-making of EU and national leaders, this study explores the environmental, social and economic benefits of different scenarios to decarbonise residential buildings.

This summary report provides an overview of the main approach and results of the technical report by Cambridge Econometrics '*Modelling the socioeconomic impacts of zero carbon housing in Europe*'.

METHODOLOGY

The modelling approach used in this project is summarised in Figure 2. An expert panel was convened to contribute expertise and knowledge, to review data and assumptions and to develop a series of different scenarios to decarbonise Europe's residential building stock (EU-27 plus the UK).

These scenarios do not attempt to be forecasts, but instead they represent "what if?" scenarios that are designed to achieve a zero-carbon building stock by 2050. Such decarbonisation pathways need to be driven by policy measures and economic instruments to ensure that clean heating technologies and energy renovations are affordable and accessible to all. More details on the scenarios can be found in the next chapter.

The panel also advised on the most relevant input data on Europe's residential building stock, renovations, heating technologies, energy and infrastructure. The agreed datasets were then fed into different models.

First, Cambridge Econometrics constructed a building stock model, which calculates the total energy need for heating and cooling under different renovation rate assumptions. Second, a heat supply model was developed to determine the uptake of heating technologies by country. The outputs from the building stock and heat supply models were then fed into the macro-economic model E3ME to evaluate the socio-economic effects.

The E3ME model embodies two key strengths relevant to this project. The model's integrated treatment of the economy, the energy system and the environment enable it to capture two-way linkages and feedback between these components. Its high level of disaggregation enables relatively detailed analysis of sectoral effects. E3ME delivered outputs in terms of changes to household consumption, energy imports, GDP, employment and CO_2 and NO_x emissions.

AN OVERVIEW OF THE MODELLING APPROACH USED IN THE PROJECT

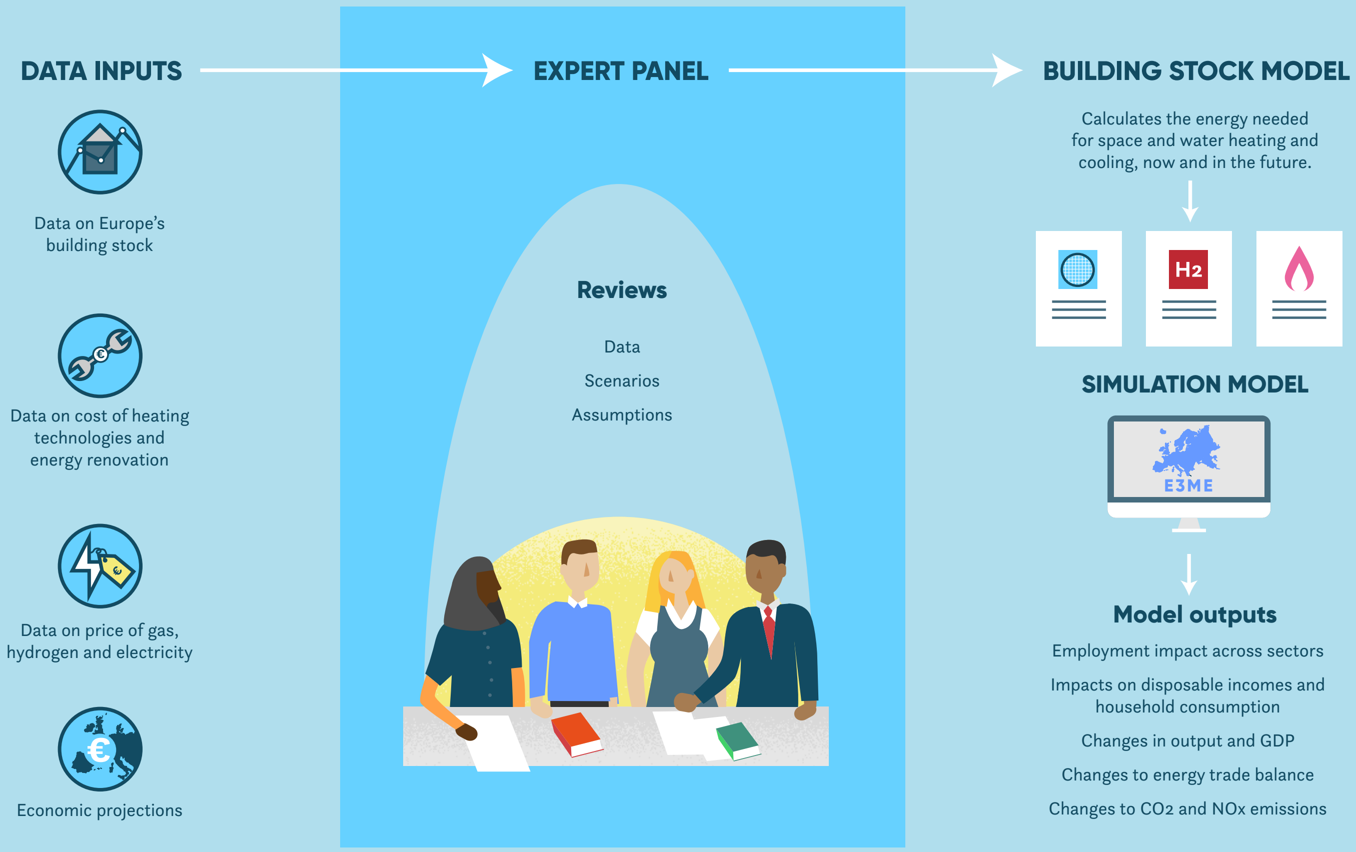


Figure 2: An overview of the modelling approach used in the project

SCENARIOS FOR BUILDING DECARBONISATION

Cambridge Econometrics modelled several scenarios that combine different renovation efforts and heat technology deployments and analysed the socio-economic impacts of each scenario. All scenarios were designed to move away from fossil fuels and fully decarbonise the heating and cooling demand of Europe's residential building stock by 2050, but they differ in how to get there.

The scenarios estimate three potential paths for heating technologies, and two potential rates of energy renovations.

THREE HEATING TECHNOLOGY PATHS WERE MODELLED:

- **ELECTRIFICATION SCENARIO:** large uptake of heat pumps
- **GREEN HYDROGEN SCENARIO:** large uptake of hydrogen boilers
- **MIXED SCENARIO:** uptake of both hydrogen boilers and heat pumps

In all the three pathways, the power sector fully decarbonises by 2050, the market share of district heating is assumed to be 35% in 2050, and the energy used in the district heating systems follows the technology uptake. This means for example that the Electrification scenarios will see a larger share of heat pumps in district heating networks, while the Green Hydrogen scenarios will display a larger share of hydrogen-based networks. The scenarios that use green hydrogen for residential heating were assumed to rely on either domestic green hydrogen or imported green hydrogen (at a lower price than domestically produced hydrogen).

ASSUMED MARKET SHARES OF HEATING TECHNOLOGIES IN 2050

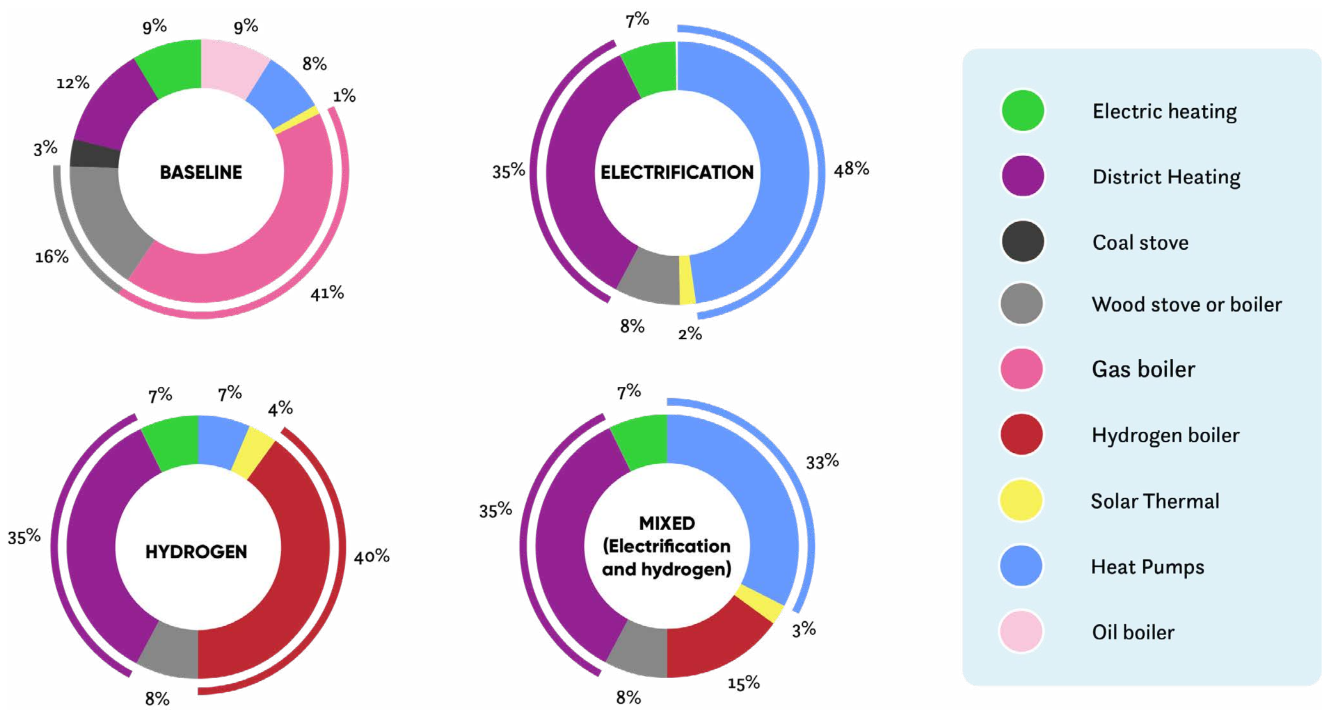


Figure 3: Assumed market shares of heating technologies per scenario in 2050

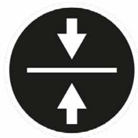
Two sensitivities on the energy renovation rate were applied to each of these heating technology paths that increase the current 1% renovation rate in the 2030-2050 period:

- **Low Renovation Rate:** 1.5% weighted energy renovation rate.
- **High Renovation Rate:** 3.5% weighted energy renovation rate.

The results of the modelling are compared to a Baseline scenario, where the market shares of heating technologies remain constant from 2022 onwards, the power sector develops in line with the EU Reference Scenario 2020 and a low renovation rate is assumed.

This summary report focuses on the scenarios with a large uptake of hydrogen (imported or domestically produced) and heat pumps, with a high or low renovation rate. The results of the Mixed scenario, which sees an uptake of both heat pumps and hydrogen boilers, fall in between the results of the Electrification and Green Hydrogen scenarios.

DESCRIPTION OF SIX SCENARIOS FOR BUILDING DECARBONISATION AND BASELINE



BASELINE

- continued high use of gas boilers and fossil fuels
- 1.5% renovation rate
- no CO_2 price on heating fuels

ELECTRIFICATION WITH HIGH RENOVATION RATE

- Large uptake of heat pumps (in individual heating and district heating)
- 3.5% renovation rate

DOMESTIC GREEN HYDROGEN WITH HIGH RENOVATION RATE

- Large uptake of heating with green hydrogen produced in Europe (in individual heating and district heating)
- 3.5% renovation rate

IMPORTED GREEN HYDROGEN WITH HIGH RENOVATION RATE

- Large uptake of heating with green hydrogen imported from abroad (in individual heating and district heating)
- 3.5% renovation rate

ELECTRIFICATION WITH LOW RENOVATION RATE

- Large uptake of heat pumps (in individual heating and district heating)
- 1.5% renovation rate

DOMESTIC GREEN HYDROGEN WITH LOW RENOVATION RATE

- Large uptake of heating with green hydrogen produced in Europe (in individual heating and district heating)
- 1.5% renovation rate

IMPORTED GREEN HYDROGEN WITH LOW RENOVATION RATE

- Large uptake of heating with green hydrogen imported from abroad (in individual heating and district heating)
- 1.5% renovation rate

Figure 4: Description of the six scenarios and the baseline analysed in this report

CLIMATE AND HEALTH IMPACTS

Except for the baseline where carbon emissions are expected to go down by 40%, the scenarios modelled in the study were designed to ensure that the European residential building stock reaches zero carbon emissions by 2050. However, they differ in how fast these emissions are reduced.

According to the European Commission, the building sector will need to cut its greenhouse gas emissions by 60% by 2030 compared to 2015 in order for the EU to meet its climate goals. This study shows that, of the scenarios considered, **only through a high efficiency and electrification pathway, with a fast uptake of heat pumps and a high energy renovation rate, can the EU achieve its 2030 emission reduction target.**

The Electrification scenario is able to decarbonise European buildings the quickest because heat pumps are a mature technology already available today and their uptake is expected to happen earlier than novel hydrogen boilers. Heat pump installations are expected to peak around 2030 while the uptake of hydrogen boilers is expected to peak only five years later. A higher renovation rate will result in lower cumulative greenhouse gas emissions than a lower renovation rate.

A LARGE UPTAKE OF ZERO-CARBON HEATING TECHNOLOGIES COULD HELP DECARBONISE EUROPEAN BUILDINGS RAPIDLY

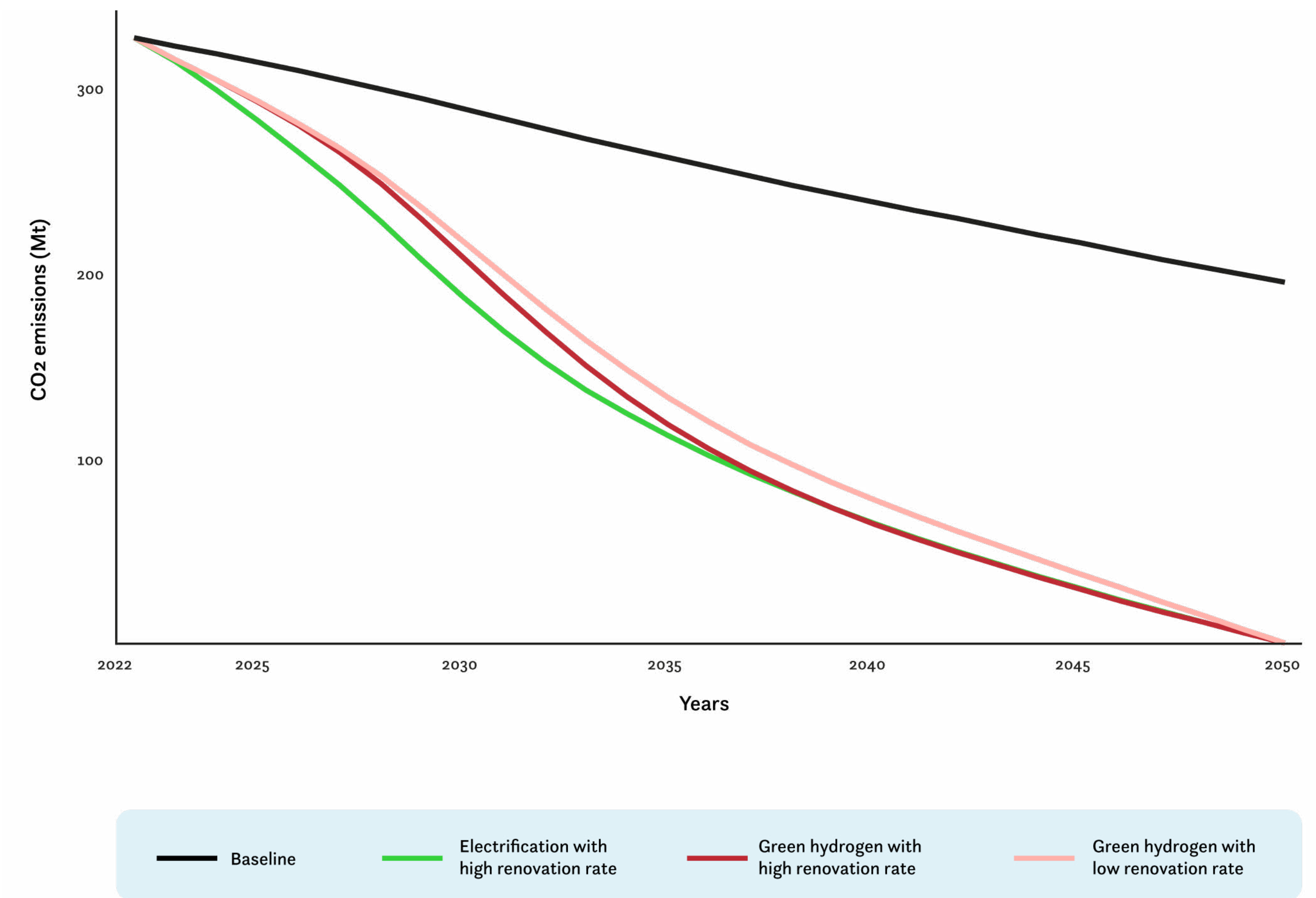


Figure 5: CO_2 emission reductions (Mt) of the European building stock from residential heating and cooling in the baseline, Electrification (with High Renovation Rate), and the Green Hydrogen (with Low and High Renovation Rates) scenarios over time

Burning fossil fuels and biomass for heating not only emits CO_2 emissions but also other air pollutants that are detrimental to public health.

Decarbonising the European building stock will generally lead to lower emission levels of such pollutants. There are exceptions: when green hydrogen is used for heating—namely in the Green Hydrogen and (to a lesser extent) the Mixed scenarios of this study—nitrogen oxides (NO_x) emissions persist. If green hydrogen becomes the prevalent heating source, the NO_x emissions from domestic heating in 2050 are estimated to be double the NOx emissions in the Electrification scenario. This is due to the take-up of hydrogen boilers, which emit NO_x while heat pumps do not.

Nitrogen oxides, including nitrogen dioxide, react with oxygen to form smog and acid rain while also contributing to a variety of health problems such as lung tissue damage. Acute and long-term exposure to NO_x has been linked with respiratory and cardiovascular issues. In 2019, over 40,000 premature deaths were attributed to exposure to nitrogen dioxide in the EU[3]. Transport is a major source of NO_x pollution, but gas combustion is also an important contributor, responsible for a fifth of the London-wide NO_x emissions for example. Forthcoming research by CE Delft for the European Public Health Alliance shows that gas combustion in European homes was responsible for 2.3 billion euros in health costs in 2018.

3 - European Environment Agency, Health impacts of air pollution in Europe (2021), https://www.eea.europa.eu/publications/air-quality-in-europe-2021/health-impacts-of-air-pollution (consulted on March 10, 2022)

NOx EMISSIONS OF RESIDENTIAL HEATING AND COOLING IN 2050

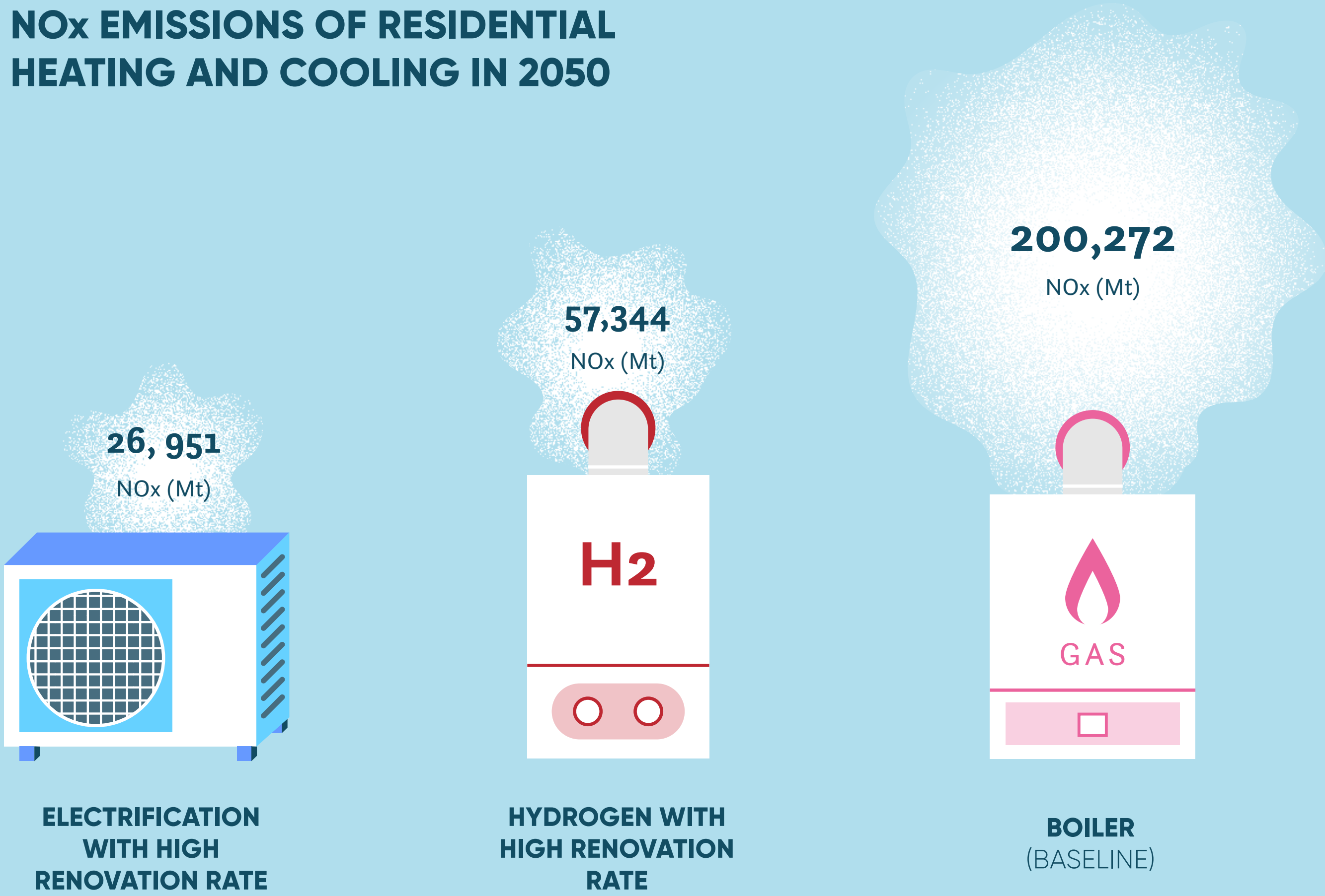


Figure 6: NOx emissions (in Mt) of residential heating and cooling in Europe in 2050 in the Electrification and Green Hydrogen (with High Renovation Rate) scenarios and in the baseline

CONSUMER IMPACTS

The transition to fossil free buildings will result in significant change for consumers. Households will need to switch to clean heating technologies and renovate their homes. This chapter looks at how decarbonising homes will affect energy bills and disposable income in Europe, and how the costs of ownership of heating technologies will evolve.

ENERGY BILLS

The price of energy is projected to change in the future. Fossil fuels such as natural gas are expected to become more expensive, for example, due to higher CO_2 costs. European average retail electricity prices, on the other hand, are projected to remain around the 15 c€/kWh mark as the power sector decarbonises through a great uptake of renewables. Green hydrogen starts off at the 25 c€/kWh mark but is expected to decline to approximately the same end-use price level as electricity.

These energy price changes will have an impact on households' energy bills. Households will initially see an increase in their energy bills compared to the baseline, because of the applied carbon price on fossil heating fuels.

Yet, this situation changes from around 2040 when more households have switched to clean heating systems and renovated their homes. **By 2050, the transition to highly efficient and electrified buildings will cut the average energy bill for heating in half compared to the baseline.**

Using domestically produced hydrogen for heating, on the contrary, is not expected to lower the energy bills of households. In this case, expensive green hydrogen replaces fossil fuels in an inefficient heating system. The production of green hydrogen requires 5 to 6 times more renewable electricity than using the green electricity directly in a heat pump[4]. Using cheaper imported green hydrogen will offset the higher energy bills to a certain extent.

4 - International Energy Agency, Global Hydrogen Review 2021, *https://iea.blob.core.windows.net/assets/e57fd1ee-aac7-494d-a351-f2a4024909b4/GlobalHydrogenReview2021.pdf* (consulted on March 10, 2022)

AVERAGE HEATING BILLS CAN BE CUT IN A HALF BY 2050 WHEN BUILDINGS ARE ELECTRIFIED AND MADE ENERGY EFFICIENT

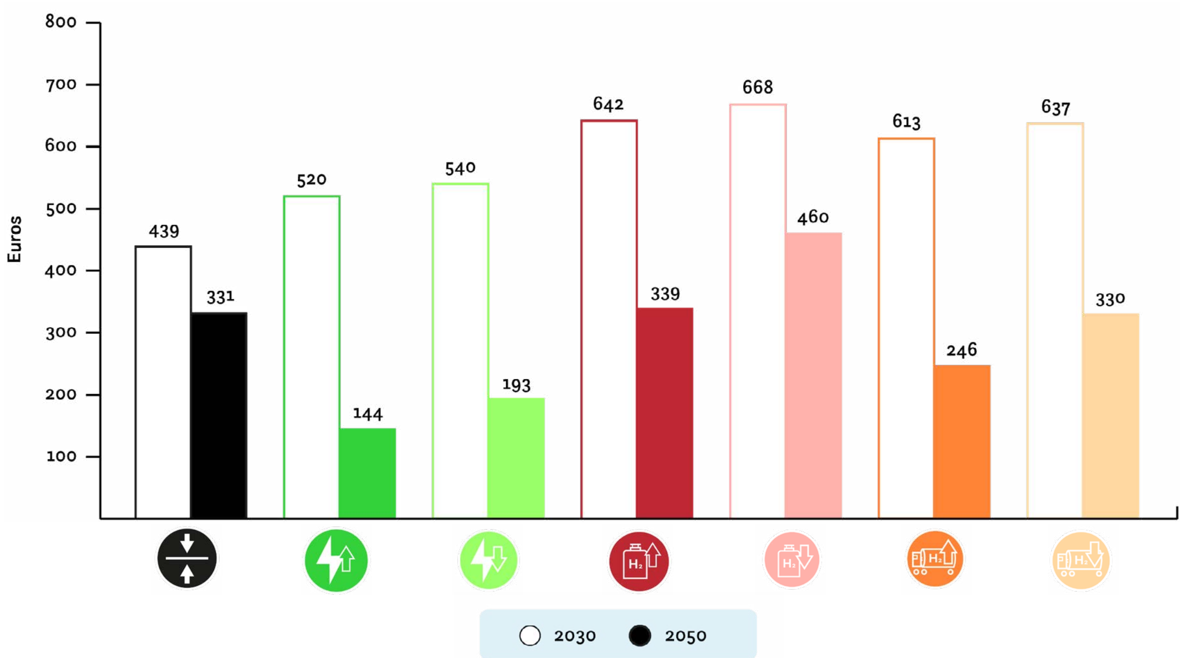


Figure 7: Average annual heating bills (in €) per household in Europe in six decarbonisation scenarios compared to the baseline

TOTAL COST OF OWNERSHIP

Today, a clean heating technology such as a heat pump is more expensive than a gas boiler. This can present a barrier in particular for consumers who lack financial means. The higher upfront costs of clean heating technologies are expected to decrease over time as the market becomes more established and economies of scale are achieved. Hydrogen boilers, even though they are not yet an established technology, are expected to have a lower purchasing price than heat pumps.

However, the upfront cost of the heating technology represents a relatively small share of the total cost of a heating technology over its lifetime. The energy costs represent the biggest share of the total costs that consumers face when owning and running a heating appliance.

The total cost of ownership combines all the costs to buy and use a heating system: the upfront costs, the energy costs as well as the maintenance costs. **For the consumer, heat pumps, district heating and solar thermal are cost competitive options because they are cheaper to run, while hydrogen boilers are the most expensive technology.** By 2028, the total cost of owning and running heat pumps is likely to converge towards that of condensing gas boilers. Implementation of a carbon price on heating fuels will lead to heat pumps becoming cost competitive immediately.

Other research such as the study done by Element Energy for the European Consumer Organisation also found that heat pumps will be the cheapest green heating option for consumers, with heat pump powered district heating a strong option for high density urban areas.[5]

5 - European Consumer Organisation (BEUC), Goodbye gas: heat pumps will be the cheapest green heating option for consumers, 2021, *https://www.beuc.eu/publications/goodbye-gas-heat-pumps-will-be-cheapest-green-heating-option-consumers/html* (consulted on March 10, 2022)

HEAT PUMPS AND SOLAR THERMAL WOULD BE THE CHEAPEST TECHNOLOGIES FOR HOUSEHOLDS IN THE NEXT DECADE

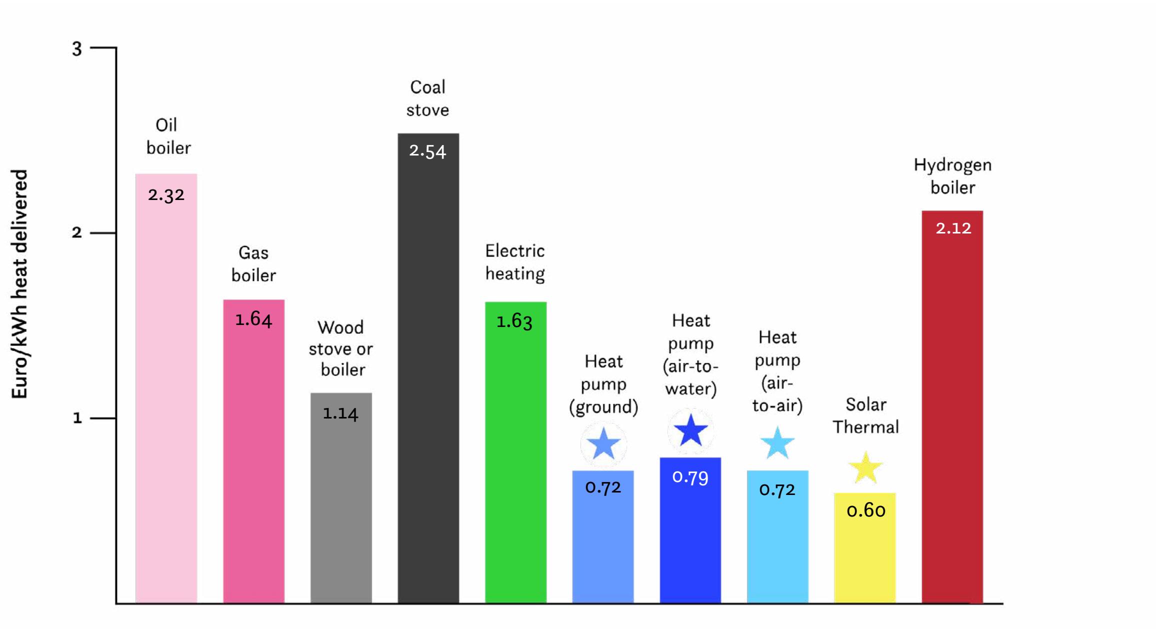


Figure 8: Total cost of owning and running different heating technology (in €/kWh heat delivered) over the period 2030-2040 (Mixed scenario with hydrogen produced domestically)

PAYBACK TIME

Payback periods refer to the amount of time it takes to recover the cost of an investment. Without the application of a carbon price on heating fuels, an average household would need to own and operate a heat pump for a period between 13 and 24 years in order to outperform a condensing gas boiler. When a carbon price is implemented this payback period is reduced to 2 to 4 years. A hydrogen boiler is not financially attractive for consumers because there is no payback time, unless a carbon price on fossil heating fuels is introduced.

PAYBACK TIME OF A HEAT PUMP IS 13 TO 24 YEARS, 2 TO 4 YEARS WITH CARBON PRICING

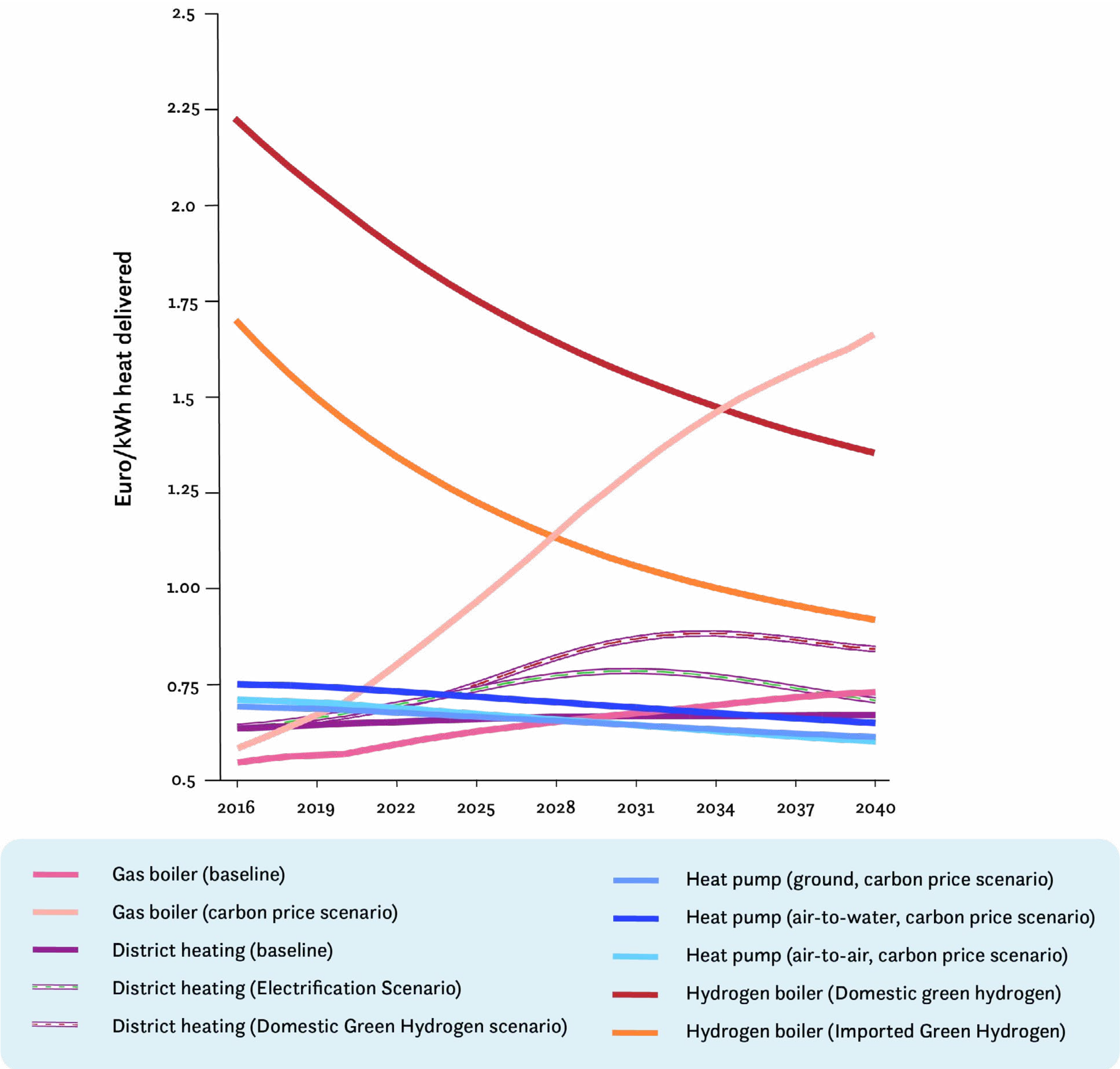


Figure 9: Running total cost of ownership (in €/kWh heat delivered) estimates, undiscounted and over a 10-years period

DISTRIBUTIONAL EFFECTS

The transition to a decarbonised building stock affects the spending capabilities of households. **If there is a large uptake of boilers using domestically-produced hydrogen, almost all middle-class and high-income groups will lose disposable income** in both the low and high renovation rate scenarios due to the increased energy costs. Importing the green hydrogen at lower prices reduces the negative impact somewhat.

The poorest households are expected to benefit from electrifying the heating supply. Low income groups spend a greater proportion of their income on energy and the use of highly efficient heat pumps will lower the expenditure on energy. Disposable incomes thus increase the most in the scenario with a large uptake of heat pumps. On the other hand, decarbonisation pathways with a reliance on high energy costs, for example due to green hydrogen use for heating, are more likely to have regressive effects.

As the lowest income households will often lack the means to finance the higher upfront investment for an energy renovation and a heat pump, there is a need to provide financial support so that clean heating options are accessible to all.

LOWER-INCOME HOUSEHOLDS WOULD BENEFIT FROM ELECTRIFYING THE HEAT SUPPLY

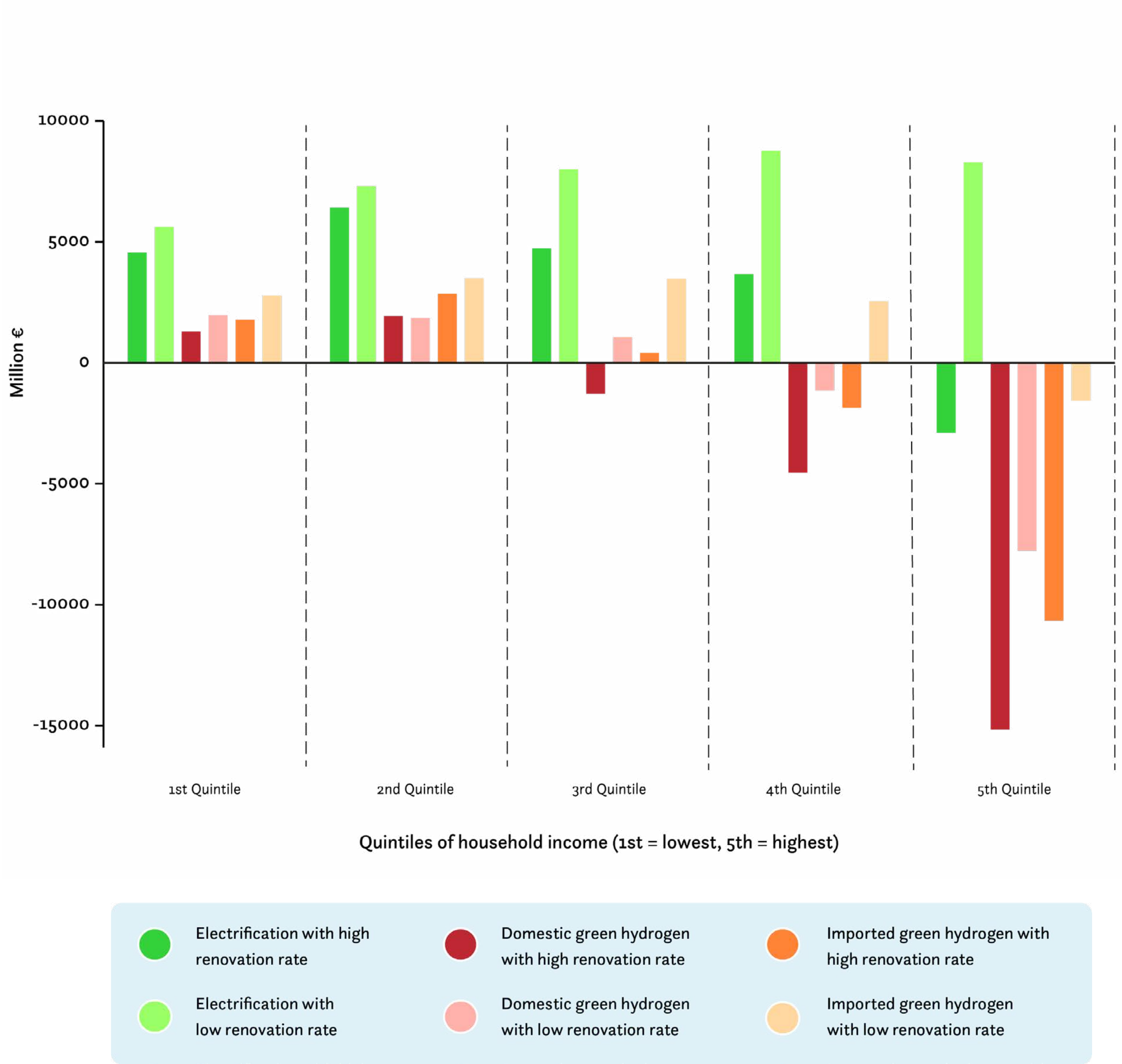


Figure 10: Disposable income change (in million €) in 2050 per quintile compared to the baseline

ECONOMIC IMPACTS

Shifting to a zero-carbon building stock will have major implications for Europe's economy. Energy renovations and the uptake of clean heating can have positive macroeconomic impacts. This chapter focuses on the impact of zero-carbon buildings on the economy, measured through gross domestic product (GDP), employment and energy imports.

DRIVERS OF MACROECONOMIC BENEFITS

There are three main factors that drive the changes in Europe's economic activity.

First, the transition to zero-carbon buildings will require significant investments in new clean technologies and energy efficiency. These investments will generate additional value for Europe.

Secondly, households will likely spend less of their disposable income on energy. As homes will consume less energy thanks to renovations and more efficient heating technologies, European households will pay lower energy bills and can shift their spending on other services and goods. Economic data shows that such spending would on average create more domestic value-added than if the same amount was spent on fossil fuels, such as gas. The scenarios relying on green hydrogen do not benefit from such an efficiency gain as the use of hydrogen for heating will increase the spending on energy by consumers. This is most extreme in the scenarios relying on domestically produced green hydrogen, which is expected to be more expensive than imported green hydrogen.

Thirdly, by reducing demand and dependence on fossil fuels, Europe will spend less on energy imports. Decarbonising buildings means that Europe moves from importing large amounts of gas to producing electricity and green hydrogen domestically. Europe will thereby start to capture a greater share of the value from energy used in buildings. The scenario with imported green hydrogen does not benefit from this impact, as it still relies on energy imports.

ELECTRIFYING AND RENOVATING BUILDINGS DELIVERS THE HIGHEST MACRO-ECONOMIC BENEFITS

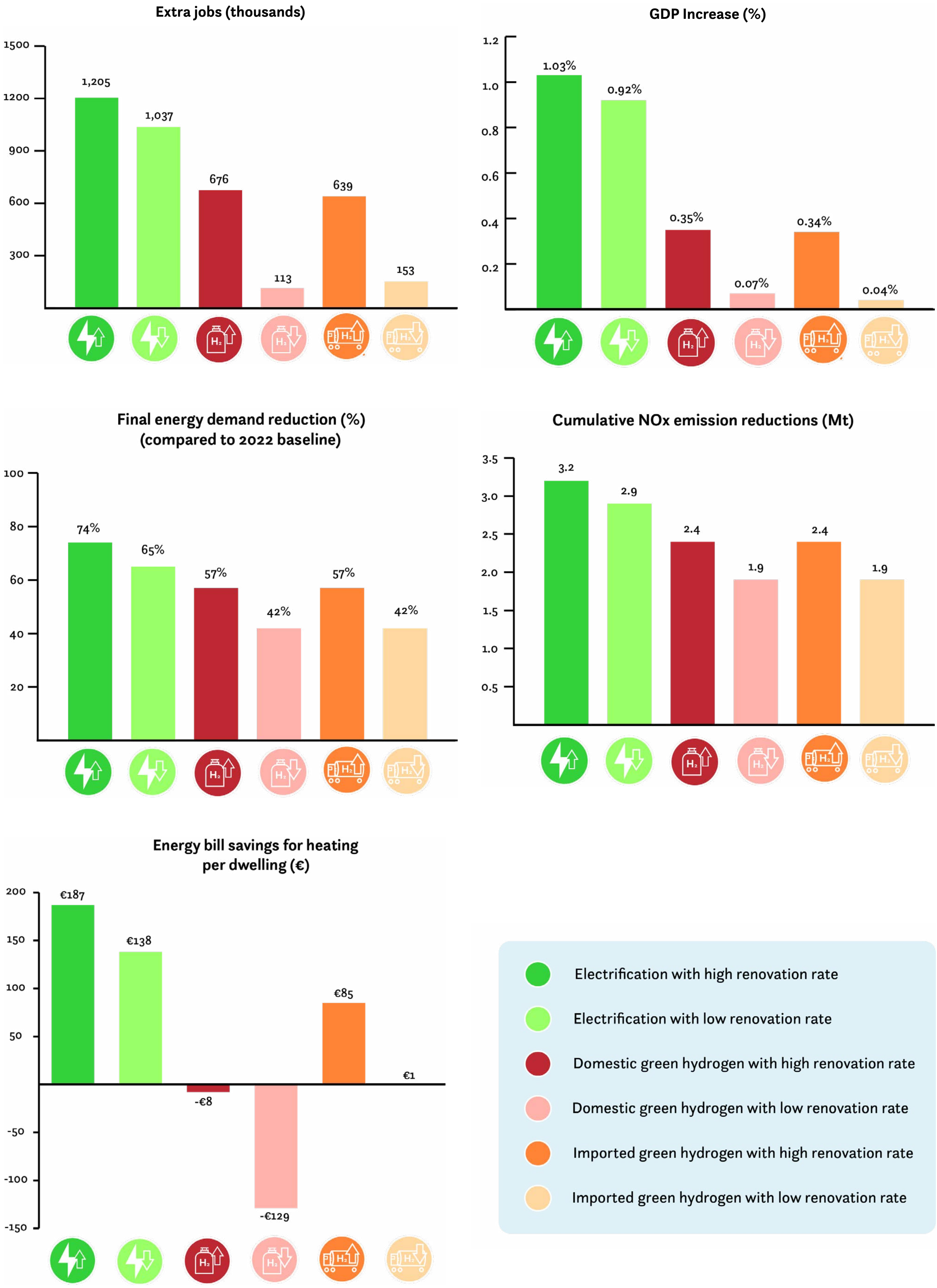


Figure 11: Socio-economic impacts of different decarbonisation pathways in 2050 (compared to the baseline)

GDP IMPACTS

In most of the scenarios explored, the transition to a zero-carbon building stock leads to a net increase in Gross Domestic Product (GDP) compared to the baseline. The exception is the scenario with imported green hydrogen and a low renovation rate. Relying on imported green hydrogen for heating and limited efficiency improvements will lead to a loss in GDP compared to the baseline in the 2035-2045 period. This scenario does not perform well because Europe misses out on domestic investments when green hydrogen is imported from abroad, which also leads to a less favourable energy trade balance. The benefit of importing green hydrogen instead of producing it domestically comes instead from the lower energy prices for consumers. By 2050, the scenario with imported green hydrogen performs approximately the same as the scenario relying on domestically produced hydrogen.

Lowering the need for heating through a high increase in the renovation rate and electrifying the heat supply shows the most favourable GDP impacts, leading to an additional 0.8% of annual GDP in 2030 and a 1% increase in annual GDP by 2050. The renovations ensure efficiency gains and reduction of energy needs, while heat pumps ensure efficiency gains on the supply-side. This results in a lower consumer expenditure on energy, which allows more consumption on other goods and services with a higher domestic content, boosting employment and improving the energy trade balance.

ENERGY IMPORTS

At present, Europe is heavily dependent on fossil fuel imports to heat its homes. Recently, energy prices reached unprecedented high levels, exposing Europe's vulnerability to volatile fossil fuel prices. This gas price crisis had a knock-on effect on electricity prices, which, in turn, were passed onto consumers by energy companies.

Reducing the energy needs of the building stock through renovations and switching to renewable heating will lower coal, gas and oil imports: **Europe could cut its spending on gas imports by 15 billion euros in 2030 and 43 billion euros in 2050 by phasing out fossil heating.** However, if the fossil fuels are replaced by imported green hydrogen then this would not lead to an equivalent improvement in Europe's energy independence. The scenario relying on imported green hydrogen and limited efficiency improvements leads to more money being spent on energy imports.

EMPLOYMENT IMPACTS

Investment stimuli lead to an initial increase in employment, but this effect slows down in the long-term when the accrued debt needs to be repaid. This is particularly striking in the scenario relying on domestically produced green hydrogen. Due to the infrastructure investments, an employment boost is noted around 2035. But after the peak in hydrogen boiler uptake has occurred, the investments and, consequently, related employment gains go down, while consumers are still faced with high hydrogen prices.

When green hydrogen is instead imported, European industries miss out on establishing a hydrogen supply sector, but consumers face lower energy prices. This means that there is no peak in employment as with domestically produced green hydrogen, but employment is stimulated by lower energy expenditures. As a result, when the green hydrogen is imported instead of domestically produced, less employment is created initially. By 2050, total employment changes compared to the baseline are similar for both domestically produced and imported green hydrogen.

The scenario relying on heat pumps shows a different pattern for employment effects. Employment steadily grows and shows the highest increase in 2050 compared to the baseline. The uptake of heat pumps starts earlier than hydrogen boilers and is spread out over a longer period, as is the investment profile. Unlike the scenarios with hydrogen, households face much lower energy bills with a large uptake of heat pumps, which unlocks spending elsewhere with positive multiplier effects. This leads to more domestic demand and higher domestic production, and thereby increased employment.

Renovating Europe's building stock and electrifying the heating supply will help create 1.2 million net additional jobs by 2050, which is a 0.5% increase from the baseline. Most jobs are created in the construction sector (475 thousand) and the power sector (300 thousand), while 240 thousand jobs will be lost in fossil fuel related industries.

ELECTRIFYING AND MAKING BUILDINGS ENERGY EFFICIENT WOULD CREATE ADDITIONAL JOBS

Figure 12: Employment increase by sector in 2050 for the scenario with electrification of heating and a high renovation rate

RENOVATION INVESTMENTS

Buildings currently account for 40% of the EU's energy consumption, but with the population stabilising and household sizes shrinking, the energy consumption of buildings is likely to continue growing unless immediate action is taken.

Europe's inefficient buildings directly affect the quality of life and budget of Europeans. Many households still live in very energy inefficient buildings which translate into a large amount of energy wasted, health problems, high energy bills and in many cases difficulties in keeping homes adequately warm. Energy poverty affects between 50 and 125 million people in Europe.

Energy efficiency is crucial for the transition to a net-zero economy, while also offering many short and long-term benefits. Renovating Europe's buildings to reduce energy consumption is essential to catalyse the uptake of renewables, facilitate the switch to clean heating and deliver a broad range of multiple benefits including comfort, health and well-being, increased productivity and building assets' value.

THE MAIN SOCIO-ECONOMIC BENEFITS OF ENERGY EFFICIENT RENOVATIONS

Source: Capturing the multiple benefits of energy efficiency, OECD/IEA, 2014

Figure 13: Illustration showing the multiple benefits of energy renovation

The study shows that Europe's economy will benefit from upgrading its buildings, boosting employment and GDP growth. The investments in renovating the residential building stock will create additional demand for the construction sector and therefore creates jobs. The scenarios with a 3.5% renovation rate also show higher GDP rates than the scenarios with a lower renovation rate.

A higher renovation rate will require significant investments in improving the energy efficiency of the building stock. Increasing the EU's renovation rate to 1.5% (from the current 1%) will require increased investments from 86 billion euros today to over 120 billion euros by 2030 and beyond. When a 3.5% renovation rate is targeted, total investments will need to grow to over 300 billion euros per year with older dwellings requiring the largest investments, especially single-family homes.

These renovation investments will have to be paid for by governments or private actors. In the modelling, it was assumed that governments pay for the renovation investments of social housing, and 25% of the total required investments of owner occupied and privately rented homes. This is the same for all scenarios.

House owners face the highest additional investment costs to increase the energy efficiency of the European residential building stock. From a macroeconomic perspective, this means that such households would need to change their spending patterns to be able to pay for such renovation levels. The investments required for privately rented homes will, for a large part, come from higher rents, unless Member States address distributional effects further by introducing measures protecting tenants, such as caps on rent. The portion of renovation investments subsidised by governments will have consequences for fiscal tax rates, which, in the absence of other changes, will need to increase to maintain net-neutrality of government balances. Such higher tax rates will again decrease consumer spending.

Yet, even though households will have to invest to make homes energy efficient and pay higher rents and/or taxes, renovations will lower their energy bills over time. **Households will save on energy bills because less energy is required to heat or cool their homes, which unlocks more money to be spent on other services and goods.** This, in turn, will generate higher domestic production, employment and lower import dependency overall.

Greater efforts to renovate homes will considerably decrease the energy need for heating and cooling, which **will have beneficial impacts on Europe's energy independence when reduced fossil fuel imports are not replaced by green hydrogen imports.** Upgrading Europe's buildings will also lower CO_2 emissions.

In the scenario with a large uptake of heat pumps and a high renovation rate, the energy need for heating decreases by 50% over the 2022-2050 period. Over the same period, the final energy demand is cut by 75%. This is the result of both comprehensive renovations and replacing inefficient heating technologies for more efficient heat pumps.

CONCLUSION AND RECOMMENDATIONS

The transition to a zero-carbon building stock will bring significant socio-economic benefits, such as less air pollution, lower energy bills, increased GDP, more jobs and less energy imports. **The socio-economic benefits are the highest when the focus is on renovating the building stock and electrifying the heating supply.**

Using green hydrogen for heating homes is not projected to lead to similar socio-economic benefits. While green hydrogen can play a role in decarbonising the EU economy, its use should be prioritised for sectors where electrification is not a possibility such as in certain highly energy intensive industrial sectors and maritime transport.

Increasing the renovation rate is a no-regret option in all building decarbonisation scenarios. Improving the energy performance of buildings in terms of strongly lowering their energy need for heating and cooling will have a net beneficial impact for the economy. It allows the adoption of low-temperature heating sources and keeps energy bills affordable, which is particularly important when relying on expensive green hydrogen for heating.

The findings of this study are consistent with other analysis, including the International Energy Agency's net-zero by 2050 roadmap, which also found that energy efficiency and electrification are the two main drivers of decarbonising buildings, and that the transformation will primarily rely on technologies already available on the market[6].

A decarbonised building stock by 2050 will not be achieved without additional and urgent action. CO_2 emissions will only be reduced by 40% by 2050 compared to today under the baseline. **Meeting Europe's climate objectives means that the historical energy renovation rate and the clean heating rate will need to at least triple up to 2030.**

This has to be the ambition that is targeted in the ongoing revisions of EU legislation on buildings, energy efficiency, renewable energy and product policy (Ecodesign and Energy Labelling). These revisions need to result in a framework which significantly increases the energy renovation rate and depth and phases-out inefficient heating appliances using fossil fuels.

Policies that mandate higher energy renovations and a fossil heating phase-out must be complemented by financial support and innovative financing models to enable, in particular, lower-income households to benefit from the transition and cope with the high upfront costs. In addition, accelerating energy efficient renovations and the deployment of renewable heat options, such as heat pumps or solar thermal, requires adequate technical support, integrated planning and programs to ensure sufficient qualified installers.

By doing so, European and national decision makers will ensure that Europe and its citizens reap the socio-economic benefits associated with the transition to zero-carbon homes.

6 - International Energy Agency, Net Zero by 2050: A Roadmap for the Global Energy Sector, 2021, *https://www.iea.org/reports/net-zero-by-2050* (consulted on March 10, 2022).

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