Your Home Our Future

How Energy-Efficient and Flexible Buildings Can Help Reduce Peak Energy Demand and Benefit the European Energy System

2024

eurima

International Copper Association Europe

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Acknowledgements

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Introduction

By burning fossil fuels directly and consuming energy in the form of electricity, heating and cooling, buildings account for **35% of the EU's energy-related greenhouse gas emissions.** It is clear that, as we strive to achieve carbon neutrality, **we need to transition away from fossil fuel-based heating systems and adopt clean heating technologies.**

Electrifying our energy infrastructure is a critical step in this direction. However, this transition presents unique challenges, particularly during periods of peak energy demand.

For instance, what happens when temperatures drop on a calm and cloudy morning?

As we turn on our heating, take hot showers, and cook our breakfast the need for space heating increases, precisely at the time when output from renewable sources like wind and solar might be low.

Failure to properly manage these moments of peak can have severe and long-lasting repercussions. **These include skyrocketing energy prices, potential blackouts, reduced capacity and/or grid congestion hampering the decarbonisation investments of European industries.**

In fact, outside of our homes, factories and transportation will also need more electricity as we switch to decarbonised manufacturing processes and electric vehicles. This can only further intensify the competition for electricity and the strain on Europe's grid infrastructure.

Managing peak demand effectively is a precondition for securing an affordable transition to climate neutrality, but how can we do so in an affordable and resource-efficient way?

Immediate action is essential. As an integral component of our energy infrastructure, building renovations are a critical lever to mitigate risks and instability from peak demand, delivering benefits not only to individual households but also to the entire energy system, from generation to transmission to end-use consumption.

What is peak demand?

Imagine a busy highway during rush hour. Cars are bumper-to-bumper, and the traffic is at its peak. Similarly, buildings also experience their own "rush hour" for energy. This peak energy demand occurs at specific times of the day, week, or year when energy consumption is highest. Transitioning to a highly electrified, renewable energy system introduces new complexities for Europe's energy system to meet peak demand. In essence, renewable energy sources are intermittent and the total energy generation capacity must take that intermittence into consideration for planning infrastructure investments.

It's about more than just energy bill savings

It's time to rethink building renovation

This report takes you on a journey, starting with a simple decision to renovate Europe. It's not just about saving on energy bills. Discover how renovating our homes, schools, and offices can create a ripple effect of benefits throughout the energy system. Let's explore the bigger picture and see how renovating your home can upgrade our future in a smart, flexible, and decarbonised energy system.

Key findings

By implementing widespread energy efficiency and flexibility improvements in buildings, the EU could reduce peak energy demand by up to 49% compared to current renovation levels and thereby:

- Reduce associated total energy system costs by **€312 billion a year.**

- Save an extra **0,2 billion tons of GHG** emissions by 2030, allowing to reduce emissions by 10% beyond current emission targets. Lower peak demand also means that coal and gas can be phased out of the energy mix by 2040.

- Save **€44,2 billion** every year in distribution grid investments and decrease shadow costs associated with transmission congestion by almost 4 times.

- Ease the pressure on renewable energy infrastructure. This reduction could potentially save up to **600 GW onshore** and **offshore** wind capacity, and **872 GW solar PV capacity.** Additionally, they allow a more efficient operation of renewable energy sources, **reducing curtailment by up to 3 times**.

- **Optimise transmission and supply investments**, decreasing total electricity prices and increasing the equality in electricity prices between European countries. These savings trickle down to end users, translating into substantial reductions in energy bills for European households and enabling European industries to operate decarbonised production processes at more competitive energy costs.

- Optimise the average required size of a home's heat pump **by 3 times**, maximising the use of available resources and helping **achieve the EU's 60 million heat pump goal** more affordably.

Policy Recommendations

Policymakers can help to unlock the benefits of building renovation for industries, citizens and the environment. Here is how:

1. **Renovations offer the highest average energy savings over the next decade and serve as a crucial investment buffer,**

   Providing flexibility in addressing short-term energy imbalances and supporting the achievement of long-term decarbonisation goals. To achieve a timely and cost-effective transition to climate neutrality, while also delivering tangible energy savings for households and businesses, we must prioritise renovations that adhere to the 'energy efficiency first' principle, starting with the worst-performing buildings to maximise economic and societal benefits.

2. **To achieve the EU's climate ambitions, policymakers should prioritise a balanced mix of energy efficiency, renewable energy, and flexibility measures**

   While the electrification of space heating systems is a crucial step, it is insufficient on its own. Without significant investments in building renovations, Europe risks compromising its energy security and competitiveness due to increased system costs and grid complexity. Europe's upcoming Electrification Action Plan should implement measures that promote both building decarbonisation and energy efficiency to ensure a sustainable and resilient energy transition.

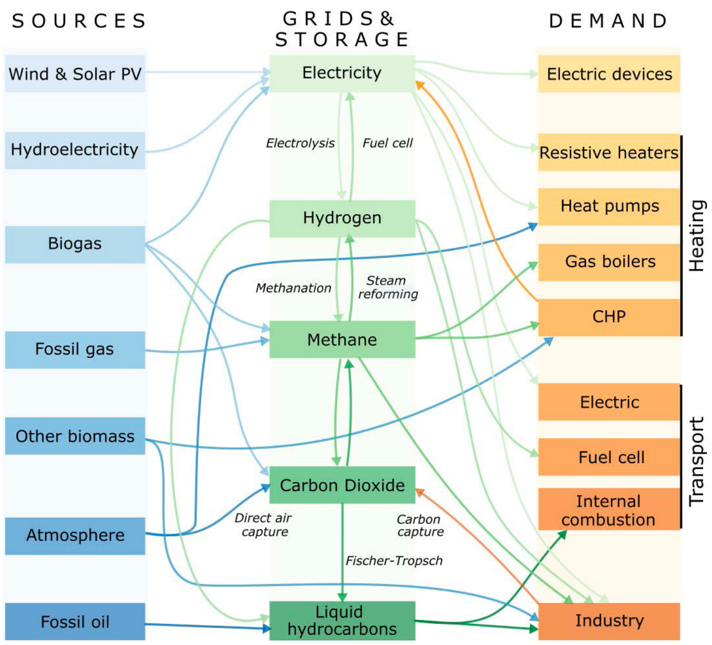
3. **To ensure accurate forecasting, efficient resource allocation, and effective policymaking, EU policymakers should revise existing models, such as PRIMES,**

   To account for the significant impacts of peak demand periods. By considering energy peak dynamics, these models will provide a more reliable guidance to underpin decarbonisation strategies and energy system investments.

Methodology

PyPSA-Eur is a model of the European energy system built using the open source PyPSA framework and based exclusively on open data and open code. This means that the model's methodology and assumptions, as well as data and source code, are completely transparent and fully available for modifications and reuse. All modifications made for this study have been contributed back to the upstream model or are available in the project's GitHub repository.

The model encompasses the most carbon-intensive energy sectors that require decarbonisation: power, transport, space heating and industry (Figure 1).



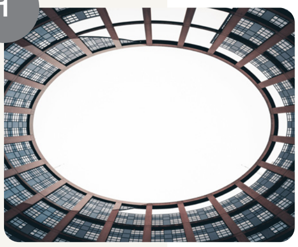
The unique feature of the model is its detailed representation of the relevant transmission infrastructure and demand distribution at a high spatial resolution (Figure 2). To accurately capture system dynamics, especially peaks in space heating demands, the model is built with the highest possible time resolution of one hour.

The overarching objective of the model is to minimise the total system costs while meeting GHG emissions targets for a given planning horizons. The model is required to achieve the decarbonisation of all considered energy sectors in three planning horizons (2030, 2040 and 2050), ultimately reaching net-zero by 2050, in accordance with the most recent policy and planning guidelines for each horizon.

Pathways to climate neutrality

To determine the most cost-effective path to achieving the EU's climate goals, PyPSA-Eur examines the impact of varying renovation scenarios on the future European energy system:

1



Baseline (2023)

This scenario represents the current state of the energy system and built environment in 2023, assuming no new interventions.

2

Widespread Renovation (WIDE+ELEC)

To minimise total system costs, this scenario allows for investments in both decarbonised heating supply technologies and building renovation measures (envelope improvements and flexibility). This setup highlights the potential benefits of a cost-optimal renovation rate (2.77%) in a fully decarbonised energy system.

3

Business as Usual (BAU+ELEC)

To minimise total system costs, this scenario allows for investments in decarbonised space heating supply technologies but not in additional building envelope or flexibility improvements. This setup demonstrates the impact of maintaining a renovation rate comparable to today's levels in a decarbonised energy system.

This report primarily focuses on the aforementioned scenarios within a fully decarbonized energy system. For a more comprehensive analysis of other scenarios and a deeper understanding of the PyPSA-Eur model, please consult the source study *'Flattening the Peak Demand Curve through Energy Efficient Buildings: A Holistic Approach Towards Net Zero'*.

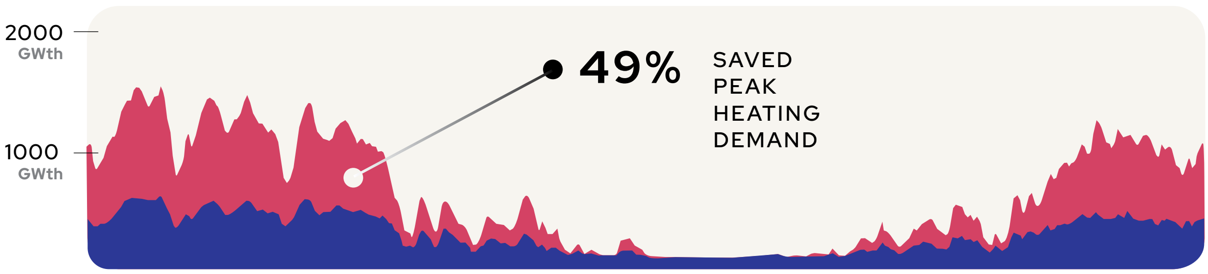
Making Climate Neutrality Affordable

By optimising investments and energy system planning, building renovations make the transition to a decarbonised energy system not only possible, but affordable.

Reducing Peak Demand

It all starts with lowering peak demand. By 2050, **widespread** energy efficiency and flexibility measures coupled with ambitious heat pump deployment can lower peak heating demand by up to 49% compared to **maintaining** current renovation rates.

2050: PEAK SPACE HEATING DEMAND BEFORE AND AFTER RENOVATION



Heat demand [GW$_{th}$] — Widespread Renovation — Business as Usual

Facilitating Heat Pump Deployment

In a widespread renovation scenario, energy-efficient buildings enhance the potential of demand-side flexibility measures, enabling heat pumps to operate more efficiently and cost-effectively. By shifting peak loads, heat pumps can maintain a lower base load, reducing operational costs and improving comfort.

In parallel to making heat pumps perform better, building renovations support heat pump deployment, reducing the average required size of a heat pump in each home by up to 3 times

2050: TOTAL INSTALLED CAPACITY OF HEAT PUMPS (IN GW$_{EL}$)

WIDE + ELEC (GW$_{EL}$)	168.11
BAU + ELEC (GW$_{EL}$)	492.67

This translates to lower manufacturing and installation costs for homeowners, making it easier and more affordable to achieve the EU's heat pump deployment targets.

Cleaning up the energy mix

By significantly reducing peak and overall energy demand, widespread renovation enables renewable energy sources to more effectively meet electricity needs.

Total electricity demand in widespread renovation scenario in 2050:

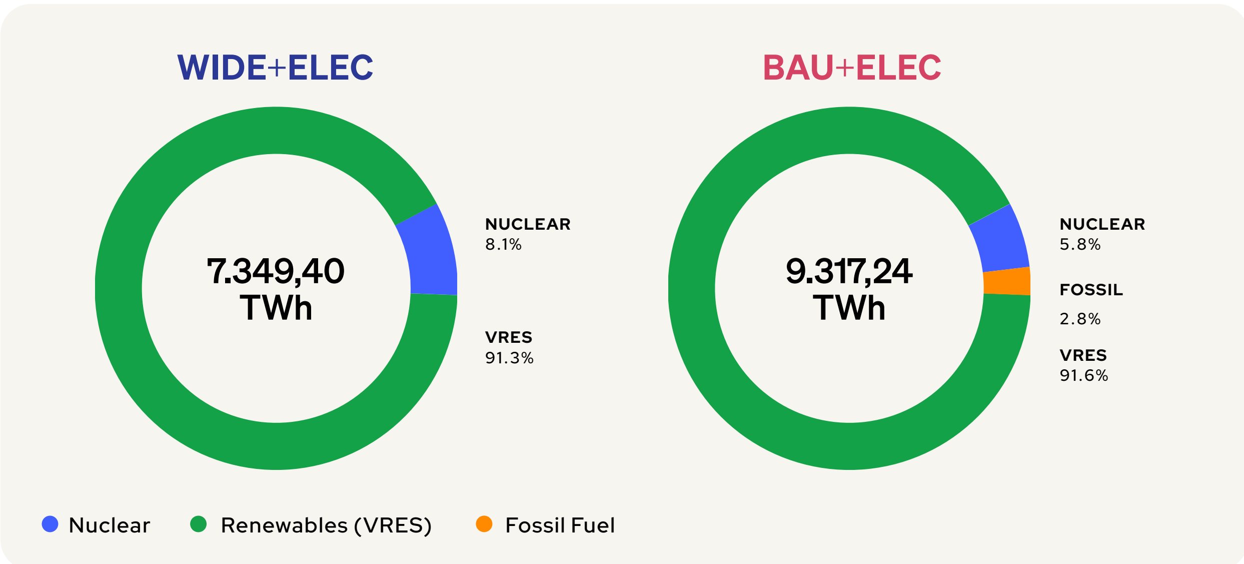
8166TWh

Total electricity demand in business as usual scenario in 2050:

9991TWh

This reduction accelerates the phase-out of gas and coal from the energy system, as they're no longer required to handle peak demand. In fact, under a widespread renovation scenario, the electricity mix in 2040 would be entirely fossil-free, while a business-as-usual approach would still necessitate some fossil fuels to meet peak loads.

ELECTRICITY GENERATION MIX IN 2040



Optimising Energy Infrastructure Investments

By strategically reducing the demand for decarbonised heating to a cost-effective level, we can optimise investments in new energy generation technologies

Widespread renovation can significantly reduce the necessary investments in renewable energy infrastructure to achieve climate neutrality compared to maintaining today's renovation rate. This reduction could be as much as 41% in 2030, 30% in 2040, and 25% in 2050, allowing for a more gradual and manageable investment timeline.

By 2050...

...this reduction could save up to **600 GW** onshore and offshore wind capacity,

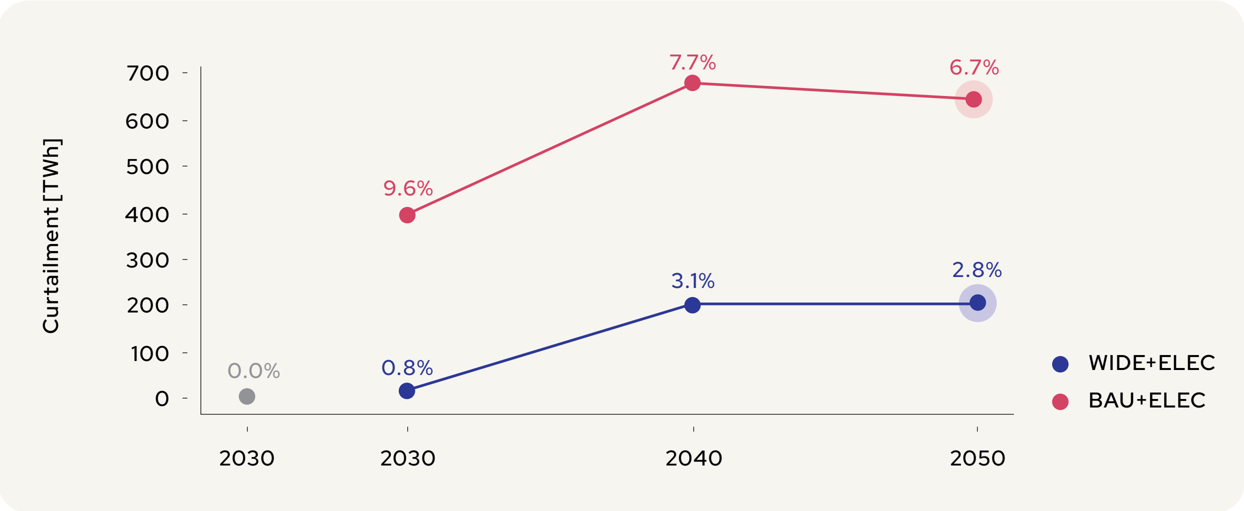
and **872 GW** solar PV capacity.

...renovation can optimise the need for wind turbines and solar PV, conserving a land mass of up to **200 km2** (that's a larger land mass than Lichtenstein!), preserving valuable land that can be used for future generations, social projects or nature and biodiversity restoration.

Moreover, by providing the most savings in the short-term to medium term building renovations create a valuable buffer time. This flexibility can help address short-term energy imbalances and free up resources for the decarbonisation of more challenging sectors.

By optimising the synergy between supply and demand building renovations can mitigate energy curtailment in a decarbonised energy system by up to three times, reducing energy waste.

CURTAILMENT OF RENEWABLE ENERGY SOURCES (IN % OF TOTAL GENERATION)



Cost-efficient Grid Expansion

The effectiveness of synergies between supply and demand will depend on the readiness of Europe's energy grids for a fully renewable future. Building renovations can significantly contribute to this readiness, bolstering system stability and improving the overall economic efficiency and reliability of the energy system.

By significantly reducing both overall and peak energy consumption, accelerating the EU's renovation rate can substantially lower the costs associated with transmission line congestion. Until significant investments in the transmission infrastructure can guarantee grid stability, which is likely to occur closer to 2040, ambitious renovation policies can reduce these costs by up to nearly four times compared to maintaining the current renovation rate.

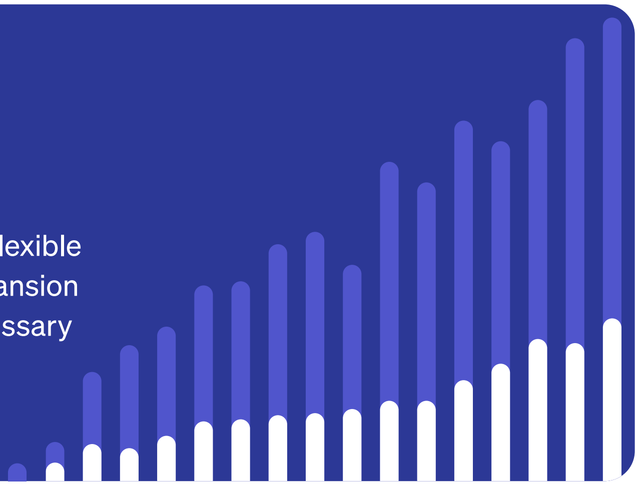
What is transmission line congestion?

Transmission line congestion occurs when the demand for electricity needed for end-use across a specific transmission line meets its maximum capacity, creating inefficiencies in the power grid.

The economic impacts of transmission line congestion are often quantified using the shadow price of the line capacity constraint. This shadow price is a value which represents the marginal cost of alleviating the congestion. High shadow prices signal that the grid is operating near its limits, leading to higher electricity prices and increased operational costs

€44,2B

The energy saved by energy-efficient and flexible buildings can also help to optimise the expansion of Europe's distribution grid, reducing necessary investments to meet rising demand by up to **€44.2 billion annually**.



Lowering the cost of energy

Widespread building renovation offers significant potential to reduce the cost of electricity across Europe, particularly in the coming decade.

Over the next decade, maintaining the current renovation rate could lead to an average electricity price for Europe of

155.27 EUR/MWh

However, implementing widespread renovation measures can significantly lower this price to

63.77 EUR/MWh

Certain countries will experience even more pronounced reductions in electricity prices, with Belgium, Germany, Romania, and Hungary showing the greatest potential. In these nations, if we maintain the same renovation rate as today, prices could increase by 210% compared to a widespread renovation scenario, with the annual average potentially exceeding

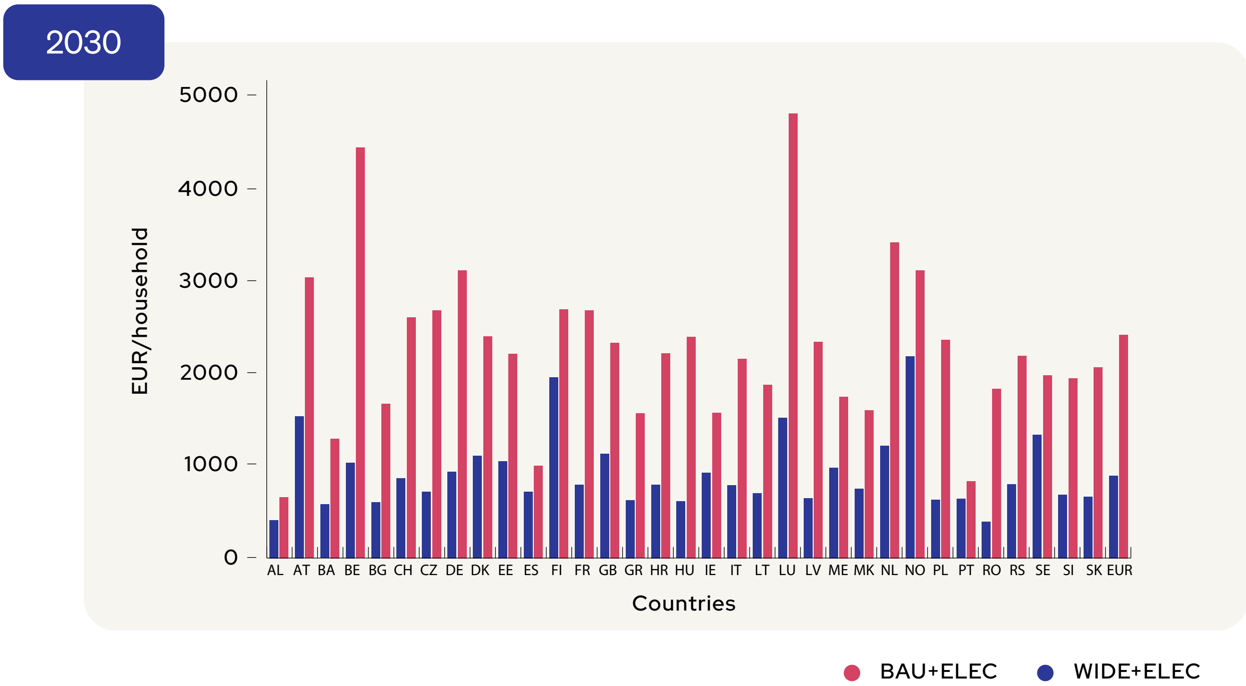
200 EUR/MWh

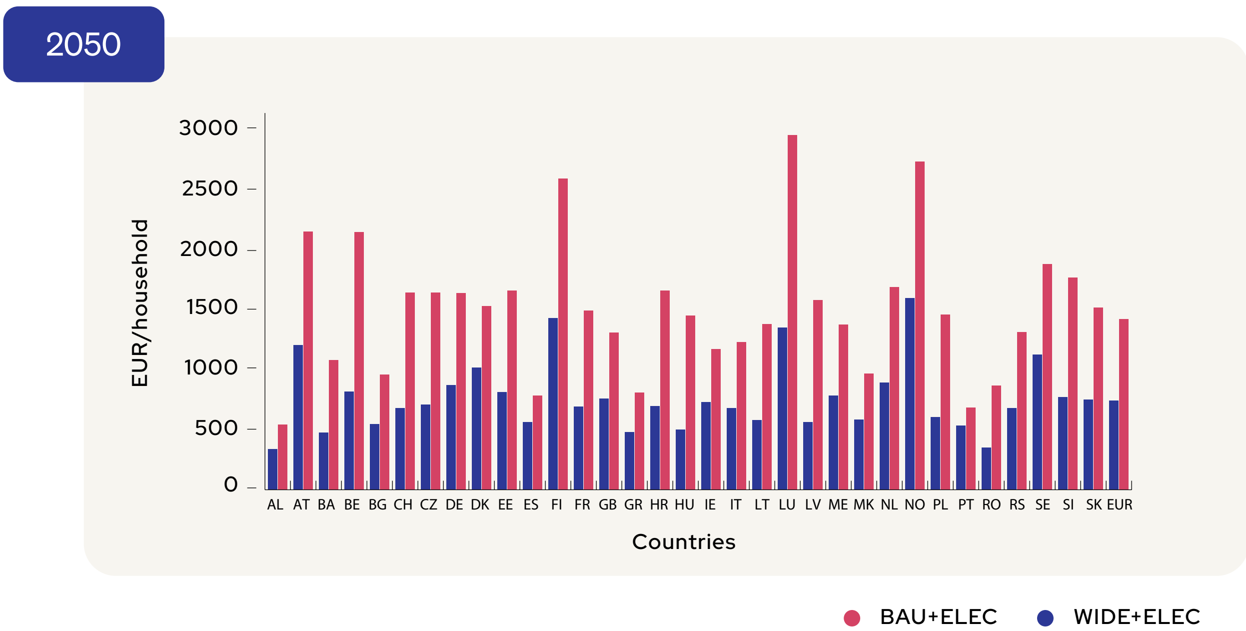
Increasing Europe's renovation rate also increases the equality in electricity prices between countries, promoting a more balanced energy market across regions.

Lower energy costs directly benefit end users, resulting in significant reductions in electricity bills for European households and enabling European industries to decarbonize their production processes at more competitive energy costs.

Reducing household electricity bills

The benefits of a more efficient energy system reach European households in the form of electricity bill savings. While the most significant savings are expected over the next decade, these reductions will persist until 2050 across all EU countries. This means that any large-scale renovation efforts initiated now will provide lasting financial advantages to European households, potentially offsetting initial investment costs.





Widespread renovation can significantly lower average household electricity bills, potentially halving them compared to a scenario where current renovation rates remain unchanged. This effect is particularly pronounced in colder countries, where higher electricity demands for space heating contribute to greater savings.

Enabling Sustainable Competitiveness

European industries require abundant, affordable, and decarbonised energy to transition their production processes and remain competitive globally. Fluctuating energy prices pose a significant threat to the European industrial base, especially for energy-intensive sectors.

From 2030 onward, **operational expenses (OPEX) related to electricity** for European industry remain lower and more stable in a widespread renovation scenario compared to a business-as-usual renovation rate.

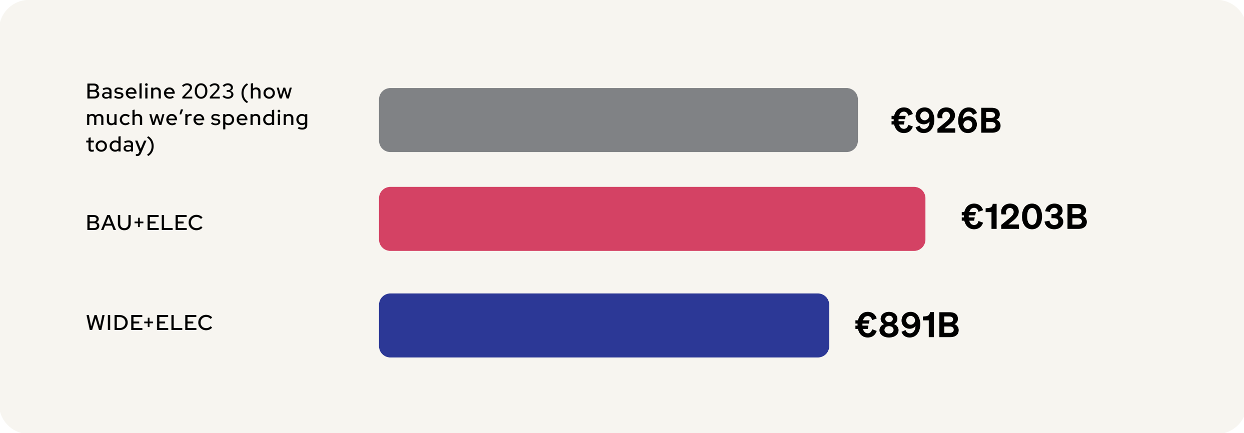
Lower and more equitable energy prices across Europe, facilitated by widespread renovation, can **encourage industrial investments** in countries that have traditionally been more costly to operate due to high decarbonised energy prices.

By creating a more stable and affordable decarbonised energy system and freeing up more available green energy for harder-to-abate sectors, **widespread renovations enhance the competitiveness and sustainability of the European economy and industry.**

Total Energy System Costs

Combining all these savings, it's evident that energy-efficient and flexible buildings will be instrumental in minimising total system costs, the overall yearly cost associated with achieving Europe's climate targets —from production to installation, maintenance, and use.

Total annual system costs to achieve 2030, 2040, and 2050 climate targets



Widespread renovations can save over €312 billion annually and are up to 26% more cost-effective than achieving the same climate targets through maintaining current renovation rates.

Moreover, when ambitious efficiency and flexibility measures are implemented in buildings, projected annual system costs can be lower than today's spending, all while achieving a fully decarbonized energy system.

Conclusions

1. Renovation allows us to achieve our climate targets quicker and affordably for everyone.

2. Widespread renovations, combined with decarbonised heating systems, substantially reduce peak and overall heat and electricity demand. This means lower electricity costs, reduced carbon emissions, and a more efficient investment strategy for energy generation and grid infrastructure.

3. Renovation provides the highest savings in electricity price, household bills, and energy infrastructure investments over the next decade. Delaying or opting for less ambitious renovations can lock us into financial and environmental losses.

4. Demand-side flexibility measures, in conjunction with energy efficiency improvements that facilitate their optimal functioning, are crucial for mitigating demand peaks.

5. Widespread renovation provides greater grid stability, enhancing the overall economic efficiency and reliability of the energy system.

6. Renovations increase the equality in electricity prices between countries, promoting a more balanced energy market across regions.

7. By bringing about significant energy system savings, widespread renovations can significantly reduce household electricity bills. This makes European households more resilient to energy price shocks. Additionally, improved system efficiency and increased flexibility, driven by energy efficiency improvements, can empower European consumers to become more energy independent and encourage the creation of energy communities.

8. Building renovation enables local European economies to be more competitive and lower carbon at the same time, making it the only mass-scale carbon action that achieves both targets using existing, scalable, and tested technologies.

Unlocking the Potential of Energy Efficient and Flexible Buildings: Reducing Peak Energy Demand for a Resilient Energy Future

Failure to properly manage peak energy demand can have severe and long-lasting repercussions. Efficient buildings are the solution for a stable, affordable, and competitive European energy system.

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