THE KEY ROLE OF ENERGY RENOVATION IN THE NET-ZERO GHG EMISSION CHALLENGE

EURIMA'S CONTRIBUTION TO THE EU 2050 STRATEGY CONSULTATION

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Executive Summary:

Paris-compatible targets require that Europe reaches net-zero by 2050 at the latest. This means that large reduction efforts are required in all sectors. The contribution of buildings is a cornerstone of any scenario: reaching zero-carbon buildings requires putting energy efficiency first with rapid improvements of the depth and the quality of renovation in more and more buildings. Concretely, to stay on track, a minimum of a 3% renovation rate per year combined with an average energy efficiency improvement of 75%, need to be reached by 2030.

This is essential for buildings to deliver their share of energy and GHG reductions, and to avoid putting excessive reliance notably on the power sector for heat decarbonization. In addition, highly efficient heat-electrified smart buildings provide part of the solution to make a high contribution of variable renewable power production sources possible.

Moreover, investing in energy efficiency brings us closer to the Europe we want, since the monetized co-benefits of energy efficiency in buildings are higher than required investments. Co-benefits amount to two to three times the required investments, and this is without taking into account avoided climate damages.

The wealth of initiatives targeting buildings renovation, and the series of buildings that have already been renovated with a factor 10 on efficiency (-90% energy consumption), as well as the existing ambitious renovation policies, all demonstrate that this transition is feasible. However, tripling the low renovation rate as well as tripling the depth of any occurring renovation project is a challenge: innovative approaches are being explored to scale-up the existing initiatives and need to be strongly supported.

Methodology:

This paper has been commissioned by EURIMA to CLIMACT in the context of the EU 2050 strategy consultation organized by the European Commission.

Quantitative analysis is based on the EU CTI model developed by the ClimateWorks Foundation and upgraded by CLIMACT for the European Climate Foundation (ECF).

The Carbon Transparency Initiative (CTI) is a project of the ClimateWorks Foundation that helps funders and decision makers track and project progress toward a low-carbon economy by analyzing the drivers of emissions trends and tracking how policies are implemented.

The EU CTI model is a simulation model that builds on this initiative. The model has been extended and upgraded for Europe with the support of the European Climate Foundation (ECF), in consultation with other experts in the field. This consultative process took place between September 2017 and September 2018 and was concluded over the summer of 2018 with the testing of the model by a range of experts who have developed their own low-carbon scenarios to explore and develop the policy options under consideration.

A webtool version of the model is available at https://stakeholder.netzero2050.eu. It features:

- A range of scenarios that online users can explore to better understand the results.
- An option to switch to a live version of the webtool, which stakeholders are invited to use to explore, design, and propose their own pathways.

Sectoral presentations to explain the assumptions and model logic in more detail can be found at https://europeanclimate.org/net-zero-2050/

Analyses reported in the present document were performed by CLIMACT for EURIMA. They are based on other analysis for the ECF reported in the document "Net-zero: from whether to how" elaborated with the support of CLIMACT in the context of the EU Commission consultation. This piece of work is intended to propose a complementary deep dive on the implications for the buildings sector.

PARIS-COMPATIBLE TARGETS REQUIRE SIGNIFICANT ACTION TO DECARBONIZE ALL SECTORS, WITH BUILDINGS AS A CORNERSTONE TO ANY REALISTIC PLAN

Europe needs to reach net-zero by 2050 at the latest. Net-zero by 2050 is a clear, scientifically supported target to limit global warming to 1.5 degrees in view of the high risks of climate damages which are already being felt today around the globe, including in Europe. Science increasingly confirms that there is a major escalation in impacts between keeping global warming below 2 degrees or 1.5 degrees and that the 1.5°C target is a significantly more stable and safer option to pursue. Science also makes clear that keeping warming to below 1.5°C requires global greenhouse gas (GHG) emissions to get to net-zero by 2055-2070. As Europe has a leading role in this transition, continuous efforts should be put on achieving net-zero by 2050 at the latest.

Net-zero means that large reduction efforts are required in all sectors, with energy efficiency providing the highest reduction share. Reaching net-zero GHG emissions is ambitious, but it is possible, and highly desirable on economic, social and geopolitical grounds. Planning to reach net-zero by 2050 at the latest means no sector can be left aside (Figure 2). It also means that the full potential for energy efficiency needs to be activated across sectors as it makes the largest contribution to reaching a net-zero ambition (Figure 3). Like for efficiency, all available options, such as fuel shift, zero-carbon power production and electrification, will need to be deployed at a much greater scale and speed, and this will need to be combined with innovation in our consumption patterns and societal organization, as well as increasing potential natural carbon sinks.

The contribution of buildings is a cornerstone of any scenario. Various scenarios were developed with the EU CTI model — highlighting that a variety of routes exist to reach net zero. Some scenarios rely on innovative technological or business model shifts while others emphasize changes to living and working patterns, including improving the way we use our land and consume food and products. However, i**n all these routes, it is clear that buildings must make a major and irreplaceable contribution. If the building sector fails to deliver its share of GHG emission cuts[1], it will leave a GHG reduction gap of 10% to 14% percentage points** (i.e. GHG emissions are only reduced to 86% to 90% below 1990 level, Figure 1 and Figure 2). This gap cannot be filled even if other sectors were to decarbonize fully. Reducing energy use in buildings, through deep renovation and full decarbonization of its supply, is therefore a crucial factor to the success of all the scenarios, and so to delivering the Paris Agreement. Actions on the envelope cannot be further delayed'.

To stay on track, a net-zero scenario with efforts shared across sectors[2] requires ramping up **the renovation rate to at least 3%/year with an average energy efficiency improvement of 75%, both reached at the latest by 2030. In this context, the long-term renovation roadmaps in the revised Energy Performance in Building Directive are particularly important to organize an adequate policy and financial framework as well as for planning an upskilling of the workforce.**

[1] Assuming the buildings sector follows the ambition of the EU Commission's GHG trends scenario « EUREF16 » (EC, *EU Reference Scenario 2016 - Energy, transport and GHG emissions Trends to 2050*, July 2016) and other sectors decarbonize further following the various net-zero scenarios

[2] This scenario includes efforts on limiting the increase of the heated floor areas. See appendix for scenario assumptions

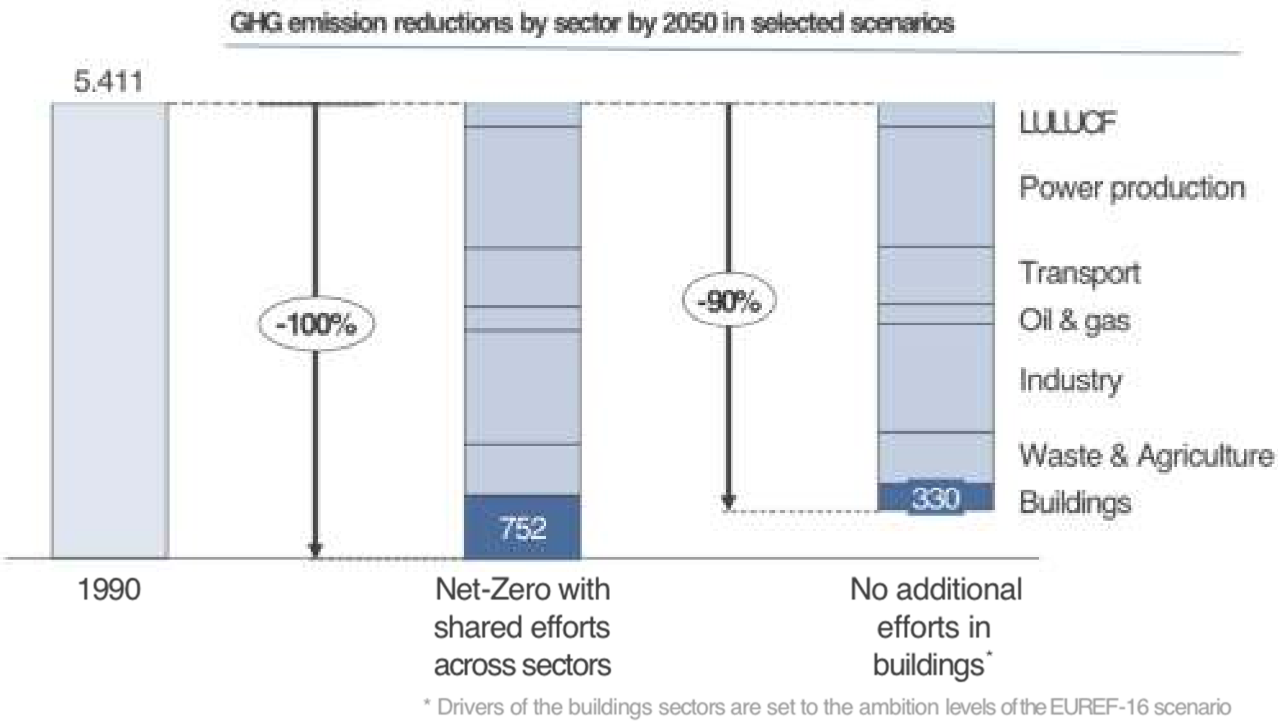

Figure 1. The transformation of the buildings sector is vital to reach net-zero (source: EU CTI model)

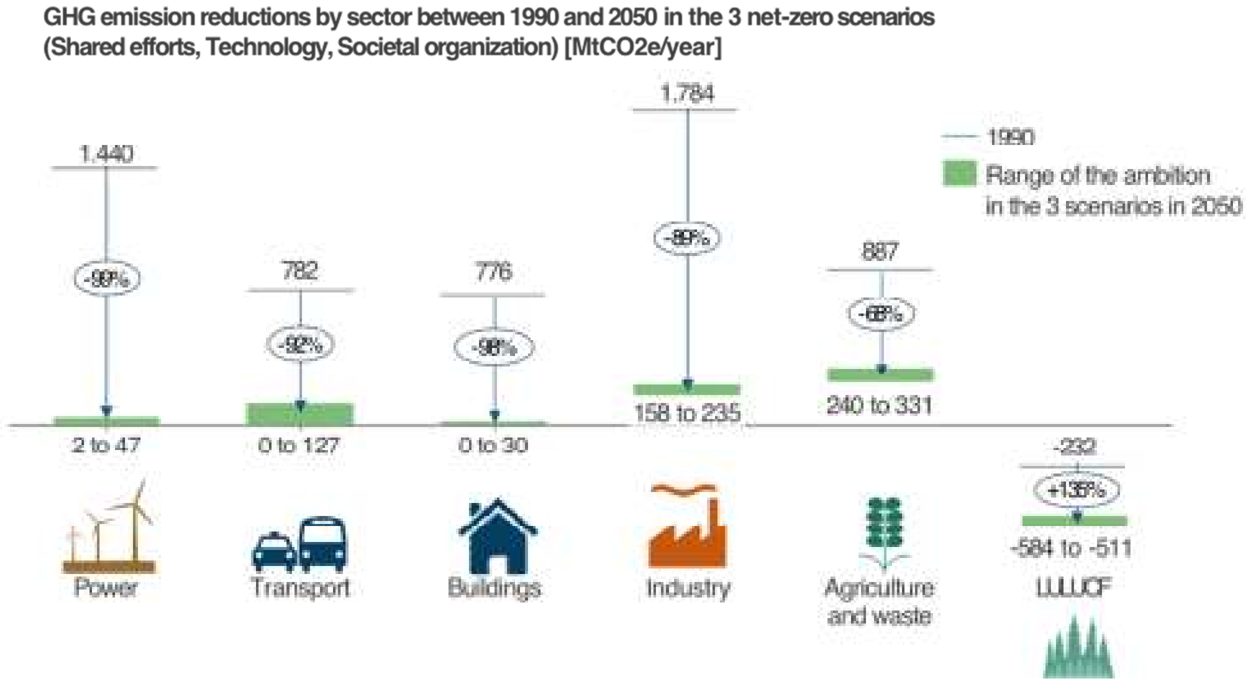

Figure 2. High ambition is required in all sectors, whatever the chosen pathway (source: EU CTI model)

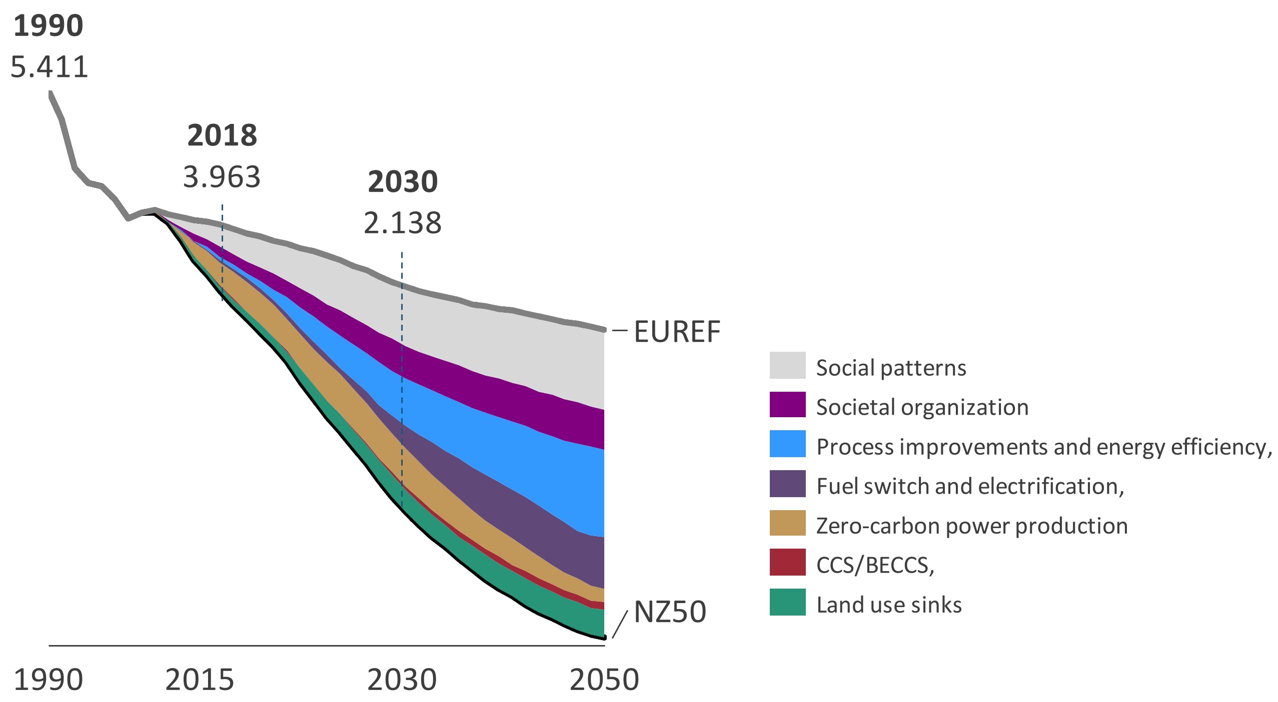

Figure 3. GHG emission reductions by lever types in a 'Shared efforts' net-zero scenario

HIGH AMBITION ON ENERGY EFFICIENCY BRINGS SIGNIFICANT MULTIPLE BENEFITS, AND ENABLES THE DECARBONIZATION OF OTHER SECTORS

Reaching zero-carbon buildings requires putting energy efficiency first. Energy efficiency is in the words of the IEA the 'most important arrow in the quiver' to address the challenges of climate change and scarce energy resources. It improves the Union's security of supply by reducing primary energy consumption and decreasing energy imports. It reduces greenhouse gas emissions in a cost-effective way and at the same time boosts competitiveness and accelerates innovation. And the impact of energy efficiency is felt all across the value chain, reducing the need for basic materials and rare minerals.

To deliver in-depth renovations, it is necessary to start by improving the building envelope (roofs, walls, floor, windows), and to plan heating and control systems in a systemic, low-carbon and cost-efficient way. This ensures that renewable energy solutions such as heat pumps and low-temperature heating districts are correctly designed to meet remaining energy demand.

Rapid improvement of the depth and the quality of renovation is key for buildings to deliver their share of energy and GHG reductions, and to avoid putting excessive reliance on the power sector for heat decarbonization.

While it is key to increase the rate of renovation, improving the depth and the quality of energy renovation is just as important, but it is often left aside in renovation policies. Given their lifetime, investments in buildings envelope energy renovation will likely occur only once between now and 2050: once renovated, buildings envelopes will not undergo other improvements. **In this 'one shot' reality, policymakers must aim to reach appropriate energy efficiency levels on enough existing buildings in the rapid timeframe needed to capture the energy efficiency and GHG reduction potential of buildings while remaining within the limits of our carbon budget[3]. The revised Energy Performance of Buildings Directive is particularly important and innovative in this context, as it requires existing buildings to target nearly zero energy standard by 2050.**

If well designed and thoroughly implemented, ambitious renovation strategies[4] enable the final energy consumption of buildings energy needs[5] to be reduced by -73% by 2050 compared to the EUREF scenario (Figure 4). This contrasts with the -54% reduction obtained in a scenario which assumes the current renovation depth remains unchanged at only -25% average energy savings[6]. This would lead to cumulated GHG emissions 33% lower than in the EUREF scenario. A 90% average energy savings could lower the energy consumption even further down to -76% by 2050 w.r.t. the EUREF scenario.

In addition, going further than 50% average energy reduction makes it possible to limit the additional demand for electricity needed to decarbonize the remaining heat demand.

Looking at the electricity consumption, r**eaching 75% average renovation depth by 2030 makes it possible to reduce buildings' electricity demand by 36% in 2050 compared to a scenario with limited renovation depth** (Figure 4). In contrast, continuing with current level of renovation depth (25% in average) would result in an *increase* of the electricity demand by about 79% compared to today's levels.

[3] Depending on the methodologies to distribute the global carbon budget across regions, a 50% chance to reach the 1.5°C target translates into a European budget ranging between 21 to 35GtCO_2 between 2015 and 2050 (source: Öeko-Institut, 2017. The 2017 Update of the Vision Scenario. A long-term scenario analysis for the EU-28). Today's annual emissions amount to 4GtCO_2e.

[4] i.e. reaching a 3% renovation rate by 2025 with an average renovation depth leading to 75% energy savings

[5] Energy needs considered: heating & cooling. For non-residential buildings, built-in lighting is also considered.

[6] This is slightly more ambitious than the 20% average energy savings that was used to mimic the EUREF scenario (see appendix)

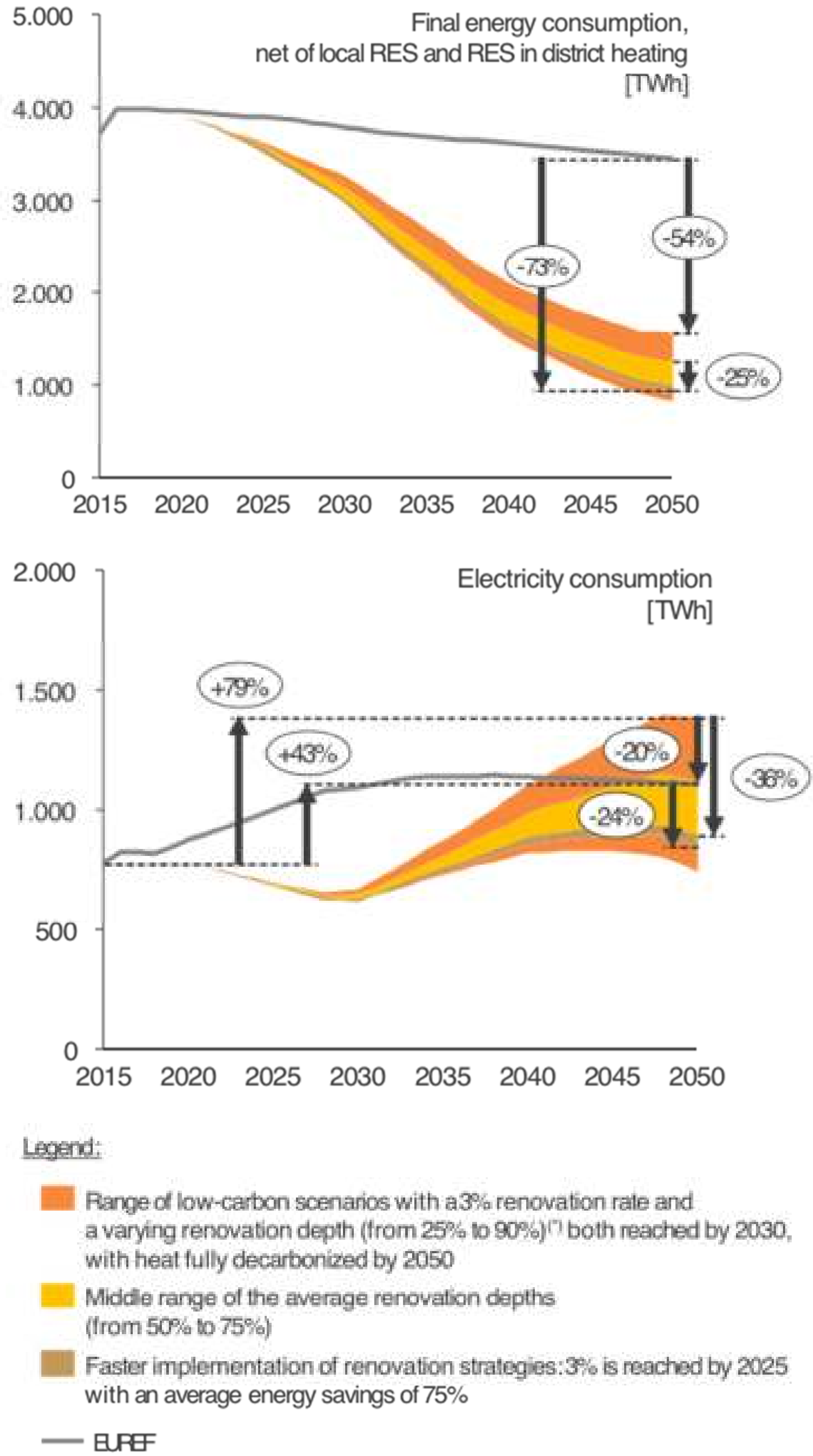

Figure 4. Impact of renovation depth ambition levels on the final energy consumption and on the electricity consumption for buildings energy needs in low-carbon scenarios

(*) renovation depth percentages corresponds to average energy savings

Saving energy in buildings reduces power demand while bringing flexibility to the power sector
In the buildings sector, prioritizing energy efficiency will significantly reduce electricity demand, making it possible to deploy low-carbon power resources to speed up the decarbonization of other sectors, like transport where electrification is key for its low-carbon transformation.

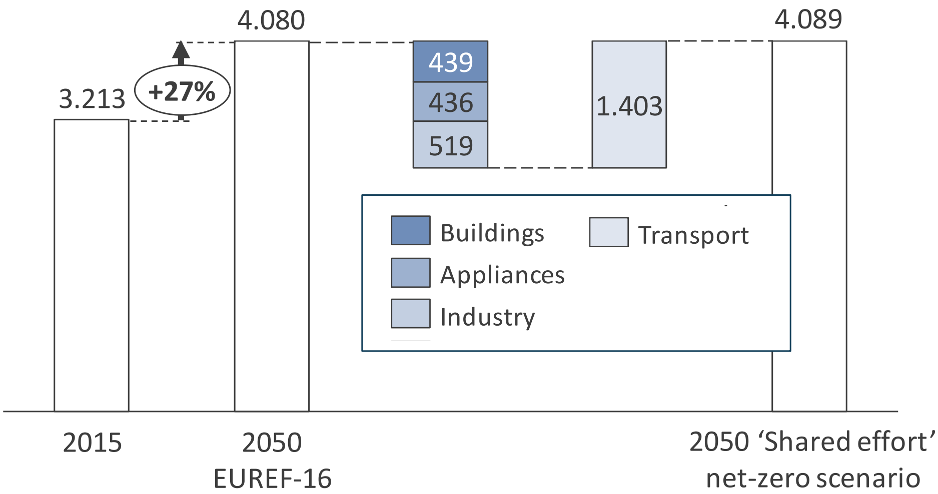

Figure 5. Difference by sector in the power demand in the EUREF-16 and the net-zero 'shared effort' scenario with significant ambition in the buildings sector[7] (in TWh)

The combination of energy efficiency, electrification and smart buildings benefits the power sector

Firstly, achieving zero-carbon power production requires a large increase in variable renewable energy sources (notably wind and solar) in the power mix. This can lead to a shortfall between the variable power production of these variable renewable energy sources and power demand profiles from buildings and transport. Avoiding such shortfalls requires a portfolio of zero-carbon flexibility options bringing higher flexibility from both the supply and the demand sides, as well as larger grid infrastructure and energy storage. **Highly efficient heat-electrified smart buildings provide part of the solution by increasing the Demand-Side Management (DSM) potential to answer (daily) flexibility requirements.**

The ability of a building to provide higher DSM potential depends on various factors [8, 9]:

1. its occupant's behavior and comfort requirements;
2. the physical characteristics of the building such as the insulation level, the thermal mass and the architectural layouts: a building with more thermal inertia and autonomy allows more flexibility while staying in the range of comfort requirements defined by its occupants;
3. the technological characteristics of the building and its appliances: ventilation, heating and cooling technologies, storage equipment, etc.;
4. the control system: the system should enable user interactions, for example to react to external signals such as electricity availability and prices.

[7] This also includes significant improvements in lighting, cooling and water heating systems

[8] G.Reynders, KU Leuven, 2015. Quantifying the impact of building design on the potential of structural storage for active demand response in residential buildings

[9] Junker, Rune Grønborg, et al, 2018. Characterizing the energy flexibility of buildings and districts. *Applied Energy* 225 (2018): 175-182.

Various studies show that efficient heat-electrified smart buildings can provide significant DSM potential to answer (daily and intraday) flexibility requirements providing a sufficient autonomy level is achieved, and adapted technologies and control systems are provided[10, 11].

Secondly, as noted above, while electrification of heat is an option for its decarbonization, energy efficiency is key to limit the burden on the power sector and particularly on the peak capacity.

- **Seasonality**. On the one hand, the seasonality of heat demand (energy must be provided only during colder months) leads to higher power production capacities per unit of energy to be delivered compared to other sectors where demand is 'averaged' on the entire year. Limiting the energy needs thanks to energy efficiency is then key to limit the required power production capacities or corresponding imports. **While the peak power demand in buildings increases by 32% in the EUREF scenario w.r.t. 2015, this increase could be limited to 19% with 50% average energy savings reached by 2030, and to just 13% with 75% average energy savings.** This corresponds to a 10% to 15% reduction in peak power demand in 2050 w.r.t. the EUREF scenario. Energy efficiency also reduces the gap between the demand and production during extreme no-wind / no-sun periods.
- **Daily demand profile**. On the other hand, daily heat demand profiles show important peak-to-average ratios[12], fostering the need for peaking production capacities. Energy efficiency helps limit the total peak demand by limiting heat losses over the day, and thereby (1) lowering the total electricity demand and (2) allowing to shift heat demand to off-peak periods thanks to higher autonomy. **Peak demand reductions for those types of buildings were estimated at 30% on average and up to 50% for experimental buildings**[6, 13].This also leads to power network and operational cost savings of up to 40%[9].

There are even more compelling reasons for higher ambition: the monetized co-benefits of Energy Efficiency in buildings are higher than required investments

The benefits of energy efficiency in the buildings sector far outweigh the investment requirements. Besides their contribution to the reduction of damages caused by climate change, GHG emission reduction policies and measures in the buildings sector also improve air quality, improve the thermal comfort of indoor habitats, reduce health risks and boost energy security and the economy's resilience to systemic risks e.g. on resources availability. There are also significant contributions to economic growth and jobs.

The literature (see detailed sources on the graph below) suggests that **monetized co-benefits amount to two to three times the required investments** without including avoided costs related to climate damages (Figure 6). These estimations derive from scenarios with energy efficiency and renewable energy targets ranging from 33% and 45% respectively, by 2030. It is expected that the benefits will be significantly higher in a 2050 timeframe.

The largest co-benefit is related to the economy, which covers economic growth, job creation and public budget impacts. In this category, the spread of results originates from the variety of energy efficiency ambitions considered in the different references.

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[10] Y.Thomas, et al, 2016. Structural Thermal Energy Storage in Heavy Weight Buildings—Analysis and Recommendations to Provide Flexibility to the Electricity Grid. 3E, *Final Report*

[11] B.Diczfalusy, & P.Taylor, 2011. Technology roadmap, energy-efficient buildings: heating and cooling equipment. *International Energy Agency, Paris, France*

[12] An average peak-to-average ratio of 6 is considered in the EU CTI model

[13] A.Arteconi, & F.Polonara, 2018. Assessing the Demand Side Management Potential and the Energy Flexibility of Heat Pumps in Buildings. *Energies*, *11*(7), 1846.

Climate-related co-benefits rank second. They refer to the avoided costs of extreme events due to climate change. Estimations of these costs widely vary between sources: from 120 billion € [6] to 3000 billion € [14]. As energy efficiency (building, transport and industry) is expected to account for 45% of GHG cuts[8] and the building sector is expected to deliver 27% of energy efficiency-related energy savings[5], this results in the ranges depicted in Figure 6.

Health co-benefits include the reduction of energy poverty-related health issues as well as mortality and morbidity related to indoor and outdoor air pollution. Health co-benefits vary between sources depending on whether air pollution is considered or not.

The energy security category includes avoided power system investments costs, increased reserve margins and the benefits of reduced dependence on extra-EU fossil fuel imports.

Finally, co-benefits related to resources model the avoided costs of exploiting less accessible resources in a scarcity context.

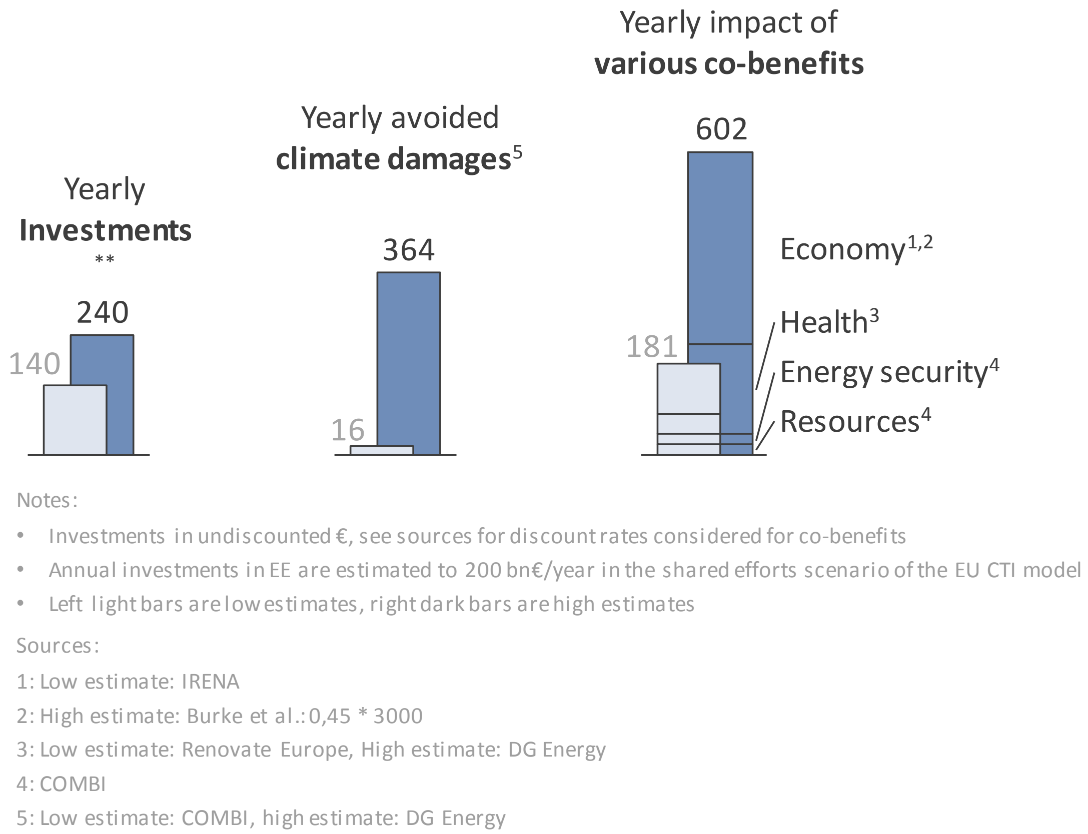

Figure 6. Investment costs and monetized co-benefits of energy efficiency measures w.r.t. reference scenario [15, 16,17,18]

[14] Burke et al., Large potential reduction in economic damages under UN mitigation targets, 2018

[15] COMBI, Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe, 2015.

[16] European Energy Agency, Climate change, impacts and vulnerability in Europe 2016: An indicator-based report, 2016

[17] European Commission, The macro-level and sectoral impacts of Energy Efficiency policies, 2016 and 2018

[18] IRENA, Synergies between renewable energy and energy efficiency, 2017

A RAPID TRANSFORMATION OF THE BUILDINGS SECTOR IS POSSIBLE

The transition is ambitious but best-practice policies and small-scale initiatives demonstrate it is feasible. The required efforts on energy efficiency in the net-zero scenarios show that, in existing buildings, the energy needed for heating must to be lowered by 45% (factor 2 energy renovation on 90% of the buildings stock) to 68% (factor 4 energy renovation on 90% of the buildings stock) in 2050 w.r.t. 2005 and emissions must be reduced by at least 90 to 100% w.r.t. 1990.

The energy efficiency ambition is consistent with the political ambition of the best-practice national renovation strategies, e.g. the French and Walloon renovation strategies target the renovation of all the buildings stock at low-consumption levels by 2050. **While their realization remains a challenge, examples of factor-10 energy renovations are increasingly available for all building typologies and in many countries. To help scale this up, many cities are experimenting with deep building retrofit initiatives, testing new business models and industrial practices to make this cheaper and less cumbersome for citizens.**

While most solutions already exist, scaling up and innovation are essential to bring us to net-zero. Commercially available solutions can already take us about 75% of the way to net-zero if deployed at scale[19]. The remaining 25% can be achieved based on known approaches and technologies for which further scaling up and commercialization is needed. In the buildings sector, **innovation will be key to increase by a factor of three both the renovation rate and the depth of any occurring renovation project.**

Setting a clear and positive direction of travel, which is required to ensure that near-term choices are aligned with long-term goals, will help to ensure the required investment in scaling up these solutions. It will also unleash further planning, investment and creativity regarding technologies and social developments, which can widen the range of options available for reaching net-zero.

While a lot of solutions already exist today, innovative business and policy approaches are required to scale-up existing small-scale initiatives. The key innovations required are the following:

- To deploy tools and processes to ensure that energy efficiency improvements are undertaken at the best and most cost-effective moment (trigger points[20], whereby e.g. energy renovation builds upon other planned works, or change of owner/ tenants);
- To continue developing innovative business models for deep-renovation, as a way to reduce cost, to enhance impact and to make it easier for users to undertake renovation (e.g. building renovation passports); and to boost deployment of successful models in similar segments;
- To invest in capacity buildings at all levels to ensure the quality of implementation; and to empower cities and regions in this context;
- To expand and develop innovative financing schemes and products, such as green mortgages[21], to overcome administrative and risks barriers; To support policy innovation, sustained efforts and a real engagement are needed from decision-makers, ranging from policy pledges to a clear commitment to implement the long-term renovation strategies in the Energy Performance of Buildings Directive and the annual savings targets in the Energy Efficiency Directive. This is essential to provide a stable and predictable policy future to investors.

[19] J. Pestiaux *et al.* (CLIMACT), 2018. Net zero by 2050: from whether to how. Zero emissions pathways to the Europe we want.
[20] BPIE, 2017. Policy factsheet: trigger points as a "must" in national renovation strategies
[21] EeMAP: Energy Efficient Mortages Action Plan. http://eemap.energyefficientmortgages.eu/

APPENDIX: DESCRIPTION OF CONSIDERED SCENARIOS

EUREF-16

The EU CTI EUREF-16 scenario is based on the PRIMES EU Reference Scenario 2016 that starts from the assumption that the legally binding GHG and RES targets for 2020 will be achieved and that the policies agreed at EU and Member State level until December 2014 will be implemented. The EU CTI EUREF-16 mimics the PRIMES EU Reference Scenario 2016 in terms of energy consumptions and GHG emissions in each sector. The activity drivers might differ from the ones considered in PRIMES, since different lever settings can lead to similar aggregate results by sector. The table below provides the main assumptions for the buildings sector.

Lever category	Lever levels
Demand for conditioned areas	The evolution of the floor area observed on 2010-2015 (+0.58%/year) is maintained from 2016 onward. The household size follows the historical trend, decreasing by -0.40% a year and resulting in a higher number of dwellings. For non-residential buildings, the yearly increase in floor area remains at 1%/year, leading to 18m²/person by 2030 and 22m²/person by 2050
Demolition rate	0.1% of the buildings stock is demolished and rebuilt each year
Renovation rate and depth	The renovation rate is increased, from 1% today, to 2%/year by 2030. The renovation depth is not increased and leads to average energy savings of 20%.
Carbon content of heat	By 2035, the contribution of fossil fuels to heat is reduced by 9% in residential buildings and by 33% in nonresidential buildings
Mix of low-carbon heating technologies	The mix of technologies does not evolve, the contribution of the different technologies is kept equal to 2015 levels
Evolution of the energy efficiency of appliances and lighting	The average energy efficiency of appliances improves by 2.0% a year up to 2020, then by 2.9% a year up to 2030. The yearly improvement is then considered to be only 0.1% from 2030 to 2050

Decarbonized buildings scenarios

Starting from the buildings sector's activity considered in the EU CTI EUREF-16 scenario, energy efficiency improvements are considered in the Figure 3 under the following additional assumption impacting the evolution of the energy needs of the buildings stock. The assumptions on the compactness and the appliance energy efficiency drivers are unchanged from the EUREF-16 scenario. The two other drivers derive from the working assumption that heat is to be decarbonized by 2050 and maximal ambition on the contribution of heat pumps to allow for conservative discussion on the impact of decarbonized heat on the power sector (higher shift to biomass f.i. would reduce the burden on the power sector and bring other stakes).

Lever category	Lever levels
Demand for conditioned areas (similar to EUREF)	The evolution of the floor area observed on 2010-2015 (+0.58%/year) is maintained from 2016 onward. The household size follows the historical trend, decreasing by -0.40% a year and resulting in a higher number of dwellings. For non-residential buildings, the yearly increase in floor area remains at 1%/year, leading to 18m²/person by 2030 and 22m²/person by 2050
Demolition rate	0.2% of the buildings stock is demolished and rebuilt each year
Renovation rate and depth	It is varied as described in the Figure 3
Carbon content of heat	Heating system replacements are considered to occur at a pace that leads to zero-carbon heat by 2050. The mix of technologies is set by the next lever.
Mix of low-carbon heating technologies	By 2050, heat energy needs are covered by individual RES-based heating systems (62%), district heating (31%) and direct electricity heating (7%). In the existing buildings stock, space heating from individual RES-based heating systems and district heating relies on heat pumps (80%), biomass (10%) and solar thermal (10%).
Evolution of the energy efficiency of appliances and lighting (similar to EUREF)	The average energy efficiency of appliances improves by 2.0% a year up to 2020, then by 2.9% a year up to 2030. The yearly improvement is then considered to only 0.1% from 2030 to 2050.

Shared effort net-zero GHG emission scenario

The EU CTI model is a simulation model that allows to define scenarios by modifying ambition levels on a selection of key sector drivers. In the ECF work[22], a "Shared efforts" scenario is defined with a comparable level of effort maintained across sectors and levers, i.e., there is no emphasis on any specific mitigation option.

[22] J. Pestiaux *et al.* (CLIMACT), 2018. Net zero by 2050: from whether to how. Zero emissions pathways to the Europe we want