White Paper on Affordable, Sustainable Energy Transition and Building Renovation

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Contents

List of acronyms

Acronym	Description	Acronym	Description
BPIE	Buildings Performance Institute Europe	JTF	Just Transition Fund
DHC	District Heating and Cooling	JTM	Just Transition Mechanism
EC	European Commission	JTP	Just Transition Platform
ECF	European Climate Foundation	LCA	Lifecyle Assessment
EED	Energy Efficiency Directive	MS	EU Member State(s)
EPAH	Energy Poverty Advisory Hub	NEB	New European Bauhaus
EPBD	Energy Performance of Buildings Directive	NGOs	Non-governmental organizations
EPC	Energy Performance Certificates	OSS	One Stop Shops
ERDF	European Regional Development Fund	REC	Renewable Energy Community
ETS	European Trading Scheme	RED	Renewable Energy Directive
EU	European Union	RRF	Recovery and Resilience Facility
GHG	Greenhouse Gas	SEL	Societal Embeddedness Level
HTR	Hard to Reach	SET	Strategic Energy Technology
IEA	International Energy Agency	SRL	Societal Readiness Level
IEQ	Indoor Environmental Quality	SRoI	Social Return on Investment
ILO	International Labour Organization	TES	Thermal Energy Storage
IPCC	Intergovernmental Panel on Climate Change.	TRL	Technology Readiness Level
IWG5	Implementation Working Group 5 on Energy Efficiency in Buildings		

Executive summary

The European Union (EU) has established ambitious objectives to significantly reduce greenhouse gas emissions, promote the widespread adoption of renewable energy sources, and improve energy efficiency. Meeting these targets requires a coordinated, multi-tiered governance strategy that actively engages vulnerable consumers. This white paper examines the primary challenges associated with the EU's energy transition, highlighting its social aspects and the consequences for energy-impoverished citizens. A sustainable and economically accessible building stock is vital for this transformation; however, considerable technical, economic, and social challenges must be overcome to facilitate a comprehensive and socially inclusive transition. By analysing the current landscape, this paper synthesizes scientific evidence, policy frameworks, and exemplary projects that present practical pathways to achieving the EU's objectives.

The shift towards a decarbonized, equitable, and financially viable energy system demands an emphasis on comprehensive building renovations, the gradual elimination of fossil fuels, increased electrification, and the reduction of energy consumption and biomass use. Renovating Europe's aging building infrastructure is crucial for enhancing energy efficiency and affordability, particularly for marginalized households. Concurrently, the transition away from fossil fuels must incorporate clean space conditioning technologies, such as heat pumps and renewable district heating and cooling, to ensure accessibility, affordability, and cost-effectiveness for all. Electrification efforts must be expanded while addressing the potential financial implications for lower-income households, and the ongoing dependence on biomass — frequently utilized by energy-impoverished consumers — warrants re-evaluation due to its adverse effects on air quality and public health.

This white paper underscores selected key EU and national initiatives aimed at promoting a fair and inclusive energy transition alongside building renovations. District heating and cooling, as well as positive energy districts present collective mechanisms to improve energy efficiency and affordability. Renewable energy communities empower citizens and local organizations to produce and manage their own renewable energy sources. Integrated advisory services, often referred to as one-stop shops, facilitate home renovations and enhance energy efficiency, particularly benefiting vulnerable consumers. These can be complemented with initiatives, such as energy coaching, to further support the most vulnerable. Building renovation passports provide a structured, systematic approach to renovations, ensuring both long-term energy performance gains and affordability. The societal readiness concept further addresses behavioural, social, and economic barriers, promoting widespread public engagement in the transition.

This white paper is part of the Implementation Working Group 5 on Energy Efficiency in Buildings (IWG5-Buildings) and contributes to the European Strategic Energy Technology (SET) Plan. Task Force 5 on Just Transition and Affordable Sustainable Renovation, coordinated by IWG5-CSA, provides expert guidance to support policy implementation and foster an inclusive energy transition. By integrating social dimensions with technical and financial considerations, this document serves as a roadmap to ensure that the EU's energy transition is not only effective but equitable for all in its multiple dimensions.

1. Introduction

The European Union has established a comprehensive policy framework to ensure a "Just Transition" towards a climate-neutral economy, emphasizing an affordable and sustainable renovation. Under this framework, an increasing emphasis has been placed on the role of citizens, mainly focused on energy poverty and vulnerable consumers in energy transitions. Concepts such as energy citizenship (involvement and engagement in the energy transition) (Thalberg and Hajdinjak, 2024) and the opportunities the transition presents to rectify inequalities associated with fossil fuel-based energy systems (Lewis et al., 2021) are identified. The energy transition is a pivotal mechanism within global, European, and national policy frameworks to address inequities and advance towards a more inclusive and participatory energy landscape. Below is an overview of relevant policies, plans, and support schemes for this white paper's scope.

In 2018, important regulation was set under the Renewable Energy Directive (RED II), which promotes renewable energy adoption and addresses energy poverty through access to clean energy, and the Energy Efficiency Directive (EED), which improves energy efficiency and prioritizes vulnerable consumer groups in energy-saving measures.

In 2019, the release of the Clean Energy for All Europeans Package established a fair energy market with provisions to protect vulnerable consumers and define energy poverty. This was followed by the European Green Deal, focusing on achieving climate neutrality by 2050 with measures to tackle energy poverty through investments in clean energy.

The Just Transition Mechanism (JTM), the Just Transition Fund (JTF), and the Just Transition Platform (JTP) (2020) are central elements of the European Green Deal. They aim to ensure a fair and inclusive shift to a climate-neutral economy by 2050 and support regions and communities most affected by the transition to a low-carbon economy. The first EU recommendation on energy poverty was also set in 2020 as the Renovation Wave communication, aiming to improve energy efficiency, boost the economy, and deliver better living standards for Europeans. As part of it, the Affordable Housing Initiative was set to improve energy efficiency and affordability in the housing sector, particularly for vulnerable populations.

In 2021, the Recovery and Resilience Facility (RRF) was launched to facilitate post-COVID-19 recovery, focusing on green transitions and energy poverty reduction. The European Pillar of Social Rights Action Plan was also launched to promote social fairness, equal access to essential services, and energy poverty. After the invasion of Russia into Ukraine, to reduce dependency on Russian fossil fuels and address energy poverty through increased energy diversification and safety, the REPowerEU Plan was published (2022).

The Social Climate Fund (2023), derived from the Emission Trading Scheme (ETS) 2 revenues framed within the revision of the ETS Directive, provides financial support to member states for the measures and investments included in their Social Climate Plans. The measures and investments supported by the Fund shall benefit vulnerable households, micro-enterprises, and transport users. This will be a 65 billion euro fund (+25% national contribution), operational from 2026 to 2032. Also, in 2023, the revised Energy Efficiency directive was published, including the first EU-wide "narrative" definition of energy poverty (Article 2), ringfencing of energy savings benefiting energy-poor households, prioritization of vulnerable and energy-poor households in energy efficiency measures, use of public funds, information, and engagement (Articles 8, 22 and 24). Following that, in October 2023, the latest Commission Recommendation on Energy Poverty was released. It provides guidelines for EU member states to enhance the identification, monitoring, and mitigation of energy poverty, emphasizing the need for target measures to protect vulnerable consumers and promote energy efficiency.

For the first time, 2024 brought an EU Commissioner (Dan Jørgensen) to work on housing, combining it with energy issues. Among other things, the plan is to set forward a European Affordable Housing Plan, unblock funding from the European Investment Bank, and set new funding sources to further progress the activities initiated under the Recovery and Resilience Facility when it expires. Also, in 2024, the Energy Performance of Buildings Directive (EPBD) recast focuses on enhancing energy efficiency by renovating the worst-performing buildings, setting zero-emission standards for new constructions, integrating renewable energy, and phasing out fossil fuel boilers.

Nevertheless, despite the strong policy framework, multiple technical and social challenges have been arising for successfully implementing climate, energy consumption, renewables integration, and energy efficiency objectives across regions, sectors, and at multiple scales. This is particularly challenging when action should go beyond business as usual and low-hanging fruit sectors and target the most vulnerable, energy-poor citizens and hard-to-reach energy users, leaving no one behind.

A set of factors contributes to varying dimensions and depth of energy poverty vulnerability across the EU, such as socio-economic, technological, cultural, and geographical (e.g., low income, high energy costs, energy inefficiency of buildings, location in disadvantaged geographical/urban/extra-urban contexts, lack of knowledge on the overall energy efficiency issue, 'seasonality' (energy poverty in cold season / warm season). This can be related to the right to access basic energy services while also promoting the "Right to Energy" which could be one of the guiding principles for a Just Transition. Housing affordability issues are also intertwined with this.

Alignment with IWG5 updated implementation plan and its innovation action targets

This document belongs to a set of contributions by the Implementation Working Group 5 on Energy Efficiency in Buildings (IWG5-Buildings), aimed to give support to the European Strategic Energy Technology (SET) Plan through its Implementation Plan (IP), which was recently updated (middle 2024). This White Paper is a fruitful contribution from Task Force 5, on Just Transition and Affordable Sustainable Renovation, coordinated by IWG5-CSA, aimed to provide expert support to IWG5 to implement the SET Plan effectively.

IWG5 promotes mainstreaming innovative renewable energy and energy efficiency technologies in buildings, improving the renovation rate while also considering resource efficiency and circularity of buildings. These objectives are aligned with EU goals in the short term (2030) and the mid-long term (2050). Since citizens, especially vulnerable ones, must be considered to promote a Just Energy Transition, this white paper intends to approach the social impacts of those objectives, their implementation, and other aspects that should be considered from a social perspective. The IWG5-Buildings Implementation Plan provides several Innovation Targets, according to two different Actions: 5.1 on Sustainable Materials and technologies for energy efficiency solutions for buildings, and 5.2. on Cross-cutting

Heating and Cooling Technologies for buildings. Considering those more intertwined with the social dimension of Just Energy Transition and Affordable Sustainable Renovation, some of those objectives are highlighted, as they involve building users within their proposals:

- Target 5.1-T1 - Reduce the energy use of buildings by 16% in 2030 with respect to 2020.
- Target 5.1-T2 - Develop and demonstrate solutions for zero-emission buildings by 2030 while retaining cost efficiency.
- Target 5.1-T3 - Develop and demonstrate market-ready solutions to reduce the average duration of energy-related construction works by more than 40% for renovation and new buildings compared to current national standard practices.
- Target 5.1-T4 - Develop and demonstrate market-ready solutions to reduce the difference between the predicted and the measured energy performance to a maximum of 15% after the commissioning period, aiming to reach 10%.

The remaining targets (Targets 5.1 T5 and T6, and Targets 5.2), although they also have inherent social dimensions to be considered, are more technical in their definition. Thus, a first approach is taken to the first four 5.1 targets, and further reflections on the social implications of EU objectives, which are also aligned to the remaining 5.1 and 5.2 IWG5 targets are offered in the subsequent sections of this document.

This white paper aims to address key challenges of the EU energy transition to become fair and just, directly affecting society and having a particular impact on vulnerable and energy-poor citizens. Besides, the current situation is explored in its multiple dimensions, and the relevance of a renovated, sustainable, and affordable building stock is outstanding, where key implementation challenges and solutions must be further defined for a deep and socially inclusive change. It is organized into five sections. The introduction unfolds the current key energy, climate, and buildings EU-level policy framework, framing the need for a socially relevant transformation and energy poverty reduction. This is followed by section 2, which depicts the focus and key concepts of the white paper around the just transition, vulnerable consumers, and energy poverty. Relevant stakeholders' profiles mapping under the quadruple helix are also identified. Section 3 assesses four key areas of action where challenges towards a just energy transition are identified, pointing out red flags and potential solutions. Section 4 looks ahead and assesses a series of relevant solutions enabling a more inclusive and socially just process, identifying selected EU and national projects and initiatives where inspiration and synergies can be explored. Section 5 concludes the white paper by summarising the main red flags, barriers, and gaps within the implementation actions while providing recommendations for the current SET Plan IWG5-Buildings Implementation Plan targets.

2. Just Transition: affordable, sustainable renovation

The ambitious EU purpose of a Just (energy) Transition entails significant challenges to face, both in terms of paradigm shift in industrial sectors, regions, and countries traditionally linked to fossil fuels, boosting greener jobs and re-skilling sectoral workers; making energy more affordable, safer, and stable for all, through governance, democratization and commitment, reinforcing the sense of belonging in communities; and mitigate energy inequities, such as energy poverty and vulnerability.

To reach this, different stakeholders are to be proactively involved at a multiscale level to guarantee that the investment mechanism provided by the EU reaches final users and communities, paying special attention to the most vulnerable ones effectively.

The following section digs into the main definitions either provided by the EU or consensually agreed upon by MS for the topics of this White Paper, such as Just Transition, Affordable and Sustainable Renovation, and their social implications. Besides, it deserves to be mentioned the relevant stakeholders to get involved in this process of transitions, including the Quadruple Helix (Public and Private sectors, Academia and Research Institutions, and Civil Society) and most disadvantaged groups, as vulnerable and hard to reach.

This White Paper of the Implementation Working Group on Energy Efficiency in Buildings IWG5 Buildings Task Force 5 focuses mainly on social perspectives of the Just Transition, integrating environmental, economic, and technical impacts on civil society, with emphasis on vulnerable populations.

Just (energy) transition

A fair and just transition to a climate-neutral Union by 2050 is at the core of the European legal and policy frameworks. It is essential to achieving the goals of the Paris Agreement, the Green Deal, and the EU's 2030 energy and climate goals.

The International Labour Organization (ILO) defines Just Transition as: "Greening the economy in a way that is as fair and inclusive as possible to everyone concerned, creating decent work opportunities and leaving no one behind". Moreover, Eurofound describes it as "the transition to a climate-neutral economy while securing the future and livelihoods of workers and their communities". Thus, a just transition to a climate-neutral economy guarantees better and decent jobs, social protection, more training opportunities, and greater job security for all workers affected by global warming and climate change policies. In other words, just transitions (meaning more than one possible pathway depending on the region) imply not only that everyone can equally access transition policies but also that everyone can equally access the benefits (comfort, air quality, skills, savings, etc) of transitioning to a greener society and economy. The "Just" dimension also encompasses empowerment and equitable decision-making access. This includes ensuring accessible participation and meaningful influence on decisions by all groups (Abram et al., 2022).

The EU aims to be the first climate-neutral region by 2050. To reach this ambitious objective, considerable investment was intended, over 1€ trillion from the European Green Deal Investment Plan, where 100 billion euros are planned to be mobilized under the Just Transition Mechanism. It will support regions, workers, and sectors affected by the transition towards a green economy. This is primarily focused on the most carbon-intensive regions and those with people working in the fossil fuel industry. Those member states will get access by preparing territorial just transition plans up to 2030, addressing social, economic, and environmental challenges.

However, if not carefully managed, transition pathways could exacerbate social inequality, trigger civil unrest, and reduce the competitiveness of businesses, industries, and markets. Transition pathways have significant distributional impacts, with job losses likely in certain sectors, regions, and communities—particularly those heavily reliant on fossil fuels or carbon-intensive industries and where opportunities for economic diversification are limited.

According to the Just Transition Mechanism Document by the European Commission (EC), there are three well-differentiated social groups or scales to be assisted in Just Transition: 1) companies and sectors, 2) people and citizens, and 3) member states and regions. Different actions are developed to reach the objectives for the three social groups, here, we highlight the ones targeting citizens:

- supporting climate-resilient investments and green (new) jobs and employment opportunities in new sectors and those in transition, besides re-skilling opportunities
- Improving energy-efficient housing
- Access to clean, affordable, and secure energy
- Fighting energy poverty

So, a deep interlinkage is found between social and economic aspects concerning energy in every stage of its value chain: production, distribution, consumption, and delivery to final users; and a clean and affordable transition to low-carbon energy resources since they imply a severe transversal renovation, transforming business models and industry sectors, and finally affecting the human capital as well.

Besides, legislative packages introduced in July and December 2021, such as "Fit for 55", to implement the European Green Deal, prioritize tackling energy poverty and safeguarding vulnerable populations. Additionally, the Renovation Wave, a key initiative aimed at accelerating the renovation of both private and public buildings, also places significant emphasis on addressing energy poverty.

Researchers have also developed the concept of a just transition based on the notion of energy justice (Sovacool et al., 2016; Sovacool & Dworkin, 2015), which promotes the equitable management of energy-related issues. It advocates for recognizing communities' diverse needs and ensuring representation in transparent and accessible decision-making processes. This requires fair and participatory procedures that empower users and ensure no one is left behind. Additionally, material and immaterial costs should be distributed equitably in quantity, quality, and spatial distribution.

Energy poverty

The EU is committed to tackling energy poverty and ensuring vulnerable consumers access essential energy services and products. The concept of energy poverty was first introduced in EU law by the Directive on common rules for the internal electricity market (2009/72/EC). Since then, the narrative of a just and fair energy transition has been broadened, and over the past decade, the EU has increased its efforts and made energy poverty a key concept through policy action, recommendations, and initiatives such as the Energy Poverty Observatory (2016-2020) and the Energy Poverty Advisory Hub (EPAH) (2021-2028). Furthermore, it has set up in 2022 the Commission Energy Poverty and Vulnerable Consumers Coordination Group for the exchange of information and coordination between the Commission and Member States on energy poverty.

Energy poverty consists of "a household's lack of access to essential energy services, where such services provide basic levels and decent standards of living and health, including adequate heating, hot water, cooling, lighting, and energy to power appliances, in the relevant national context, existing national social policy and other relevant national policies, caused by a combination of factors, including at least non-affordability, insufficient disposable income, high energy expenditure and poor energy efficiency of homes".

In addition, vulnerable households comprise households in energy poverty or households, including low-income and lower middle-income ones, that are significantly affected by the price impacts of the inclusion of greenhouse gas emissions from buildings within the scope of Directive 2003/87/EC and lack the means to renovate the building they occupy[1]. In this context, private household, or just household, means a person living alone or a group of persons who live together, providing oneself or themselves with the essentials of living[2].

Moreover, the vulnerability of these households is also shaped by the physical condition of the buildings they inhabit, as well as neighbourhood infrastructure services, accessibility, and the capacity to offer spaces for social cohesion, healthy outdoor living, and the strengthening of public and interpersonal relationships. Obsolescent building components, inadequate insulation, and outdated heating systems further exacerbate energy poverty, while limited access to essential services, public transport, and neighbourhood safety can heighten social and economic exclusion. Addressing these multidimensional factors is crucial for ensuring inclusive and effective energy transitions.

Hard-to-reach energy users is also a concept that has been receiving growing attention among researchers, policymakers, and practitioners, defining those who are difficult to reach physically, underserved, or hard to engage or motivate – are a vital concern for just energy transitions (Ambrose et al., 2019; Rotmann, et al., 2020, Mundaca et al., 2023). An International Energy Agency Users TCP task deals explicitly with these HTR energy users. HTR profiles have been identified in Sequeira et al. (2024) that systematizes a theoretical framework, proposing thirteen profiles for vulnerable households (i.e., low-income, low education, rural, multi-family, elderly, young, single parents, migrants, unemployed, ill-health and disabilities, ethnic minorities and Indigenous groups, homeless and informal settlements, travellers and nomadic communities), two for high-income households (high-income, sumptuous spenders), and two for tenants and landlords (tenants, landlords). A significant share of the EU population intersects at least two profiles, compounding the barriers to their engagement.

[1] Article 2, point (10) of REGULATION (EU) 2023/955 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 10 May 2023 establishing a Social Climate Fund and amending Regulation (EU) 2021/1060: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32023R0955

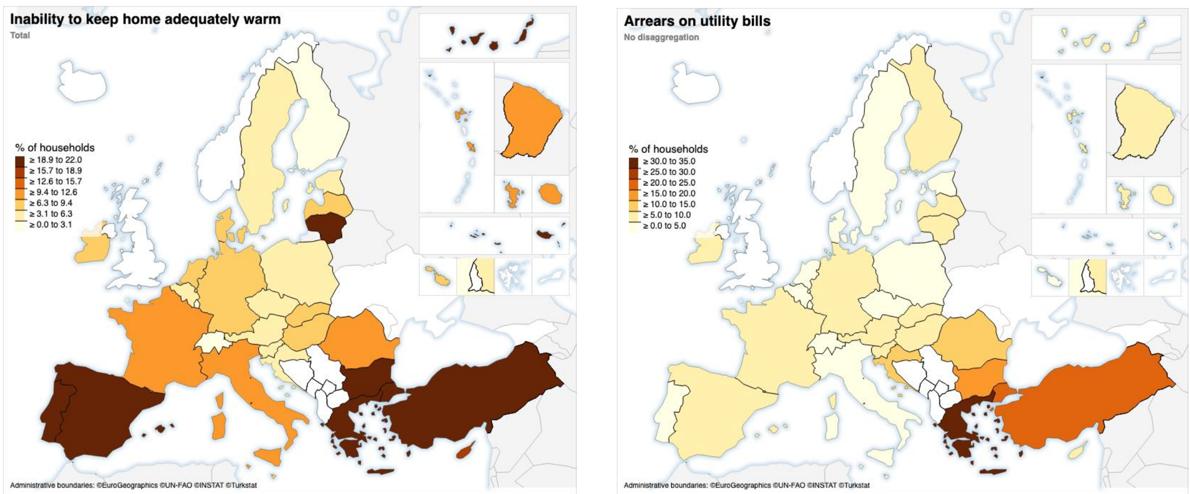
[2] Article 2, point (15), of REGULATION (EU) 2019/1700 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 10 October 2019 establishing a common framework for European statistics relating to persons and households, based on data at individual level collected from samples, amending Regulations (EC) No 808/2004, (EC) No 452/2008 and (EC) No 1338/2008 of the European Parliament and of the Council, and repealing Regulation (EC) No 1177/2003 of the European Parliament and of the Council and Council Regulation (EC) No 577/98

Energy is vital to our daily lives. Maintaining adequate heating, cooling, and lighting in our homes is necessary to ensure a decent quality of life and support our health. Energy poverty arises when a household is forced to cut back on energy usage to a level that harms the health and well-being of its members. It is primarily driven by three main factors: High energy prices, low household incomes, and poor energy performance of buildings and home appliances. Stojilovska et al. (2021) highlight emerging debates linked to energy poverty, which include good governance, citizens' agency, new energy services, and new threats from the energy transition.

Because it primarily affects households and is multifaceted, energy poverty remains a significant challenge for the EU. It displays significant disparities across EU countries, as it is influenced by heterogeneous national realities such as climate, geography, natural resources availability, buildings and energy infrastructure, and national and local policies and support schemes. The situation has been exacerbated by the COVID-19 pandemic, rising energy prices, and the Russian invasion of Ukraine in February 2022, which has made an already difficult situation even worse for many EU citizens.

The situation in the whole EU is concerning since vulnerability to multiple energy poverty-related situations has increased and depicts different depths across member states. Depending on the indicator selected, between 8% and 16% of the EU population could be facing energy poverty, while most of the energy poor are not income-poor (Maier & Dreoni, 2024).

Examples of relevant indicators showcasing important dimensions of energy poverty vulnerability are the proportion of households "unable to keep adequately warm their homes" which has increased from 6.9% in 2021 to 10.6% in 2023, being Southern countries, such as Spain or Portugal (both with 20.8%) in the top of EU. EU27 average on "Arrears in utility bills" has also increased from 6.4% in 2021 to 6.9% in 2023, making Greece the worst one, with 32.9% of the households reporting problems. The population living in a dwelling with presence of leak, damp and rot has progressed from 14.8% (average EU27) to 15.5%, with Cyprus (31.6%) and Portugal (29%) the worst-performing countries. Housing costs overburden rates have also increased from 8.7% to 8.8%, with Greece unfolding 28.5% of the population affected. Further discussion of other energy poverty-relevant indicators portraying its multiple dimensions can be found in Gouveia et al. (2022) and Gouveia et al. (2023) (Figure 1).



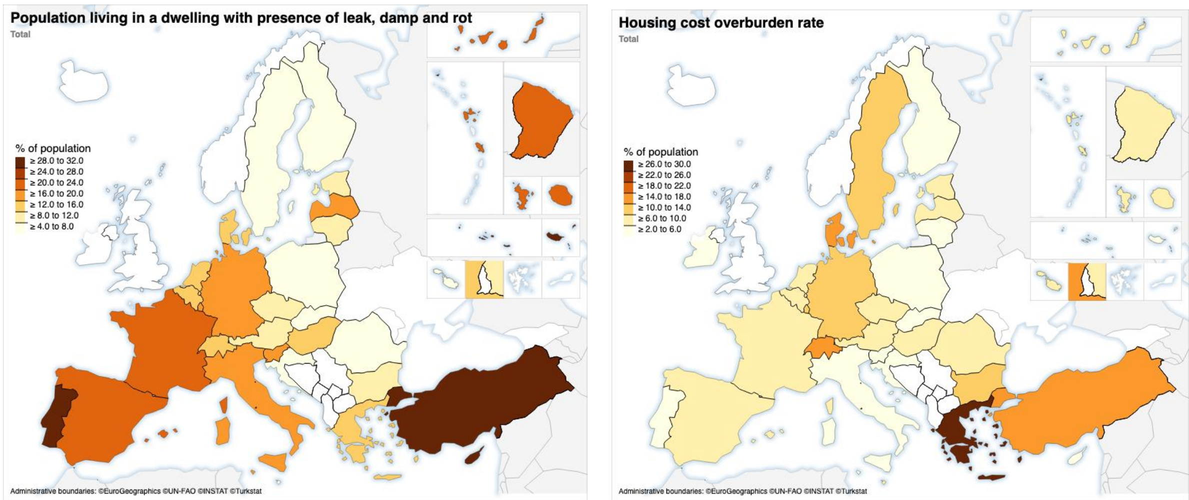


Figure 1 - Inability to keep home adequately warm (2023) (top left); Arrears on Utility Bills (2023) (top right); Population living in a dwelling with presence of leak, damp and rot (2023) (bottom left); and Housing Cost Overburden Rate (2023) (bottom right) (EPAH, 2025)

Energy poverty must be tackled by addressing its root causes through structural and targeted measures, particularly by increasing energy efficiency for buildings' infrastructure and domestic appliances and equipment. Tackling energy poverty requires holistic efforts at all levels of governance, from the European to the local level, encompassing climate, regional differences, socio-economic conditions, and cultural habits. Therefore, contextualized solutions are very relevant.

Affordable and sustainable renovation

A key challenge in housing and buildings is to ensure minimal adequate conditions for the health and well-being of their occupants through safe and stable access to domestic energy and its efficient use to optimize the households' expenditures on it. Achieving this requires a blend of passive and active measures within buildings and their energy services. Passive measures focus on the building's design and material selection. In contrast, active measures involve clean heating and cooling technologies, domestic hot water, lighting, and energy required for other home devices and appliances.

Therefore, the concept of building renovation encompasses any energy-related building renovation, that has the aim of increasing the energy performance of buildings, such as the insulation of the building envelope, that is to say, the walls, roof, floor and replacement of windows, and the installation of technical building systems, compliant with any relevant national safety standards, including by contributing to the renovation requirements established in the EPBD (recast).

The Renovation Wave strategy aims to double the annual rate of building energy renovations by 2030, targeting the renovation of 35 million buildings, at least doubling the annual rate of energy renovations in the EU, and promoting job creation in the construction sector. It emphasizes reducing the whole-life-cycle emissions of buildings, starting with new constructions and including renovations. The strategy calls for phasing out fossil fuels in heating and cooling to decarbonize the sector. It sets a vision for zero-emission buildings with very low energy demand and no fossil fuel emissions by 2030 for new buildings and 2050 for existing ones. Major renovations should focus on cost-effective energy performance improvements, low climate impact (GHG emission), and resource-efficient solutions, with flexibility in defining the renovation scope. Energy needs for zero-emission buildings can be met by renewable energy sources such as solar, geothermal, and district heating, as depicted on the EPBD (2024). In addition to this, heat pumping technology and heat recovery could contribute to energy saving.

Sustainable

Building energy consumption not only involves the operational stage but also the whole life cycle of buildings, their construction materials and methods, so sustainable use of natural resources and energy has to be considered, from their design, production and construction to their removal, under principles of circularity and minimal and efficient material use, for any of their components and the building as a whole. Proximity and local production of raw materials and providers, less transportation, and efficient use, as long as possible, also considering it for a potential replacement or disposal. It is also relevant to guarantee, especially for innovative, transformative, or recycled materials, to accomplish other performance requirements according to the intended use (Cuerdo et al., 2014; Kioumarsi & Shafei, 2024). In the case of energy, the EU mandates require it to be clean, encompassing local renewable energy generation or recovered from other energy processes, thermal energy storage (TES), heat recovery, and distribution throughout the building. The use of passive building design strategies is key to ensure that the building energy needs can be fulfilled to a large extent without resorting to, or at least minimizing, the use of mechanical systems. Building renovations are an opportunity to improve building performance.

However, not much analysis is still carried out concerning social aspects when considering sustainability and LCA approaches in building renovations or reconstructions (Leichter & Piccardo, 2024), being needed to focus more on social and economic impacts, to explore comprehensively the sustainable approach of renovation (Fahlstedt et al., 2024), and the potential affordability of those interventions, especially for vulnerable population.

Sustainable interventions must also enhance energy awareness, particularly among vulnerable communities, where efficiency and renovation may not be a priority due to more immediate concerns and already frugal lifestyles. With institutional support, local initiatives and civil society organisations can help bridge this gap. Services like One-Stop Shops (Bertoldi et al., 2021) can assist residents by providing guidance on energy management and facilitating the adoption of technologies such as mechanical ventilation systems and heat pumps.

Affordable

Bearing in mind that 85% of EU housing was built prior to the year 2000, and three-quarters of those perform poorly in terms of energy, their homeowners could potentially face expensive costs to meet the new requirements established by the EU and their updated mandates.

As recognized within the European Parliament Resolution on Decent and Affordable Housing for All (2021), the Commission and the Member States aim to ensure equal access for all to decent housing, including [...] a high-quality indoor environment and to affordable, reliable, sustainable energy for all, thereby contributing to eradicating poverty in all its forms, protecting the human rights of disadvantaged households and supporting the most vulnerable groups, to protect their health and well-being.

So, to defend the "Right to Energy[3]" and ensure a proper, safe, stable and permanent home energy supply, not only energy access has to be guaranteed, but also the affordability, in terms of the cost of energy services and the ability of consumers to pay for them, without compromising other essential needs. Solutions have to facilitate support mechanisms to enable access to a renovated housing stock and to more efficient energy services, appliances, and devices while promoting social knowledge on energy efficiency (energy-conscious behaviour) for living.

The Affordable Housing Initiative builds on several key EU actions, including past housing partnerships and resolutions by the European Parliament and other committees, focusing on energy efficiency and affordable housing. It is a flagship of the New European Bauhaus (NEB), emphasizing sustainability, aesthetics, inclusiveness, and energy-efficient buildings. The initiative aligns with the European Pillar of Social Rights, particularly Principle 19 on housing, and supports the EU's cohesion policy for 2021-2027. It strengthens locally-led development strategies with the European Regional Development Fund (ERDF) funding for sustainable urban development. The initiative also aligns with the NextGeneration, EU Recovery plan, REPowerEU, and updates to the Energy Efficiency and Energy Performance of Buildings Directives.

Stakeholders

The Just Transition associated with the decarbonization of the MS economies is a multifaceted phenomenon that involves a 'diversified set of stakeholders' ranging from government and public authorities in a multi-level governance system to industry players, academia and research institutions, and civil society. Every stakeholder type plays an important role in a framework for innovation and collaboration. Cooperation in a holistic approach is necessary for the aimed Just Transition to be effectively achieved.

Current policy initiatives seek to engage citizens in the transition to e.g. environmentally sustainable and energy-efficient practices, climate action, and building renovation while encouraging them to adopt eco-friendly behaviours. To achieve these objectives, it is essential that citizens feel both empowered and inspired to take part. Nevertheless, the avenues available for citizen participation, especially for the most vulnerable, can be intricate, often favouring individuals with higher education, income, and literacy levels while restricting participation opportunities for those lacking these advantages (Castro et al., 2024). In addition to the vital contributions made by citizens and local governments, entities such as businesses, non-governmental organizations (NGOs), and educational institutions play pivotal roles in facilitating and driving green transitions. Looking at each one more specifically, we can see their importance in supporting a more just energy transition:

- The Public Sector plays an important role in policy creation, regulation, and funding. It can design and implement affordable and sustainable building renovation policies, set eligibility criteria for the most vulnerable, and allocate funds and incentives through funding programs under the Recovery and Resilience Plans, the Just Transition Fund, and other EU initiatives.

[3] The right to energy means that all individual humans enjoy certain rights and entitlements to be able to enjoy access to energy services necessary for health, well-being, social inclusion and full participation (ENGAGER, 2021)

- The Private Sector provides market structure, innovation, technological solutions, and investment. It can, for example, participate in public-private partnerships for renovation projects, develop innovative technologies and materials, or implement solutions such as solar PV systems or heat pump installations on the ground. Under this type are, for example, private housing companies that can decide on investment in renovation, heating systems, rent levels, etc. Sometimes, they lack the competence and incentives to make long-term investments. These challenges also apply to public housing. Another example related to industry stakeholders is power utilities and energy distributors, which are key players in the energy transition.
- Academia and Research Institutions generate knowledge, research, and technical expertise for implementing solutions and supporting policies. These stakeholders can offer training programs to upskill workers in the green economy, provide technical expertise to government bodies (national to local), assess the impact of just transitions policies, conduct research on energy-efficient technologies or sustainable materials, and develop and support the sector with fact-based decision-support tools.
- Civil Society, which includes citizens and non-governmental organizations, advocates for social equity, inclusivity, and broader sustainability of policies and measures. This can be done by their participation in community-led renovation initiatives or renewable energy community development. Civil society is also vital in ensuring projects and actions address vulnerable populations' needs (e.g., energy poverty and affordable housing). Challenges arise, for example, to private owners (both multifamily and single-family buildings) related to lack of information, competence, and incentives to carry out renovation, change heating systems, or replace old inefficient appliances. Vulnerable groups such as the elderly, retired people with old homes and low income, women, migrants, unemployed, single parents with small children, disabled, and persons with permanent health conditions are of particular attention.

3. Implementation

Since a just transition should be not only for the people but with the people, in this section, we identify a set of areas where buildings decarbonization-related challenges are already arising. We also suggest a deeper look at integrating the most vulnerable citizens' perspectives and related impacts. For each one, we a) synthesize the current situation, contextualizing it on policies and depicting key figures across the EU; b) identify related short-term to long-term objectives of EU policies; c) explore multiple social dimensions for each topic addressing situations such as operationalization and bureaucracy, existing support mechanisms and funding, knowledge, market response, and potential environmental, social and economic impacts. We conclude with a series of actions and recommendations linking to relevant related initiatives. The areas covered by this white paper, where the EU and MS establish their objectives with clear social implications, are:

- Prioritize holistic building renovation
- Set fossil fuels phase-out
- Increase electrification
- Reduce energy use and consumption of biomass

Prioritize holistic building renovation

Buildings contribute 40% of the EU's final energy demand, presenting significant untapped potential for energy savings. As a result, buildings play a crucial role in achieving the sustainability targets outlined in the European Green Deal and European Climate Neutrality targets, aiming to reduce net greenhouse gas emissions by at least 55% by 2030 (CORDIS).

Renovating Europe's building stock presents significant potential for fulfilling its climate commitments. The main challenges lie in improving building renovation' rates, quality, and effectiveness. The long-term renovation strategy aims to support the renovation of their national building stock into a highly energy-efficient and decarbonized building stock by 2050.

One of the key EU objectives regarding buildings' renovation is set on the Renovation Wave, aiming for double building renovation rates in the next 10 years, increasing energy and resource efficiency of building renovation. The renovation of around 35 million buildings while creating 11-18 local jobs per million euros invested aims to reduce 60% of GHG emissions, 14% of energy consumption, and 18% of heating and cooling.

The Renovation Wave's ambitious objectives and implementation can be seen across multiple EU regions as potentially challenging energy poverty goals and overly ambitious, overlooking the affordability and social consequences for low-income households and on-the-ground implementation problems. Additional challenges might arise from tenants and homeowners. Many policies prioritize owner-occupied homes, leaving renters in precarious situations or increased situations of "renoviction" after landlords renovate the houses, passing costs onto tenants through higher rents, leading to gentrification and displacement. Moreover, low-income owners will not have the financial capacity to renovate their houses to meet the Renovation Waves' objectives. This will also generate "renoviction" and worsen energy poverty condition of the low-income population, regardless if they are tenants or homeowners.

These initiatives have to be also promoted by homeowners, and their representatives, who often are not aware of the benefits of building energy saving and improved efficiency (Prafitasiwi et al., 2022), of the technologies available, their availability and viability. According to Neuroject, many people do not know the financial mechanisms to support these projects and their economic benefits, or distrust the timing, implications and disturbances generated by works (Serrano-Jiménez et al., 2021). Furthermore, other European initiatives, such as Housing Europe, the European Federation of Public, Cooperative, and Social Housing, help building stakeholders, not only homeowners and tenants, to explore funding paths, legal frameworks, and other mechanisms to renovate buildings and be more efficient, primarily focused on the underserved.

Renovations generate an added value that could deal with moving tenant households to cheaper and even worse-quality homes, so inequalities are perpetuated or even worsened (Granath & Femenías, 2022). It should lay on five interrelated justice dimensions: distribution, recognition, participation, capability, and responsibility (Broers et al., 2022).

Tenants are one of the most vulnerable social groups due to the lack of capacity for decision-making and potential improvement on the dwelling or the building, affecting their daily tasks and indoor environmental quality, with potential consequences on health and well-being (Cuerdo-Vilches et al., 2021; Cuerdo-Vilches & Navas-Martín, 2024). At the same time, their energy consumption patterns may slightly differ, affecting the related considerations and indicators within the renovation process (Hernández-Cruz et al., 2024). However, the tenants' reactions may vary from skeptical or resistant to satisfied and even demanding (Palm et al., 2020). Once renovated, the added value associated with housing should be regulated with proper legal and policy mechanisms to minimize the impact on vulnerable people in this tenancy situation, allowing them to stay in their homes (Mangold et al., 2016).

Renovation rates for residential buildings are more prominent on light ones, reducing complexity and cost levels. The 2012-2016 average for EU28 showed that the percentage of deep energy renovations was just 0.2%. The annual weighted energy renovation rate was estimated for that period to 1.0%, with significant variations among MS (Figure 2). Due to recent, more ambitious policies on buildings renovations and funding derived from the RRF and REpower EU, it is expected that more recent figures showcase more significant renovation rates.

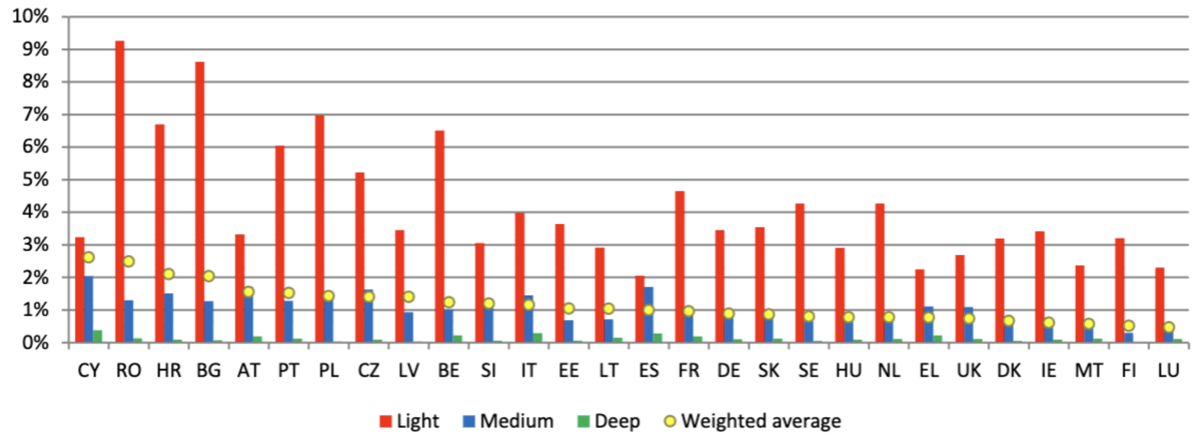


Figure 2 - Renovation rates in residential buildings in the EU28 MS by renovation level, annual average 2012-2016 (EC, 2021b)

According to EC (2021a), by 2030, envelope renovation rates must rise from the current 1.3% to 2.0% for homes with non-fossil fuel heating, 2.5% for those using natural gas, and 3.3% for homes reliant on oil and coal. Beyond 2030, the renovation rate for homes using oil and coal is projected to exceed 5%. However, the reduction of oil use needs to be four times as high (-60%), and natural gas use twice as high (-30%), so envelope renovations need to be complemented with renovations that decarbonize heating systems, switching them away from fossil fuel (EC, 2021a).

Following what [Buildings Performance Institute Europe (BPIE)]() exposes, deep building renovation presents a more comprehensive way of reaching the full potential of a building to reduce its energy demand, bearing in mind its typology and climatic area. Although there is no legal definition in EU legislation, the European Commission has often referred to the proxy of '60% primary energy savings' for determining what a deep renovation is. Its potential energy savings and performance are optimized, and the minimized energy needed comes from renewable energy sources. This scheme of exhaustive renovations also considers the carbon footprint and embodied energy of constructive materials and the sustainable use of resources in the whole lifecycle of the building to achieve climate goals. However, it still struggles with difficulties since only a few projects have implemented a deep renovation. Some barriers come from the need for higher investment costs and long contract periods, surpassing a decade.

From a holistic buildings renovation perspective, a lifecycle perspective is missing, with harmonized tools such as the Life Cycle Assessment and Environmental Product Declarations (both even for whole buildings) (JRC, 2018; Gu & Bergman, 2018) not just for the operation stage, but also for production and construction, could lead to worse building management of resources and energy, and thus, poor performance of the building in terms of energy and IEQ, being more inefficient and GHG-emitting, which also brings more costs in terms of maintenance, replacement, and energy. A social perspective on the LCA has only been addressed in a few countries (Mjörnell et al., 2024, Mjörnell et al., 2019), and further social indicators could be considered, as well as the Social Return on Investment (SRoI) (Bottero et al., 2017).

Furthermore, National Building Renovation Plans and Social Climate Plans must work together to ensure EU policies are implemented effectively, protecting vulnerable households. To that end, tools such as Long-Term Renovation Strategies (LTRS) guarantee that adequate financial support is available and earmarked for the most deprived. Measures to reach that purpose with effectiveness could include transparent and inclusive consultation processes, timely action, improving the role of local level, better-targeted funding and regulatory frameworks, and large-scale integrated projects, with other actions furthering the boundaries of buildings, including neighbourhoods and districts (CAN Europe, 2024).

Decarbonization should primarily focus on building renovation, reducing energy needs, and improving indoor thermal comfort. Therefore, measures and investments should prioritize, whenever possible, enhancing the energy performance of buildings through interventions in the passive components of buildings. However, there are also innovative systems for installing supply and exhaust ventilation with heat recovery with minor interventions (Bebo, Sabo, and Energimyndigheten, 2014).

When considering the replacement of equipment, it is essential to consider any renovations that have been completed or are planned for the building. Energy-efficient renovations—such as wall and roof insulation and high-performance windows—can significantly decrease energy consumption and enhance comfort, potentially rendering the installation of new energy-consuming equipment unnecessary in some climates. Conversely, this may suggest that equipment with a lower capacity could suffice.

It is also essential to follow up and support proper energy behaviour among energy users following the implementation of renovation solutions. This suggests the need for parallel campaigns to educate and inform occupants and the role of strategic design that reflects users' needs and habits, in line with the principle of recognition and justice.

Nevertheless, the investment required to decarbonize energy use and deep energy renovation of homes far exceeds the amounts currently allocated by the EU and national governments. Therefore, it is essential to significantly increase public funding streams to meet the decarbonization and renovation targets by 2050, primarily targeting vulnerable families. To increase the funding for decarbonization, the carbon tax could be applied to any carbon-based industries, boosting them to leave those energy sources (Geroe, 2019).

A clear example of successful deep renovation of social housing, with pilots in France and Italy, is the HEART EU project. The Holistic Energy and Architectural Retrofit Toolkit (HEART) brings together different components and technologies that can transform existing buildings into smart buildings, thus contributing to the Renovation Wave to decarbonise Europe's building stock.

Set fossil fuels phase-out

Eliminating energy consumption from fossil fuels is fully justified by the considerable negative impact fossil fuel consumption has on the environment and populations, including GHG emissions, such as carbon dioxide, which cause global warming, and its contribution throughout its lifecycle to various other environmental problems, such as soil degradation, water pollution, air pollution, and ocean acidification (NRDC, 2022). Fossil fuel pollution was responsible for 8.7 million deaths globally in 2018 (Vohra et al., 2018).

The recent Energy Performance of Buildings Directive Recast (2024) strengthens decarbonization objectives through a twofold objective: contributing to reducing buildings' GHG emissions and final energy use by 2030, providing a long-term vision for buildings, and ensuring an adequate contribution to achieving climate neutrality in 2050. This is underscored, among others, by introducing zero-emission buildings as a standard for new buildings, calculating whole life cycle carbon, phasing out incentives for fossil fuels, and defining the new legal basis for national bans.

In 2022, households represented 25.8% of final energy consumption. Natural gas accounted for 30.9% of the EU final energy consumption in households, electricity - 25.1%, renewables and waste - 22.6%, oil & petroleum products - 10.9%, and derived heat - 8.2%. A small proportion - 2.3% still used coal products (Figure 3) (Eurostat, 2024).

Historically, efforts to replace fossil fuels with renewable energy sources to cover domestic hot water, heating, and cooling demands have been slow and overly reliant on biomass. However, advancements in heat pump technology and industry innovation have marked a significant shift, accelerating their adoption in buildings (EEA, 2023a).

The International Energy Agency (IEA) projects a substantial increase in the adoption of heat pumps, a validated eco-friendly technology that, when operated using renewable electricity, has the potential to cut heating emissions by up to 90% compared to traditional gas boilers, contingent upon the electricity generation mix. A report from the European Climate Foundation (ECF) indicates that the installation of 60 million heat pumps across the EU by 2030 could facilitate a 40% decrease in gas consumption for buildings relative to 2022 levels, alongside reductions of 46% in carbon dioxide emissions and 40% in nitrogen emissions, respectively (ECF, 2023).

The International Energy Agency calls for implementing "carrot and stick" policies, such as banning the sale of gas boilers starting in 2025, to accelerate the adoption of this type of equipment (IEA, 2021). On the other hand, converting fossil fuel boilers to biomass systems may lead to a "fuel lock-in" situation, as these systems last for many years, with implications for forest resource availability, air quality, and public health (EEA, 2023). This is especially relevant for vulnerable consumers in multiple EU countries still relying on the use of wood in fireplaces (Stojilovska et al., 2023).

Looking to the current status of EU member states households' energy use profile, it is clear that decarbonizing buildings is imperative but also a challenging path, with significant obstacles to overcome: implementing energy efficiency standards, promoting building renovation to ensure improved energy performance, creating effective support and financing programs, and ensuring access to technologies for transitioning to renewable energy for space and water heating (Baker et al., 2022). These are just some of the challenges that must be addressed to achieve the goal of building decarbonization.

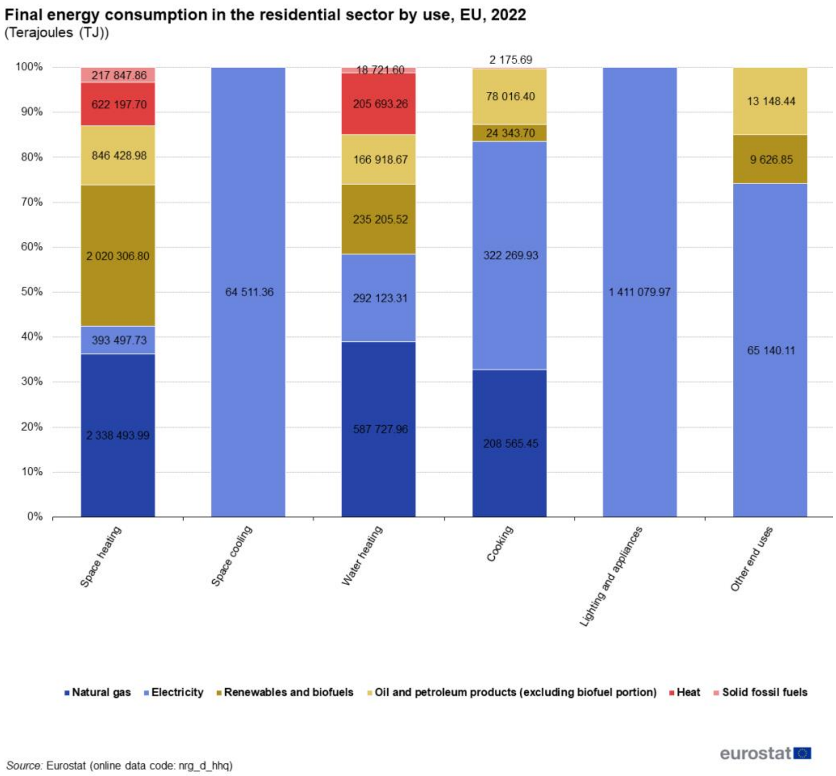


Figure 3 - Final energy consumption in the residential sector by use and fuels, EU, 2022 (Eurostat, 2024)

Beyond heat pumps, other clean heating and cooling technologies, renewable energy sources, and thermal energy storage could be further considered in energy building renovation. Nevertheless, several challenges and barriers are still to be overcome, such as cost reduction, further development, and performance -especially under certain conditions, such as easy-to-install components, allowing scalability and flexibility throughout the whole building's lifespan. Some of those barriers are also social since more information on the innovative solutions available in the market and how they can be combined and integrated into the building is needed. Moreover, once more, the funding and incentives for deployment, commissioning, operation, and maintenance must be clearly exposed to potential and final users, adopting surveillance mechanisms to support them (van Helden et al., 2024).

Under this perspective, it is worth mentioning the relevance nowadays of cooling systems due to the increasing overheating that EU buildings have to struggle with due to the effects of Global Warming and the subsequent progressive growth of mean temperatures, together with the tightness of renovated buildings or highly insulated ones, apart from passive-cooling strategies and the adoption of mechanical or hybrid ventilation systems, according to the current Building technical codes and national regulations. Setting a ban on the sale of gas-powered equipment starting in the near future could be an essential step towards decarbonization goals. Nevertheless, a significant share of the EU population still relies on bottled gas (butane/propane) (i.e., over 16.8 million people use LPG for heating (AEGPL, ND), remaining somewhat sceptical about transitioning, for example, to electricity. This scepticism often stems from the perception that bottled gas offers greater access security, as it does not rely entirely on the grid and can still be used during power outages.

There is a need for awareness campaigns to highlight the advantages of fossil fuel phase-out, particularly regarding energy efficiency and the reduced risk for health, such as air pollution and accidents within the home. It also must be accompanied by support mechanisms for replacing these systems with more efficient electric or renewable energy equipment, focusing on vulnerable consumers. Concerning this, a major effort of funding and communication by any channel (TV, radio, social media, etc) should be done, pushing forward the communication and dissemination from specialised scientists, other stakeholders, and relevant influencers, which can locally spread the word through supported campaigns on solutions and mechanisms to find local alternatives to phase those fossil fuels out. The interconnection of governments and public administrations at a multiscale level and other social representatives is needed to push these kinds of initiatives and reach the citizens effectively.

Increase electrification

Although improving energy performance through renovation should be the foundation of the sector's transformation, electrification is considered the main pathway for decarbonizing energy consumption in buildings, mainly by installing equipment such as heat pumps, which enable significant efficiency gains (Zachman et al., 2021).

In 2022, electricity met 100% of the energy demand for lighting and space cooling in the EU and 50.7% for cooking. Fossil gas (i.e., natural gas) is still a key energy source for space heating (36.3%), water heating (39.0%), and cooking (32.8%). Renewable energy contributes 31.4% of the energy needs for space heating, 15.6% for water heating, and 3.8% for cooking. Derived heat is significant for water heating (13.7%) and space heating (9.7%). Oil products still account for 13.1% of energy use for space heating, 11.1% for water heating, and 12.3% for cooking (Eurostat, 2025).

The European Scientific Advisory Board on Climate Change recommends that member states promote the electrification of final energy consumption sectors (EEA, 2023b). However, the expected increase in electricity demand must be matched with renewable electricity to avoid transferring emissions from the building sector to the electricity generation sector.

Air Conditioning (AC) equipments are not yet widely adopted in European households, with a penetration rate of only around 19% (from 10% in 2000), compared to 90% in the US (Euronews, 2023). Assessing current ownership rates of air conditioning and space cooling energy consumption across the EU, we can identify important distinctions across countries. For example, in Portugal, cooling represents just 1.5% of total final energy consumption (INE/DGEG, 2021) when compared to other countries with similar climates, such as Greece, Cyprus, Spain, and Malta, supporting the hypothesis of insufficient energy consumption as described in e.g., Palma et al., (2019) to avoid high energy bills, by using adaptive strategies (Navas-Martin et al., 2024). Climate change and extreme weather events such as heatwaves can further increase disparities and energy demand for cooling and associated GHG emissions (e.g., Castaño-Rosa et al., 2021), which can result even worse when combined with the urban heat island (UHI) effect. The increasing number, intensity, and duration of extreme weather events can exacerbate the already high share of Europeans suffering from summer and winter energy poverty, with subsequent effects on their health and well-being (Cuerdo-Vilches et al., 2023).

Overall, the increasing electrification of consumption may also be coupled with investments in upgrading the electrical infrastructure of residential properties. This could involve improving the electricity installation of individual homes or the power demanded from the low-voltage grid, as is already the case, for instance, to enable the charging of electric vehicles in multifamily buildings. This increase in domestic power infrastructure often entails an extra fixed cost in the energy bill, regardless of whether adequate power consumption is made or not, potentially exacerbating the energy vulnerability cases.

The shortage of qualified labour could also delay the energy transition. For heat pumps, manufacturers and installers often choose to invest in more "turnkey" technologies, such as monobloc models, to avoid relying on highly specialized technicians certified for handling refrigerant gases. Decarbonization through electrification will require an increased workforce with specific qualifications and certifications to handle the refrigerants essential to heat pump technology.

In the market for more efficient solutions, the perception might exist that the energy transition objectives set for the forthcoming years may be too ambitious. This is influenced by the current production capacity for efficient equipment, the investment costs in relation to the average savings for households, the time it takes to make proper and deep energy renovation, and the necessary dwelling adaptations to implement these technologies. This is a red flag from short-term objectives and targeted support to vulnerable groups that could be left behind in the urgency of MS to meet spending targets or set goals.

Besides, non-market social barriers lay on the lack of awareness, knowledge, acceptance of comfort of new technologies in households, showing reluctance to those new power-based technologies, which also implies additional home space, technological skills, and often increasing energy costs. Additionally, some economic barriers to the market penetration of power-based technologies could come from the prevalent use of electric appliances since they are cheap and easy to install. However, they become unsustainable because of their poorer energy performance, increasing their energy bills. In this sense, electrification should not imply the unlimited use of inefficient power devices.

Reduce energy use and consumption from biomass

As seen above, biomass constitutes a significant share of final energy consumption within the EU residential sector, influenced by cultural traditions, accessibility, and economic factors. This energy resource is common in EU households, especially in rural regions. Utilizing firewood for space, water heating, and cooking is deeply embedded in various EU countries' cultures. Many families have complimentary access to this resource due to their residence in rural areas where it is plentiful, whether sourced from their property, adjacent lands, or communal forests.

Although biomass is internationally classified as carbon-neutral in emission calculations, this classification has been challenged by various experts (Ter-Mikaeilian et al., 2015; NRDC, 2021; Ahmer, 2022). The IPCC emphasizes that automatically categorizing biomass as carbon-neutral is highly problematic (IPCC, 2021). In addition to carbon dioxide, biomass combustion emits harmful pollutants, including carbon monoxide, methane, volatile organic compounds, nitrogen oxides, and particulate matter, adversely impacting air quality and public health. Biomass smoke is associated with approximately 40,000 premature deaths in Europe attributed to respiratory and cardiovascular diseases (Tomlin, 2021). Furthermore, chronic exposure to air pollution in the household leads to pneumonia, COPD (chronic obstructive pulmonary disease), and lung cancer (e.g., Bruce et al., 2000). It is the leading risk factor for burns (WHO, 2023), increasing the risk of cataracts (Lim et al., 2012).

Concurrently, it is essential to recognize the critical role of biomass in addressing energy poverty (Stojilosvka et al., 2023). Although fireplaces are generally less efficient than alternative heating methods, many energy-poor households benefit from complementary firewood, mitigating their vulnerabilities. For these households, the prospect of incurring additional energy costs for alternative systems, even though they are more efficient, is often perceived unfavourably, even if such systems might enhance thermal comfort and indoor air quality.

In Europe, the transformation of the energy system—shifting towards secure and low-carbon energy sources—is crucial for enhancing the health of millions and protecting the environment. Moreover, other biomass fuels, such as pellets, have gained traction. Pellets are usually certified for quality, are more efficient in burning, emit less pollution, and therefore are less problematic. Ideally, they should also possess certifications verifying sustainable sourcing. While they are easy to manage and supply, pellets are pricier. They are more susceptible to fluctuations in the European market when compared to firewood, leading to increased expenses (Bioenergy Europe, 2023).

Another consideration is the challenge some households face in modifying their practices and adapting to new heating equipment that differs from traditional fireplaces. The transition from traditional fireplaces to heat pumps will necessitate investments in raising awareness (e.g., Nardello, 2019), information campaigns, and support for affected groups to ensure an equitable and smooth transition. Insufficient digital literacy may exacerbate this challenge. As previously highlighted, some individuals may have free or cheap biomass, which would assist them in partially alleviating their vulnerability. An alternative approach could involve upgrading less efficient biomass equipment to the most efficient, such as wood stove recirculating the heated air and securer options available in the market. These solutions may consider indoor air quality control by isolating the burning camera from the indoor space and collecting ashes in a separate deposit.

4. Looking ahead: exploring solutions and recommendations for a socially just and fair energy transformation

Over the past few years, the EU has made an increased effort to address energy poverty while improving energy efficiency and promoting renewable energy adoption. A socially inclusive energy transformation means, for example, putting renewable energy into the hands of communities and people, fostering the renovation of vulnerable homes, and implementing instruments, funding schemes, and solutions suitable for persons with potentially less literacy (e.g., energy, financial, digital). Mechanisms and innovative ideas such as renewable District heating and cooling systems, inclusive, positive energy districts and renewable energy communities (RECs), and one-stop shops (OSS) can significantly advance decarbonization efforts, particularly when endorsed and supported by governmental entities. Their primary objective should be to facilitate an equitable energy transformation, with a strong emphasis on advocating for and including the most vulnerable citizens. Public support programs should be progressive and adaptive to the economic difficulties of households to ensure that energy-poor families who cannot afford the necessary investments are not excluded. This is also one of the key objectives for implementing the Social Climate Fund. Multiple initiatives have been set forward as essential enablers of this socially responsible energy and building transformation, which we explore below.

From district heating and cooling to positive energy districts

In the context of decarbonization, energy-efficient technological solutions include those collectively adopted, with clear advantages beyond the optimization of production, use, and distribution of energy, allowing the evolution towards schemes from nZEBs or zero-emission buildings to Positive Energy Buildings (EPBs) and Districts (EPDs), according to minimum energy needs, totally covered or even providing a positive energy balance, and with a high energy performance compensating GHG emissions associated. Among those advantages, they allow the democratization of energy, promote governance, and minimize energy-related inequities, supporting the public acceptance of clean energy sources and the social awareness and commitment to more efficient behaviours. This could be to implement intermittent heating when the house is occupied and short-time window ventilation to improve efficiency and decrease heat losses. Also, they could be based exclusively on energy production, distribution, or potential storage, such as Renewable Energy Communities (REC), a shared heating and/or cooling scheme for a building, neighbourhood, district (DHC), or a combination.

These collective interventions allow community members to afford initial costs with significant reductions. They also provide more flexible schemes and potentially combine them with other technologies, such as thermal energy storage or grid delivery, in case energy is not used for self-consumption. Some of the challenges this kind of initiative entails are reluctance from municipalities with unfavourable urban plans.

District heating and cooling (DHC) networks, also known as district energy systems, are centralized systems that generate and distribute thermal energy (heating and/or cooling) to residential, commercial, and industrial buildings, through a network of insulated pipes and other technical elements and devices, within a defined area, such as a city or neighbourhood.

This thermal energy is distributed to connected buildings and urban infrastructures for heating, hot water, or cooling, according to seasonal and occupants' needs.

According to the results from the W.E. DISTRICT Interactive DHC map, the share of DHs and DCs is uneven within the EU Member States, with Sweden, Denmark, Lithuania, Slovakia, and Estonia being those EU countries with a higher DHC stock, whilst Southern and Mediterranean ones have the lowest DHC ratio.

DHC systems could be energy-supplied by different energy sources, either non-renewable ones, based on wasted energy from industry or other thermal processes, for instance, or by renewable energy sources (RES). These energy combinations can address growing urban energy demands, boost efficiency, reduce emissions, and improve local air quality. Despite many DHC systems relying on fossil fuels, such as coal and gas, they could be upgraded or adapted to introduce renewable technologies, such as solid biofuel, solar, or geothermal energy.

Renewable-based DHC systems offer benefits linked to energy security, public health, and reduction of environmental impact, according to local conditions. However, DHCs with RES need greater support to encourage their expansion by incorporating them into their future municipal and regional energy plans (IRENA, 2017).

According to the European Association, which promotes sustainable district heating and cooling (Euroheat & Power), public funding is key to fostering DHC networks across Europe. EU and state financing provide a valuable opportunity for stakeholders to access resources, boosting innovation and commissioning. EU funding programs come from the R&D advocacy by organizations such as RHC-ETIP, ECTP/Built4People partnership, the Smart Cities Marketplace, or the SET Plan-PED, for Positive Energy Districts.

Despite the lack of literature regarding DHCs as mitigation for energy poverty and vulnerability, some exploratory approaches have been made for certain regions, such as in Czechia, where district heating is recognized as a cleaner alternative to traditional coal or fuelwood-based beating, offering profits in terms of indoor air quality and stable internal temperatures, as well as facing socio-economic and market challenges, and policy shift. However, some constraints are seen on promoted, decarbonized systems, such as heat pumps and solar technologies, due to technical reasons and legal barriers supporting distribution system operators over local communities. In that sense, a long-term, diversified strategy is needed for greater resilience and to reduce energy vulnerability and poverty. DHCs are not exempt from controversy, so local acceptance, further research, and flagship initiatives are key to informing policies addressing energy vulnerabilities (Kodouskova, 2023). A study in London and Riga found that waste heat may reduce consumer energy bills, compared to replaced technologies, when energy poverty reduction is considered as an impact indicator. Although more research is needed to value DHC schemes by conditions and structures, this collective infrastructure, with waste heat, could alleviate energy poverty (Lagoeiro et al., 2024). Further, EU-funded projects have explored the social dimension of DHC, either searching citizens as stakeholders (STORM and OPTi EU projects) and even encouraging their proactivity or as user-centric strategies where final building users are taken into consideration (SMARTER TOGETHER, REDREAM, RESPONSE, and SPARCS EU projects)—nevertheless, the social implications of citizens as agents are unevenly assessed, with some deficiencies and limitations.

Positive Energy Districts (PEDs) aim for energy efficiency, not only optimizing the use of this essential resource in buildings for daily life but also doing it so that the energy production exceeds its consumption and the energy balance results are positive. A major effort has been made by the Implementation Working Group (IWG) on PEDs, trying to unveil all the challenges still present concerning the development, implementation, and commissioning of this kind of collective urban energy scheme, as well as the strategies and mechanisms needed to make it a reality across Europe, according to the objectives of the European Strategic Technology (SET) Plan Action 3.2, and the European Commission itself. As a result, in 2018, the Implementation Plan (IP) of the IWG-PED established a roadmap on what should be expected and provided to reach those goals from the EU and Member States. Within some of the challenges and requirements for deploying PEDs addressed, some social implications are explicitly exposed. The first is related to social innovation, entrepreneurship, and citizen participation to "spur the deployment of PED with an integrated urban transformation process." Another one refers to technological, financial, and regulatory aspects, also covering new roles, such as prosumers, for instance, and the resulting investment risks that require investment concepts and access to new financing schemes. Third, the path towards PEDs needs to support capacity building, education, and training, together with co-creation and support through public sector innovation and procurement, with an overall vision that covers all the relevant stakeholders, including civil society. Pilots and demonstrators, such as living labs, innovation playgrounds, and urban prototyping, could promote replication, upscaling, and mainstreaming, focused on the usage stage and operation & maintenance. New business models could be understood as a good opportunity for energy sharing and management.

A good number of funded EU initiatives on-the-ground could be found in the PED EU NET COST Action repository, including ongoing projects, several funded by Driving Urban Transitions programme within the Positive Energy Districts Transition Pathway. Among those ongoing projects, some flagship ones highlight for their special consideration on social aspects regarding PEDs.

COPPER INTERREG project strives to increase the engagement of citizens across energy communities (ECs) to create human-centric positive energy districts (PEDs). ENERGY4ALL project explores and stands out the role of communities and the human dimension in designing and implementing Positive Energy Districts (PEDs) and Energy Communities (ECs), where participatory governance practices are carried out after detecting related barriers. CO2PED project aims to build concrete tools to strengthen the urban transformative capacity of stakeholders toward developing positive energy districts (PEDs) in vulnerable neighbourhoods. A few of them address social profits, such as tackling energy poverty.

Krangsås et al. (2021) identify interacting challenges related to governance, incentive, social, process, market, technology, and context. Gouveia et al. (2021) analyzed the Portuguese case study of Alfama, a historic district in Lisbon with significant energy vulnerability. Their research highlighted the potential of the PED scheme for such areas, emphasizing two key strategies: energy efficiency measures to lower demand and decentralized renewable energy production. However, challenges remain, including social resistance to integrating renewable systems into historic buildings and the absence of mandatory energy efficiency targets in legal frameworks. From Hearn's (2022) research, energy poverty mitigation should be integrated into PEDs from the outset, with greater emphasis on social dimensions in decision-making. Stakeholders recognize PED's potential to reduce energy poverty, and the increasing energy poverty levels enhance PED's financial viability. Ultimately, PED replication can create synergies between decarbonization and energy poverty mitigation.

Renewable energy communities

Recent EU legislation emphasizes the role of citizens and communities in driving the energy transition, projecting that by 2050, approximately half of Europeans will be generating their own renewable energy. The REPowerEU Plan put forward the shared political objective of achieving one energy community per municipality with a population of more than 10 000 by 2025. Local actions such as RECs, activating citizens and communities, play, therefore, an essential part. The social role of RECs is also highlighted in EU policies and depicted as a potentially relevant solution to alleviating energy poverty. It mandates the inclusion of all social groups in RECs, with particular attention to those currently underrepresented (Hanke et al., 2021).

The primary goal of a REC should be to deliver environmental, economic, and social benefits to its members or the communities it serves rather than prioritizing financial profits. This could be achieved through access to affordable energy tariffs and the implementation of energy efficiency measures while exploring a genuinely inclusive dimension, bringing vulnerable citizens together as part of the community and not only as “end users.”

There is still limited empirical evidence demonstrating the ability of RECs to include underrepresented and vulnerable groups and address energy poverty as a specific aspect of energy justice, allowing for the capture of both distributional and procedural justice. Setting up an inclusive REC should consider how benefits and risks are distributed spatially and socially among actors (distributional justice), the fairness of decision-making, and the processes through which decisions are made. In community initiatives, openness and transparency should be clear in development and ownership procedures (Goedkoop and Devine-Wright, 2016; Caramizaru & Uihlein, 2020), avoiding, e.g., companies' capture of this concept.

Key challenges identified regarding inadequate inclusivity and accessibility for vulnerable and low-income households in RECs include a lack of awareness and understanding of energy poverty among key stakeholders and persistent biases that categorize these groups as disinterested in participation. Furthermore, as summarized by Koukoufikis et al. (2023), significant regulatory, financial, business model-related, and technical barriers exist, compounded by inadequate resources and knowledge necessary for effectively engaging marginalized communities.

Implementing targeted policies, financial incentives, and capacity-building initiatives is crucial to enhance inclusivity. This necessitates establishing trust with vulnerable households, integrating technical and social processes, and providing staff and volunteer training in energy and interpersonal competencies. As highlighted by FOE (2023) and CEES (2024), RECs should develop clear protocols for community engagement that respect privacy and safeguard participants while utilizing local networks to foster collaboration, identify vulnerable families, and promote synergies with other local activities. Additionally, they should secure sustainable funding, adopt innovative solidarity mechanisms, and align their missions with energy justice principles to reduce systemic barriers and promote equitable energy access.

Examples of initiatives trying to overcome these barriers can be found, e.g., in REC Telheiras in Portugal; RESCHOOL EU project in Netherlands, Sweden, Greece and Spain; and LIGHTNESS EU project with pilots in Poland, Netherlands, Italy, France and Spain, being the latter good examples of popular integration and democratization of energy production and management, besides the potential shift of paradigm regarding renewable energy sources (Cuerdo, 2024). From European to local, policies should focus on overcoming the barriers that prevent vulnerable households from participating in RECs.

One-stop shops

Another innovative strategy to address energy poverty and increase building renovation through awareness raising and technical support are one-stop shops (OSS), mentioned in the recast of the EPBD. OSS can be virtual and/or physical while providing services adapted to the local context and target audiences. They can serve as a centralized resource offering a comprehensive variety of services for home energy renovations to the communities where they are located. These hubs streamline the energy efficiency improvement process by acting as a single point of contact for families. They provide services such as energy audits, personalized renovation recommendations, support with financing options and funding scheme applications, energy bill assessment, and referrals to contractors.

Vulnerable households need customized engagement and support, which OSS can effectively provide through multidisciplinary collaboration and partnerships with local authorities and social support institutions. Robust and diverse data collection enables projects to adjust support in real time based on the local population needs. While a well-coordinated local action framework can significantly impact vulnerable households, implementing the advice provided often requires substantial and consistent financial assistance (FCG, 2024). OSS can serve as a vital link, simplifying access to complex financial support programs for vulnerable individuals.

These models remain underdeveloped in most European countries; however, the concept is gaining traction, with a growing number of exploratory examples being implemented across Europe, such as the Barcelona Advise Points (Spain) and the mobile OSS based on a renovated maritime container Ponto de Transição (Portugal).

Digital ones, despite not being the best approach to target the energy poor, can reach out to more people and complement on-ground support. Consumer associations are teaming up with energy experts through the LIFE project HORIS Home Renovation Integrated Services (Italy, Spain, and Portugal) or the Solutions4Renovation developed under the Turnkey Retrofit and providing a free online diagnostic (France, Spain, Ireland).

By simplifying the renovation process in multiple dimensions, OSS can empower economically disadvantaged families to lower their utility expenses and improve indoor thermal comfort.

Energy coaching

Tutoring programme such as energy coaching represent a relevant tool to address energy poverty. It has been proved to have a higher impact in homes not owned by the occupants as it is the case of social housing and shown in Figure 4, which shows the impact of energy coaching on the energy bill reduction for not owner-occupied (blue line) and owner-occupied (red line) (Croon et al., 2024).

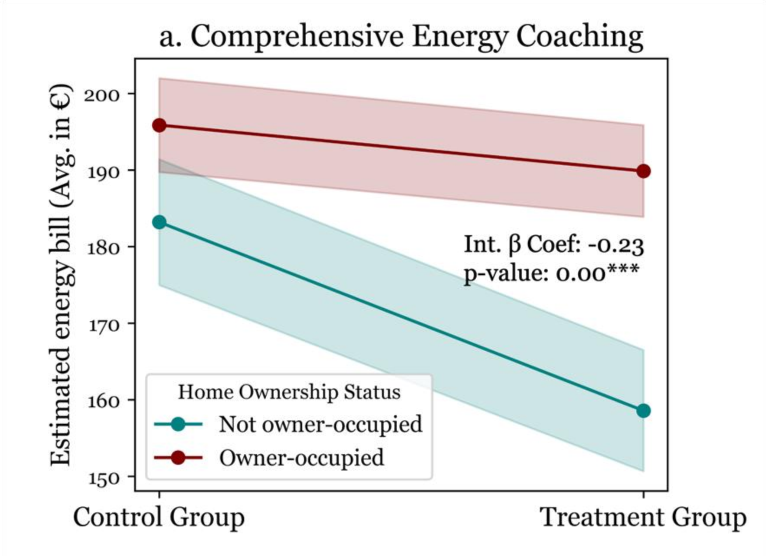


Figure 4 - Impact of energy coaching on the reduction of energy bill (Croon et al., 2024)

Energy coaching could represent a valid alternative to one-stop shops (OSS) for the most vulnerable groups related to energy poverty, such as low-income elderly people who often are not in physical conditions to visit the OSS or have a lack of digital knowledge to access online services. Energy poverty disproportionately affects specific vulnerable groups, such as elderly households (OECD, 2022). Energy coaches can visit elderly people in the houses where they live, offering company in parallel to energy tutoring, and therefore reducing the feeling of loneliness, which is one of the causes of their unhealthy conditions. This social issue will be more and more relevant in the future due to the increase in the elderly population. Figure 5 compares age class for 2019 (solid colour) and the projection for 2070 (bordered). The age pyramid is changing shape, with a growing proportion of the European population over 65, and a significant number over 85 (European Commission, 2024).

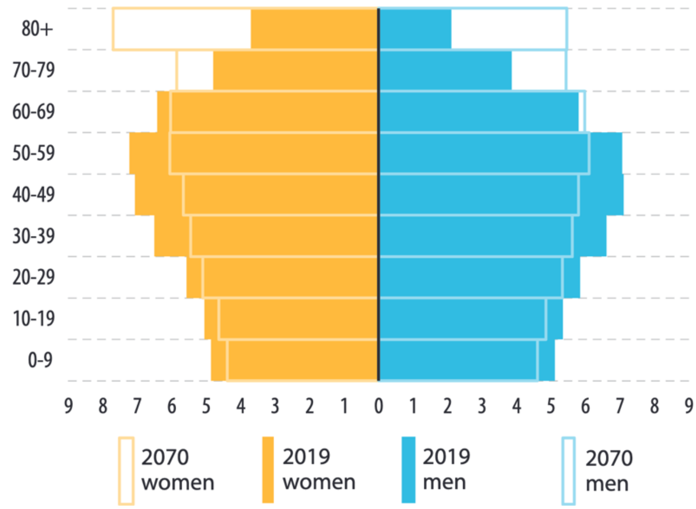


Figure 5 - Population pyramids, age group share of total population (%) (Eurostat, 2020)

One of the most striking aspects of the pyramid for 2070 is the lengthening of the bars for the upper age group (compared with those for 2019), indicating that a more significant share of the population will live to be very old (85 years or more). According to Eurostat (2024), such developments are likely to have profound implications, not only for individuals but also for governments, businesses, and civil society, impacting, among others, health and social care systems, labour markets, public finances, and pension entitlements. Low-income older people, and especially the elderly, do not always have the mental and physical capacity, nor the financial resources, to take care of the energy issues of their house or apartment. They are also more vulnerable due to their age, their health situation, and the fact that they spend much time at home. They deserve additional attention and need external help to reduce their energy poverty status. Low-income older people are already distressed due to the recent increase in electricity and gas bills. Many have been forced to choose between paying for energy and essential needs like medical treatments or food as they struggle to afford both.

Building renovation passports

From the experience of renovation interventions in building communities and to promote a better-planned and easier-to-understand instrument, a roadmap for long-term renovations has been developed at the EU level, promoted under legal frameworks, such as the EPBD, to reach high energy performance and reduced emissions in the mid-long term: the Building Renovation Passport.

A Building Renovation Passport (BRP, or BP) is a document, either electronic or paper-based, describing a long-term renovation, step-by-step, during the period it is developed (up to 20 years). It supports owners with adapted advice on their renovation options and further spells out all renovation stages for all involved parties (European Commission, 2024). Besides, this optional scheme is expected to stimulate long-term renovation strategies for buildings, including staged deep renovation and support targeted, cost-effective measures and renovation. This instrument boosted within the Directive (EU) 2018/844, has been further promoted in the recent EPBD recast (Gokarakonda et al., 2024). Recent studies establish how to face energy vulnerability and poverty, whilst reducing building emissions by applying this tool to real scenarios (Nicoletti et al., 2025). It will give consumers easier access to information and lower costs when planning the renovation of their buildings.

This tool, combined with material passports too, could contribute to the knowledge and understanding of renovation stages and implications for building users and other stakeholders, generating social awareness and commitment. It also creates further recording and better application of better practices from a life cycle assessment perspective due to the detailed info regarding renovation activities and interventions in usage, operation, and maintenance stages, which positively push forward to the adoption of Circular Economy to the building scale (Leindecker et al., 2025), by actions as increasing the intensity of use, choosing long-lasting building materials and products, and delaying building demolition (EEA, 2022). Although it has potential importance, the effects might be slim, as the passport is not mandatory.

Some examples of BRPs developments at national levels are PASE-E from GBCe Spain and iBroad, resulting from an EU project implemented in ten EU countries. This project became a new one, also from Horizon 2020, the EU project iBRoad2EPC, carried out in six EU countries, which aims to integrate BRP in Energy Performance Certificates (EPCs), trying to overcome the barriers found for the two separated tools.

Despite the efforts in developing this tool, further R&I activities are needed to reach society, mainly focused on Building Renovation Passports taking into consideration vulnerable populations, which may be reached through channelling financial mechanisms to support Long-Term Building Renovation interventions for more deprived areas, as reported by iBroad2EPC project here.

Societal readiness approach

Exploring whether society is ready to undertake all that implies the ambitious European goals concerning energy transition and building renovation is a significant challenge to making them real. Moreover, several instruments measure the extent to which citizens are prone to accept or even implement a technology or innovation (Büscher and Cronshaw, 2022).

Societal Readiness Level (SRL) consists of an indicator to express the degree of societal adaptation or acceptance of a particular social project, technology, product, process, intervention, or innovation (social or technical) to be integrated into society. This indicator was initially created following the Technology Readiness Level (TRL), aimed to convey to what extent a technical solution is ready for the market and, thus, to be implemented in real conditions of use. Both are numbered from 1 to 9, being 1 the lowest, and 9, being the highest one. In the case of SRL, this scale could express this societal acceptance as follows:

- SRL 1 to 3: early-work stages, from the conceptualization of the need to the initial testing of solutions with relevant stakeholders
- SRL 4 to 6: actual solutions, testing in a relevant context, cooperating with relevant stakeholders, and evaluating impact and societal adaptation expectations, which have to be deeply described and part of the test, when possible.
- SRL 7 to 9: final stages of the research project, reshaping solutions, implementation, and communication of results and/or solutions. It will include a plan to address societal readiness on a practical level, to increase the impact, awareness, knowledge, etc, of those results (Innovation Fund Denmark, 2018).

Other authors have developed similar indicators to tackle the social willingness regarding a new technology or system or even a challenge such as Energy Transition or Climate Neutrality. Some of them are Societal Embeddedness Level (SEL) (Sprenkeling et al., 2022), or even elaborating a broader scheme to address the societal dimensions of research and innovation, calling it the Societal Readiness (SR) Thinking Tool, not only based on similarities with TRL, but also integrating Responsible Research and Innovation (RRI) approach, sustainability and design thinking in research and innovation cycles. Alternative ways to measure the social impact of activities from economic organisations are indicators such as Social Return on Investment (SRoI), generally drawn on social entrepreneurship and impact investment, and the cost-benefit analysis framework, widely applied in public policy evaluations. The SRoI indicates the shift value generated per monetary unit spent on a project or intervention; the latter expresses the cost-benefit ratio for one or more stakeholders generated by social impact (European Commission, n.d.).

Regarding the Societal Readiness approach, as far as we know, no studies have considered those indicators and their potential or real implications on vulnerable people. Nevertheless, and as announced in November 2024 by Science Business, the European Commission is preparing some EU calls to be launched during 2025, to test indicators, such as the SRL, as part of the HORIZON Europe Programme, Pillar 2, Cluster 5, “Climate, Energy and Mobility”, since, as they expressed, ”The Societal Readiness approach aims, when integrated into R&I processes, to improve the consideration of different societal needs and concerns and to respond to them, thereby increasing the potential for societal uptake”. Perhaps this is a perfect occasion to further explore energy poverty and vulnerability's impacts.

5. Conclusion

The transition to a climate-neutral, affordable, and sustainable energy system is one of the most pressing challenges facing the European Union. Decarbonization should not be undertaken without considering justice and social inclusion, the vulnerabilities of different territories and populations, and equitable access to safe, renewable, and affordable energy technologies and sources. Ensuring a socially fair transformation requires decisive action, strong political will, and effective implementation. Beyond setting ambitious goals, policymakers must prioritize enforcement mechanisms, improve financing accessibility, and streamline administrative processes to accelerate energy efficiency improvements across the building sector. Vulnerable and energy-poor populations must be at the centre of these efforts, with targeted policies that protect their access to affordable, sustainable energy while preventing unintended negative consequences, such as energy renovations-induced displacement or increased financial burdens.

This paper aimed to explore the current key challenges of the EU energy transition to become fair and just, which directly affects society, with a particular impact on vulnerable and energy-poor citizens. Besides, the current state-of-play was explored in its multiple dimensions, outstanding the relevance of a renovated, sustainable, and affordable building stock, where implementation barriers and solutions must be further defined for a deep and socially inclusive shift. A key takeaway from this analysis is that no single solution fits all contexts. The transition must be adaptable to different national and regional circumstances, and solutions must be designed with local participation and citizen engagement, considering the positive and negative impacts of any solution that might bring to the most vulnerable. Some of the challenges, barriers, and red flags related to the social implications of the implementation of EU targets are summarized as follows:

- Prioritising holistic building renovation is essential for reducing energy needs and improving indoor environmental conditions, including hygrothermal comfort. More focus and financial support must be intended for follow-up projects to assess the enhancement of recently finished EU or national projects and offer supplementary aid to households regarding energy behaviour and related pattern shifts, especially in vulnerable cases.

- Phasing out fossil fuels in buildings requires effective implementation of energy efficiency standards, comprehensive buildings renovations, and robust financial support for more sustainable alternatives. Adoption barriers, particularly among vulnerable households, must be addressed through targeted incentives, public awareness campaigns, and industry engagement to ensure accessibility and trust. A just transition demands a multidisciplinary approach prioritizing health, well-being, and economic feasibility, ensuring that all citizens benefit equitably from cleaner, more sustainable energy solutions.

- Expanding the electrification of buildings requires careful planning to reduce the risk of increased energy vulnerability, especially as more efficient technologies like heat pumps continue to rise and integrate additional financial and operational challenges. The need for improvements to the grid and higher power contracts may result in higher fixed costs for households, which could disproportionately impact lower-income families. Efforts aimed at electrification should prioritize energy efficiency and sufficiency, guaranteeing that any rise in electricity consumption is optimized, affordable, and primarily sourced from renewable options.

- Biomass remains, across multiple member states, a vital energy source for households facing energy poverty, providing a cost-effective heating solution despite its considerable risks, health and environmental concerns. Although transitioning to more sustainable, electricity-based heating systems can enhance indoor air quality and overall health, this transition must be conducted cautiously to prevent unintended financial strains on vulnerable consumers. It is critical to ensure that affordable and accessible efficient alternatives are available, accompanied by targeted support measures to mitigate the risk of deepening energy poverty. The phase-out of biomass should be incremental, balancing decarbonization and energy efficiency, public health efforts, and fostering the adoption of safer, low-emission technologies adequate to vulnerable house conditions.

Given the EU's energy objectives and their implications for households—especially those that are vulnerable and experiencing energy poverty—the current solutions provided by EU mechanisms and strategies are still insufficient, inadequate, or disproportionately accessible to citizens. To address this disparity, it is essential to advance additional flagship initiatives across municipalities, regional governments, and public administrations, facilitating improved dissemination, practical implementation, and quantifiable short- and mid-term effects. Promising initiatives, such as renewable district heating and cooling, positive energy districts, and renewable energy communities, are acquiring momentum but still necessitate enhanced financial and policy backing. At the same time, one-stop shops are still kickstarting, having significant potential to increase awareness and proximity support to households on domestic energy expenses, energy literacy, home renovation options, and related financing alternatives, as well as supporting applications to funding schemes. To mitigate the constraints of social measures such as one-stop shops for hard-to-reach population, generally vulnerable in terms of energy, alternative strategies have to be met, and energy coaching seems to be a good add-on, potentially reaching those citizens who, for different reasons, need more energy advice, but could not be reached easily. Similarly, the application of Building Renovation Passports is not yet widespread, emphasizing the requirement for robust EU and national initiatives to foster their adoption and efficacy in practical scenarios.

The current SET Plan IWG5-Buildings Implementation Plan outlines specific targets under Section 5.1. Still, their definitions could be expanded to fully incorporate the societal implications and impacts necessary for achieving a just energy transition across the EU. Based on the insights gathered in this document, we propose that these targets could be revised to explicitly consider social dimensions, as follows:

Target 5.1-T1 - Reduce the energy use of buildings by 16% in 2030 with respect to 2020, prioritizing passive measures in building renovation while promoting targeted financial support to the most vulnerable households.

Target 5.1-T2 - Develop and demonstrate solutions for zero-emission buildings by 2030 while retaining cost efficiency. These solutions must be promoted, incentivized, and made known to promote social trust, acceptance, and commissioning for a fair and inclusive energy transition.

For targets T3 and T4, EU and national funding for follow-up initiatives based on EU-funded projects could be adequate to assess the impacts of renovations and technological enhancement in pilots or demonstrators, with energy and IEQ monitoring, combined with social research techniques and methods to holistically approach the complexity of the social implications of Energy Transition and Affordable Sustainable Renovations. For all those solutions, a significant effort must be made regarding the social implications of EU objectives and strategies on decarbonization and energy transition to be effectively considered just and fair, particularly with the most underserved. In this sense, the mentioned highlighted barriers and red flags must be faced through funding on EU and national initiatives focusing on user-centred perspectives, with more remarkable attention on vulnerable populations, including different tools to further comprehend the problem complexity.

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