THESIS FOR THE DEGREE OF LICENTIATE OF TECHNOLOGY

RETHINKING RENOVATION PRIORITIES

Mapping and Evaluating Housing Renovation Needs in the EU

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Rethinking Renovation Priorities: Mapping and Evaluating Housing Renovation Needs in the EU
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Abstract

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The move to decarbonise buildings and alleviate energy poverty through housing renovations is slow, with increasing evidence of unintended social and environmental consequences. At an EU level, policies which are aimed at reducing greenhouse gas emissions from the building sector have been shown to unfairly burden lower income households. Therefore, the need to integrate analysis of climate and social impacts of housing renovations, identify conflicts, trade-offs, and synergies between the two objectives becomes increasingly crucial to achieving a just green transition.

This thesis aims to evaluate the extent to which long-term renovation strategies of EU Member States contribute to a *Just Green Transition* by addressing the renovation needs of vulnerable households. It draws from EU databases to first map energy sources, systems, building and household characteristics to provide a comprehensive overview of conditions faced by vulnerable households. Long-term renovation strategies of EU Member States are then analysed to identify priority concerns, segments, and renovation measures to understand which segments will be affected and how they will be affected by renovation strategies. Gaps in measures aimed at vulnerable households are highlighted as a result. By identifying these areas of concern, the thesis contributes to a deeper understanding of how EU directives, transposed by Member States, impact vulnerable households.

Keywords: Affordable Housing, Energy Justice, Energy Transition, Priority Segments, Renovation Needs, Vulnerable Households

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List of Publications

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E. Elangovan: Writing – review & editing, Writing – original draft, Visualisation, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualisation. L. Thuvander: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualisation. H. Wallbaum: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualisation, Funding Acquisition.

Additional publications

Elangovan, E., Thuvander, L., Wallbaum, H., Audycka, B., & Szygulska, J. (2026, January). *Energy efficient renovation measures review* (Work Package 8, Deliverable D8.1). EqualHouse Project. https://equalhouse.eu/media/Publications/Making_Housing_Affordable/D8.1%20Energy%20Efficient%20Renovation%20Measures%20Review_Final.pdf

White Paper on Affordable, Sustainable Energy Transition and Building Renovation
Gouveia, J. P., Cuerdo, T., Caneva, S., Del Pero, C., Ricci, D., Elangovan, E., Mlecnik, E., Abdelhalim, E., Leonforte, F. & More Authors, 2025, IWG5 Buildings. 44 p. https://build-up.ec.europa.eu/system/files/2025-03/Eqrf0pDvCx_18_03_2025_165406.pdf

Divia Jiménez Encarnación, Liane Thuvander, Ioanna Stavroulaki, Emiline Elangovan, Leonardo Rosado, Mapping opportunities for a neighbourhood-scale sharing economy: A geospatial methodological framework focused on household products, *Journal of Cleaner Production*, Volume 521, 2025, 146237, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2025.146237.

Contents

1. Introduction

The practices of maintaining, repairing and improving the buildings we inhabit are typically shaped by locally specific environmental, social and economic conditions. Broadly termed as renovations, these practices need to adhere to, among other things, municipal regulations, the local climate, technical building specifications, the means of those financing them and perhaps most importantly, the specific needs of those who occupy them (Rodriguez-Alvarez et al., 2021; Szép et al., 2023). However, since the operation of buildings has a compounded and significantly adverse impact on the earth's climate (the stability of which is vital to ensuring decent living conditions for households in the long run) the issue of renovations has also become one that needs to be tackled on a transnational scale.

Renovation measures aimed at improving the energy efficiency of residential buildings have been identified as one of the key strategies across Europe to decarbonise the building stock and have been a policy priority at the EU level for the past two decades. Under the umbrella of the European Green Deal [1], initiatives like the Renovation Wave (COM/2020/662) [2] and Affordable Housing Initiative [3] provide strategic frameworks and funding to boost the rate of housing renovation in the EU (European Union). Directives such as the Energy Performance of Buildings (EPBD) EU 2024/1275 (European Commission, 2024) and Energy Efficiency Directive (EED) EU 2023/1791 (European Commission, 2023), reinforce the importance of renovating the residential building stock through mandatory components such as the submission of long-term renovation strategies (LTRS) [4] and national building renovation plans [5].

While building decarbonisation is the primary goal of EU level renovation policies, the importance of energy renovations in alleviating energy poverty is gaining recognition. The past five years have been shaped by economic slowdown caused by the pandemic and an energy crisis triggered by the Russian war on Ukraine in 2022. These events also contributed to a persistent housing affordability crisis, changing energy poverty levels as well as energy consumption patterns as a result. The percentage of households who feel that they are unable to keep their homes adequately warm in the EU had previously been steadily decreasing from 9.6% in 2015 to 6.9% in 2019. However, the outbreak of the

[1] The European Green Deal is a high-level policy framework encompassing a wide range of measures to help achieve the legally binding target of 55% emissions reduction by 2050 (Regulation (EU) 2021/1119)
[2] The Renovation Wave strategy aims to renovate 35 million buildings by 2030, at least doubling the annual rate of energy renovations in the EU
[3] The Affordable Housing Initiative was introduced as part of the Renovation Wave Strategy
[4] The Long-Term Renovation Strategies were submitted to the European Commission in 2020
[5] National Building Renovation Plans are in the process of submission by EU MS to the European Commission

COVID-19 pandemic in 2020 brought about a reversal in this trend with energy poverty increasing to 7.5% in 2020 (Eurostat, 2025). Those who are at risk of poverty were disproportionately affected with 16.4% unable to keep their homes warm in 2021 and 22.2% in 2023. Increasing global geopolitical tensions between the US and Iran and its subsequent impact on energy supply (and prices) reinforce the idea that the events of the last few years may not be anomalies. Alongside the more acute and recent issues outlined above, long standing housing wealth and income inequalities have exacerbated the inability of more vulnerable groups to access affordable housing.

Since energy poverty is understood to be driven by a combination of low incomes, high energy prices, and poor energy efficiency have been established as the drivers of energy poverty, renovations that improve energy efficiency can play a long-term role in energy poverty alleviation. Provisions to define the phenomenon and prioritise buildings occupied by households facing energy poverty have been officially adopted into the latest revision of the EED (EU) 2023/1791) and EPBD (Directive (EU) 2024/1275) which have previously focused on the more technical aspects of energy efficiency. These developments emphasise the deeply intertwined nature of the goals of residential building decarbonisation and energy poverty alleviation when planning energy renovations.

However, Member States face a broad range of barriers to implement them at the rate required to reach 2030 and 2050 climate goals agreed upon by the EU. They include but are not limited to high upfront costs (D'Oca et al., 2018), lack of skilled labour (Jagarajan et al., 2017), split incentives to renovate (Bertoldi et al., 2021), administrative complexity, and lack of awareness of the benefits of energy efficient measures (McCabe et al., 2018).

More critically, in cases where they are implemented, there can be unintended negative consequences on households such as rent increases, or displacement from their dwellings (Polanska & Richard, 2021; Streimikiene et al., 2020). Policies aimed at supporting energy efficient renovations have been shown to have particularly regressive effects on lower-income households (Platten et al., 2020). Reaching climate or energy security goals can also come at the expense of households' access to adequate energy to meet their needs. For instance, the European Environmental Agency's (EEA) analysis of energy consumption trends in the last few years, partially attributes the EU's success in achieving its voluntary target of 15% reduction in gas consumption from 2022 to 2024 with an 18% reduction to the underconsumption of energy after price energy price spikes triggered by the war in Ukraine, especially among low-income households. This reiterates the importance of implementing "green" targets in a manner that does not worsen inequalities.

The plethora of complex issues associated with scaling up energy renovations is well-documented and since the EU is not on track to meeting building decarbonisation targets within agreed deadlines (Maduta et al., 2023), specific segments of the residential building stock need to be prioritised for urgent renovation to focus. The need to prioritise worst-performing segments in terms of energy efficiency is acknowledged in article 2 of the EPBD (Directive (EU)2018/844) and article 3 of the revised EPBD (Directive (EU) 2024/1275). Member states are recommended by the European Commission to outline how they will tackle worst-performing or challenging segments that are underserved by market mechanisms.

However, there is little research on the nature of these renovation priorities and how they are implemented, even at an EU level where such strategic national priorities are directly impacted by European regulations and funding. This research, therefore, uses long-term renovation strategies [6] (LTRS) as a key data source to investigate renovation priorities in six EU Member States. The systematic analysis of national renovation priorities contributes to research on a *Just Transition* in the built environment by demonstrating how strategic priorities affect specific segments of the residential building stock, types of households and the renovation measures planned for them. Identifying these specificities lays the ground for more nuanced research on how *Just* the Renovation Wave is in practice.

Moreover, studies typically focus on country-specific conditions or regional countries. However, as EU legislation protecting households facing energy poverty strengthens, an EU level perspective is increasingly needed to understand how broader transnational conditions affect households and provides the added possibility of transferring policies between similar contexts.

Taking the prioritisation of the renovation needs of vulnerable households as a point of departure, this thesis seeks to first understand what the renovation needs of households across the EU are and as a second step understand how renovation priorities align with renovation needs.

1.1 Research Aim and Questions

The licentiate thesis aims to evaluate the extent to which long-term renovation strategies of EU Member States contribute to a just green transition by addressing the renovation needs of vulnerable households. Therefore, the main research question guiding the thesis is:

To what extent do long-term renovation strategies of EU Member States align renovation priorities with the needs of vulnerable households?

This question is divided into three sub-questions:

[6] Long-term renovation strategies are strategic renovation plans that Member States are required to submit to the European Commission every five years.

- How can the renovation needs of vulnerable households be characterised and mapped in the EU?
- How can a framework be developed to understand renovation policy priorities in the long-term renovation strategies of EU Member States in relation to vulnerable households?
- To what extent do national renovation policy priorities address renovation needs of vulnerable households?

1.2 Research Scope

The research presented in this thesis is part of the Horizon project, EqualHouse[7] which aims to investigate different dimensions of housing inequality and recommend affordable, inclusive, and sustainable housing solutions. It is more specifically tied to work package 8 of the project which aims to tackle energy poverty and unsustainable housing, through renovations (See Figure 1). The project covers 27 EU Member States and the UK, which has also influenced the transnational scale of research presented in the thesis.

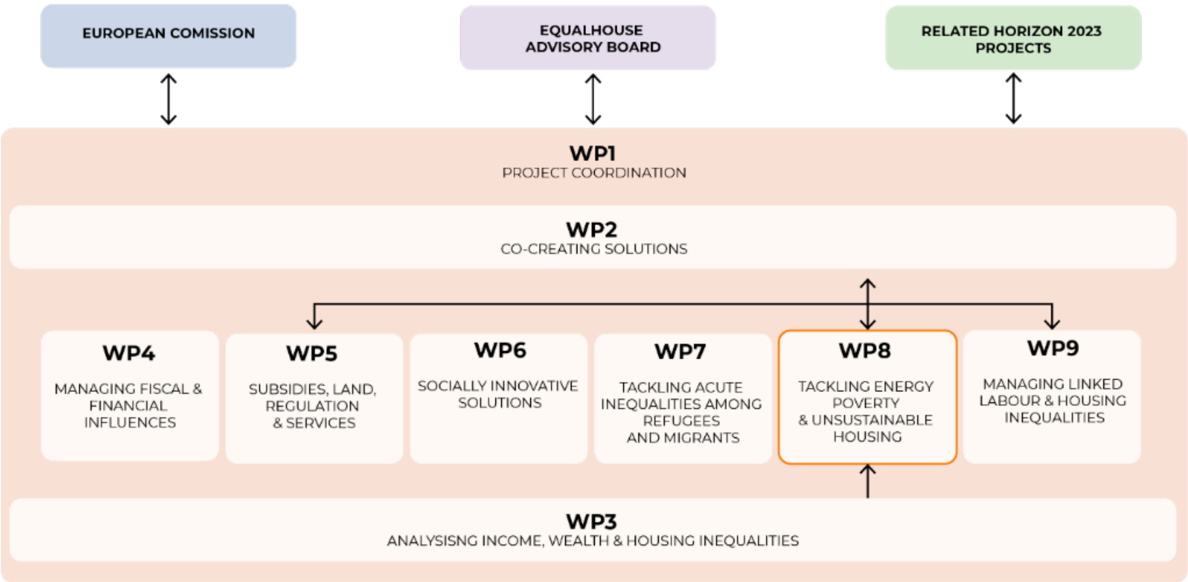

Figure 1 Organisational structure of the EqualHouse project. WP = work package. The thesis is connected to WP8.

While all 27 EU Member States are within the scope of the research, the study on renovation priorities which forms the basis for the appended paper, samples six geographically dispersed countries that have a varying set of housing, welfare, and climatic conditions (see Appendix A, Section 3.1.1). The use of housing and welfare regimes is a common framework used in critical housing studies and the EqualHouse project to cluster countries into groups according to their tenure and welfare systems.

[7] More information on the EqualHouse project can be found at https://equalhouse.eu/

The thesis focuses on conditions faced by households across the EU, to be able to ultimately contribute to the formulation of more tailored EU-level renovation policies for vulnerable households. Although the primary purpose of renovations is to improve building conditions, renovation measures and the manner they are implemented address the needs of different actors to varying degrees. For instance, switching energy sources may help landlords adhere to mandatory climate laws but not address the household renovation need to improve indoor thermal comfort. Therefore, the concept of "renovation needs" is investigated from the perspective of households rather than solely in terms of poor building conditions or from the perspective of other stakeholders in the system such as housing owners or municipalities.

Energy poverty, vulnerable households, climate-neutrality, and energy renovations are the key concepts that underpin this thesis. Hence, renovations that do not include energy efficiency measures are not investigated.

1.3 Structure of the thesis

The rest of the thesis is divided into six parts (chapters two to seven). Chapter two provides the state of the art on affordable and climate-neutral renovation literature. Chapter three covers the theoretical frameworks of socio-technical transition systems and just transition which underpin the research, followed by the key concepts used. The subsequent chapter on the research approach outlines the overarching pragmatic paradigm and mixed-method research design before introducing the data sources of EU databases and long-term renovation strategies that help to characterise renovation needs and form a systematic understanding of renovation priorities respectively. The chapter concludes with a justification of the methods of hierarchical cluster analysis, document analysis and triangulation of the two data sources employed in the thesis. Chapter five presents the country clusters which characterise renovation needs of households in 27 EU Member States as well as renovation priorities of six Member States through the analytical framework of targeted segments, technical renovation measures, and supporting policies. These results are then discussed through the lens of *Energy Justice* in chapter six. The thesis concludes with an outlook of the next steps in the PhD research process.

2. State of the Art

Current research on the prioritisation of households in energy renovations of the residential building stock, shows that households are often not prioritised for several reasons and in the cases where they are, those facing the most vulnerable conditions do not benefit from the measures.

The prioritisation of decarbonisation and energy efficiency as the primary goals of energy renovations is reflected in the dominant research agendas related to the renovations. Previous research on the topic has focused on scaling up energy renovations by identifying the different types of barriers to implementing them (e.g. Hoppe, 2012; Gonzalez-Caceres et al., 2020; Zerari et al., 2024)., strategies to address the identified barriers (e.g. Häkkinen et al., 2019; Ibañez Iralde et al., 2021; Lihtmaa & Kalamees, 2024) as well as the potential unintended consequences of the renovations (Collins & Dempsey, 2019; European Commission., 2025; Fernández et al., 2022). More recently, there is increasing focus on ensuring that the embodied emissions from renovation measures also remain low with strategies through reused and bio-based materials (Cihan Kayacetin & Versele, 2022; Zhang et al., 2025). While these technical aspects are important in making sure renovations address long-term societal need for a stable climate, they do not address the conflict it creates in addressing households needs.

Energy renovations can conflict with household needs when improving energy efficiency is the primary or only goal. This can be caused by technical standards that do not account for practical realities or changing climate conditions. The lack of accurate building energy consumption models or information (Visscher et al., 2016; D'Oca et al., 2018) has been shown to lead to an overestimation of energy consumption of older buildings also known as the prebound effect which results in less savings in energy bills for households than expected. This is partially due to low-income households consuming less than energy models to reduce bills (Galvin, 2023; Sunikka-Blank & Galvin, 2012). Higher concentrations of CO_2 due to climate change can also make current technical standards for airspeeds inadequate to achieve a comfortable indoor environment (Dimchev et al., 2025) and higher temperatures can lead to dwellings previously insulated to improve energy efficiency overheating in summer (Arriazu-Ramos et al., 2023; Figueroa-Lopez et al., 2021; Heracleous & Michael, 2018).

Technical constraints in buildings can even render energy renovations risky for households. In cases where internal insulation is the best option for renovating a building due to its structural qualities, poor execution can result in mould, worsening indoor comfort and placing the health of households at risk (Pagoni et al., 2023). In extreme cases, deep renovations pose a risk to the structural stability of the building, which can be a barrier to drastically improving its energy efficiency (Galimshina et al., 2024).

Another goal that is prioritised in energy renovations is cost-effectiveness for the financier or investors which can conflict with households, especially in tenant occupied housing. Split incentives can occur when a landlord has no incentive to finance energy renovation measures when the improvement in indoor comfort and reduction in energy bills will be experienced by the tenant (McCabe et al., 2018; Garcia-Teruel, 2024). This can be worse in the case of short-term rentals since the tenant in this case may not be willing to undergo the disruptive process for a short-term stay (DemiRtaş, 2024).

Cost-effectiveness of measures can also differ amongst cooperative owners of apartments who are at different stages of life, have different means, and occupy parts of the building with differing thermal comfort levels (Elgendy et al., 2026). For instance, occupants who live on the top floor of a building or in a corner apartment will have a higher need for thermal insulation than apartments who have less contact with external walls. The legal and organisational barriers of building consensus on renovation measures amongst owner-occupants who in some cases have differing means and needs is also a barrier to vulnerable households accessing energy renovations.

Including heating bills in rent as is the case in Scandinavian countries resolves the split incentive between tenant and landlord. However, since this requires a fundamental change in tenant laws, a more commonly cited strategy to address the split incentive between landlords and tenants is that of energy performance contracts which place the burden of financing on energy service companies in return for the reduction in energy bills to be directed to them (Bertoldi et al., 2021).

The long payback periods (Bahaj & James, 2007; Jerome et al., 2021) that are typical of renovation projects make them a risky investment (Femenías et al., 2018). In such cases, public and private partnerships in financing projects are encouraged (Copiello, 2015). Financial products such as green bonds (Mangold & Mjörnell, 2023) and white certificates (Bertoldi et al., 2010) have also been rolled out to distribute the risk of investment across multiple actors in society. There is a risk, however, that opening housing to private investment would lead to its increased financialisation (Knuth, 2018), causing investments to be shaped by shareholders instead of household needs (Aalbers, 2016; Van Der Wal et al., 2025). Therefore, tools for standardisation such as building renovation passports and energy performance certificates risk becoming tools of finance even though they create more trust in renovations and make them more reliable for investments (Mugarra et al., 2025).

Deep renovations which are considered more cost-effective, have been shown to be more disruptive, causing households to be displaced (Femenías et al., 2018). In countries where there are no regulations rent increases after renovations, tenants are priced out or evicted, a phenomenon known as "renovictions" (Bergoënd, 2022; FEANTSA, 2022; Polanska & Richard, 2021).

When measures to protect the interests of households are prioritised in energy renovations, they are not necessarily accessible to vulnerable households because they may have greater or different energy needs. For instance, flexible energy pricing which encourages households to shift their energy consumption according to daily price changes, exclude households who have energy needs that are not easy to shift such as those who are chronically ill or unemployed (Rigaux et al., 2024).

Subsidies and grants have been shown as favourable policies to incentivise households to undertake deep renovations or even single measures that have significant benefits like heat pumps (Barnes & Bhagavathy, 2020; Katris et al., 2024; Peñasco, 2024). However, since they are often paid out after the initial investment is made and improvements in energy efficiency have been proven, making them inaccessible to households who are unable to pay the upfront costs. In cases where they are paid out first, changes in material and labour prices can also result in suboptimal energy efficiency improvements (European Union, 2026).

Furthermore, energy efficiency is typically calculated according to floor area and not per capita and since people in lower income households also tend to live in more crowded households, the per capita energy performance of dwellings may be better in dwellings that perform poorly in terms of energy consumption per square meter (Platten et al., 2020). Thus, energy renovations targeted at buildings with the worst energy performance can end up placing the burden of implementing expensive and disruptive energy-efficient measures on those who are the most vulnerable to poverty.

The different ways that vulnerable households are disproportionately disadvantaged in both accessing energy renovations that they need and in shouldering the burden of having their homes renovated has led to calls for tailored support for these households (Frantál & Dvořák, 2022; Stojilovska et al., 2022).

The first step to providing tailored support is to identify households facing vulnerable conditions. Households who are marginalised or considered vulnerable tend to fall into one or more of the following categories. Low-income households are recognised as needing additional support due to a lack of resources or capacity to respond to renovation needs or obligations, but other sociodemographic characteristics are also often associated with vulnerability (Greene & Fahy, 2020).

Tenants (marginalised due to a lack of power in decision-making processes) are often more vulnerable to the unintended consequences of renovations. It is easier to scale up renovations in urban areas due to the more standardised nature of urban residential buildings and their proximity to each other. However, the risk of "green gentrification" or "renoviction" is also higher. Low-income households who are unable to afford higher rents after major renovations are forced to move out (FEANTSA, 2022). Both the barriers to implementing renovations and the risks of unintended consequences are especially higher in the less-regulated private rental sector (Garcia-Teruel, 2024).

Some households can have higher household energy needs due to factors such as chronic illness, old age, or unemployment (Streimikiene et al. 2020). It has been established in several studies that the elderly are more vulnerable to energy poverty related health issues (Willand & Horne, 2018; Lara-García et al., 2024). Retired homeowners face an additional hurdle with high heating and maintenance costs of under-occupied apartments (Mcabe et al. 2018). They are also less likely to undertake expensive or technically advanced energy renovations of homes they own (Charef et al., 2019). The elderly have also been shown to be more likely to relocate to avoid the uncertainty and disruption caused by renovations despite it being a challenging process for them (Femenias et al., 2026).

In general, households with higher energy needs are vulnerable to major disruptions in their living situation due to extensive renovations (displacement, even evictions), reduced capacity to meet all household needs (heat-or-eat dilemma), and poor indoor environmental quality due to building defects.

The abovementioned sociodemographic factors are used to identify vulnerable households but household characteristics only partially account for conditions of vulnerability. It is also created by underlying conditions which can place those who are not typically considered at risk of poverty by EU standards (Duclos 2002) in a vulnerable situation. One example of this is energy systems that rely on global fuel supply chains which make households susceptible to global energy price shocks.

Households in rural areas face specific issues such as physical isolation, high poverty rates, and older, inefficient building stocks which place them at greater risk of facing energy poverty. Rural housing in many countries have poorer indoor thermal comfort and energy performance (Piekut, 2020; Szép et al., 2023). It is also more common for these households to use fossil-fuelled, or wood heating systems which greatly reduce indoor environment quality and pose health risks to occupants. The ageing population often found in rural areas is more vulnerable to such health risks. The lower real-estate value of these areas makes it less lucrative for large investments like renovations to be made and the unique characteristics of single-family houses prevalent in rural areas make it a difficult sector to implement systematic or large-scale renovations in (Apostoliotis et al., 2024).

Public housing providers, especially larger organisations with more resources and access to funding, have been actively participating in renovation programmes (Cauvain & Karvonen, 2018). Despite these efforts, energy poverty is still prevalent among public housing tenants, who are often excluded from the traditional housing market and face greater socio-economic challenges (Croon et al., 2024).

Kyprianou et al. (2019) grouped measures tackling energy poverty into 4 categories: consumer protection, financial interventions, energy savings and RES integration, and information provision.

Croon et al. (2024) who investigate different methods of providing targeted support for vulnerable households facing energy poverty but note that energy efficiency measures are hard to implement. In the long term, dedicated funds for renovations known as revolving funds which are a form of soft loans with low interest rates have proven effective in financing renovations but require around 30 years for initial loans to mature (European Commission. Joint Research Centre., 2019).

Strategies for more inclusive processes that recognise the needs of households have also been studied with a push towards neighbourhood or district-level renovations which incorporate socially inclusive processes and educational campaigns. The concepts of positive energy districts and renewable energy communities have become more established partly in recognition of the need for integrated approached to energy renovations that do not treat them as solely technical interventions (Gouveia et al., 2021; Hoicka et al., 2021). This has also led to the need for emerging roles that mediate the technical and social aspects of renovations like energy coaches, more engaged facility managers, and community energy advocates (Ebrahimigharehbaghi et al., 2022; Van Der Wal et al., 2025). Similarly, complicated administrative processes to gain access to public financing for renovation measures and to plan the whole process has also been recognised, leading to research and pilot projects of one-stop-shops which consolidate all the renovation-related services in either one physical service centre or on one digital platform (Bertoldi, 2021). Gouveia et al. (2025) call for more specific support for households by providing the option of house visits by experts. In the Swedish context, Von Platten et al., (2021) conclude that amidst increasing general and housing inequalities, it would not be advisable to target the buildings with the worst energy performance in the renovation wave which focuses on deep renovations. Instead, they suggest focusing on less extensive renovation measures that address the immediate needs of households without compromising their long-term ability to afford housing.

The above-mentioned strategies to provide tailored support for vulnerable households are primarily process-related or short-term in how they address their needs. Ricci et at al. (2025) provide evidence that energy efficiency measures for vulnerable households is an overlooked method of addressing energy poverty. At the same time, the need for more research on understanding needs has been acknowledged in several studies. Integrating post-renovation audits into workflows would help gain insights into how these factors manifest in specific local contexts over time (Chiu et al., 2014). Maxim et al., (2016) identified the need to better understand regional differences and need to better understand the drivers of fuel poverty by distinguishing between direct and indirect factors. (Fizaine & Kahouli, 2019) recommend that studies dealing with the relationship between fuel poverty and other poverty-related concepts such as monetary poverty, health, education and social exclusion, should be conducted. The relationship between general poverty and energy poverty is still unclear since the choice of indicators changes the levels of energy poverty identified across

Europe. (Zalostiba & Kiselovs, 2021) also found discrepancies between the European-level and national statistical data that need to be verified.

While there is increasing attention paid to the negative consequences that the drive to decarbonise residential buildings has on households, a systematic understanding of different forms of energy needs is lacking across the EU. Having such an overview would provide EU policy-makes better insight as to where to prioritise funding so that a just green transition occurs.

3. Theoretical Framework and Key Concepts

This chapter introduces the two underlying theoretical frameworks that underpin the thesis. The theory of socio-technical transition systems is used as an analytical framework guiding the research scope, methods and analysis of results. Meanwhile the Just Transition framework is used as a normative guide to evaluating to what extent renovation strategies address the needs of vulnerable households. The chapter also introduces the concepts of energy needs, energy poverty, vulnerability, climate neutrality, decarbonisation and energy renovations which are related to the theoretical frameworks and central to the thesis.

3.1 Socio-Technical Transition Systems

The theory of Socio-technical transition systems is used in this thesis to frame the decarbonisation of the existing building stock (through energy renovations) as a socially embedded process that relies on multiple levels of change (from niche innovations to socio-technical regime) to be achieved.

The theory of socio-technical transition systems which has its roots in institutional studies, was proposed by Trist & Bamforth, (1951) in relation to human and technical system interactions in British coal mines. It has since evolved into an analytical framework for wider societal shifts, such as transitions to sustainability. This thesis investigates renovations as processes that are rooted in both technical and social systems, which include aspects such as consumer practices and public policies (Geels, 2002).

Central to the concept of Socio-Technical Transition Systems is the concept of Multi-Level Perspectives which recognises that transition in any system is enacted by multiple actors, operating at different levels (Geels, 2002). It posits that transitions occur start with niche innovations supported by small networks of actors who develop the innovation through experimentation. For instance, the concept of energy communities or positive energy districts that are studied by researchers and local housing practitioners in demonstration projects can be considered niche innovations in the context of building decarbonisation (e.g Malakhatka et al., 2025). The niche innovations seek to disrupt the incumbent socio-technical regime which is a currently stable configuration of actors ranging from policy-makers, municipalities, housing and construction companies, homeowners, and tenants with varying degrees of power and interest that shape the current condition of low renovation rates. Both the existing socio-technical regime and the niche innovations for building decarbonisation are shaped by underlying external factors such as EU policy and climate conditions grouped under the term, socio-technical landscape. Changes to the sociotechnical landscape creates windows of opportunity for niche innovations to disrupt the current sociotechnical regime and create a new norm.

In the line with Patterson et al., (2017)'s framing of Socio-Technical Transition theory as a useful descriptive and analytical tool for ex-ante or forward-looking change processes, this thesis uses the theory to both describe social, institutional, technological and economic components in residential energy renovations, and subsequently analyse their consequences on alleviating energy poverty and achieving building decarbonisation. Figure 2 shows the conceptual map of the renovation system that was the point of departure for mapping conditions of the socio-technical systems of renovations.

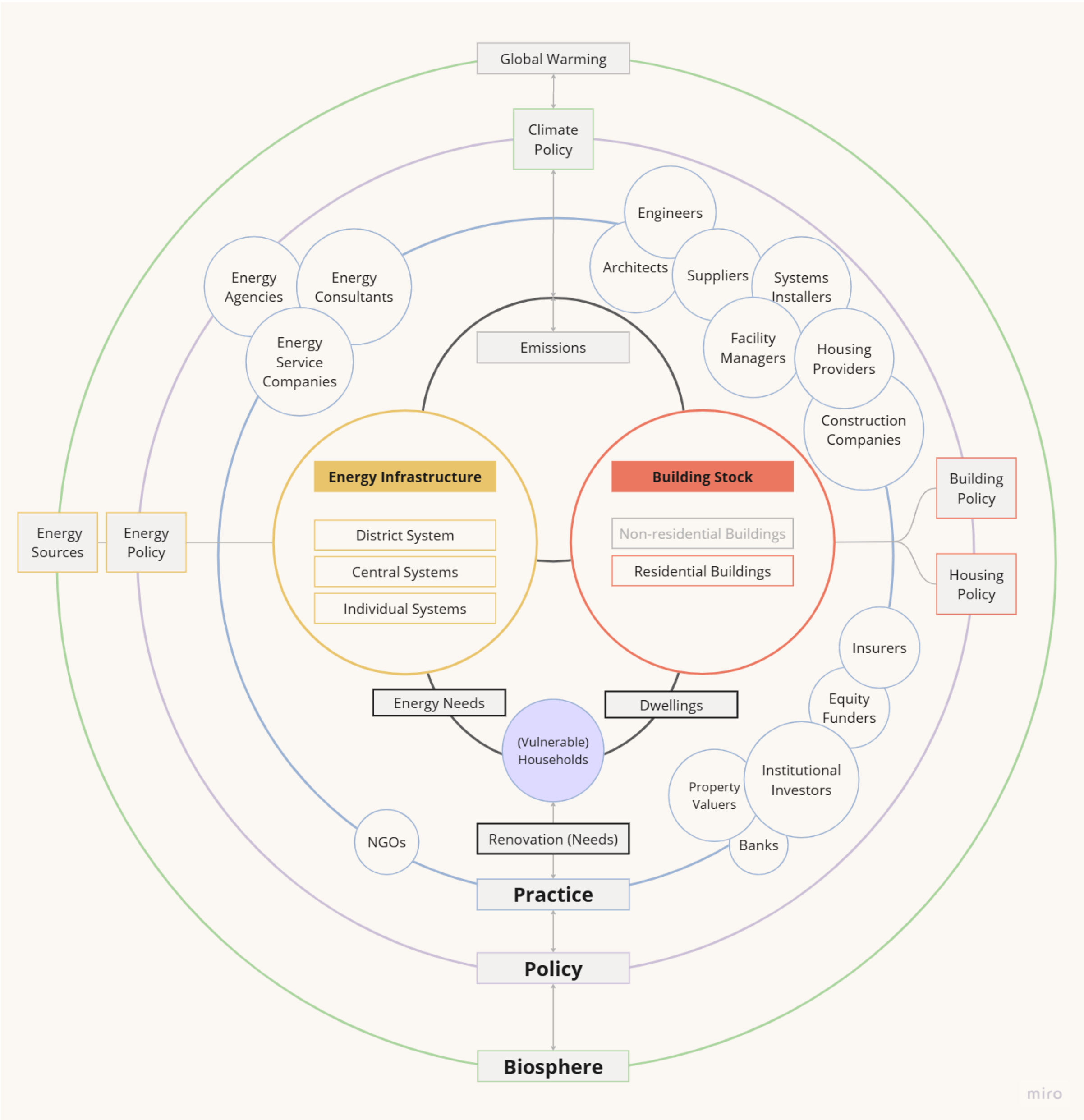

*Figure 2 Conceptual Diagram of Socio-technical System of Renovations Used in this Thesis. *Non-residential buildings and practitioners are not included in the scope of the thesis.*

The conceptual diagram of socio-technical systems of renovations is an adaptation of Kate Raworth's embedded-economy diagram proposed in her work on a safe and just space for humanity within planetary boundaries (Raworth, 2017: 78–84) and the value-chain of actors in renovations adapted from the DREEAM project on upscaling renovations (Von Geibler et al. 2019).

In broad terms, the thesis investigates the mediating effect of renovations between housing systems and energy systems on vulnerable households. This can be approached from various levels or scales as demonstrated through the concentric circles. The outermost sphere represents the biosphere or planetary system which everything else is bounded by. In terms of the multi-level perspective framework, this can be considered a fundamental part of the socio-technical landscape including the energy resources. The next sphere represents policy and governance, which is also part of the exogenous conditions but more directly dictates the rules that socio-technical regimes must adhere to. The next sphere of practice represents the actual socio-technical regime that is in transition towards a "sustainable future". This includes housing companies, energy service companies and the physical infrastructure they manage. Embedded in this sphere, households are shaped by, and in turn shape technical renovation measures. Both ultimately, have environmental consequences (See Figure 2). While acknowledging the entire system, the thesis focuses on investigating the impact of actions at the policy level such as the EPBD and the EED on households, mediated through renovations. It then investigates how the technical renovation measures and renovation policies can be altered to make the impact on households more equitable or just.

3.2 Just Transition

The Just Transition framework is used as a normative tool to evaluate to what extent renovation priorities outlined in national long-term renovation strategies address the needs of vulnerable households. It is a framework that is used both in research and policy aiming to shift towards a sustainable world economy that is also fair and inclusive for everyone. Parallel to the concept of Socio-Technical Transition Systems, a Just Transition framework has emerged from recognition that large scale, systemic transitions such as the decarbonisation of buildings place unequal responsibilities on certain groups (often those considered vulnerable) with unequal outcomes. Distributional, procedural, recognition, and restorative justice have been identified as key aspects of a just transition (Gillard et al., 2017). Several authors including (Mangold et al., 2018; Santamouris et al., 2007) have shown that low-income households are disproportionately affected by energy efficiency measures, focusing on distributional justice. Ricci et al. (2025) have developed a conceptual framework for a Just Transition through energy renovations which elaborates how different aspects of renovations align with the three main elements of distributional, procedural, and recognition justice. Energy justice applies the just transition principles of distributional, procedural, recognition, and restorative justice to the production, management, and consumption of energy (Jenkins et al., 2016).

What is apparent in these studies is an inherent conflict in the idea of a just green transition, where there are inevitable trade-offs between multiple renovation goals which range from decarbonisation, energy poverty alleviation, job creation, to the increasingly important goal of energy security. Von Platten et al. (2020) highlight the conflict between the push for deep renovations at the EU level which prioritise achieving climate goals and cost-effectiveness for the investor and the affordability of rent for the low-income households which are particularly affected by this policy. Ricci et al. (2025) also recognise that there are trade-offs between carbon, energy efficiency, and resident well-being in the design outcomes of renovations which can affect how just these outcomes are. The concept of Just Transition is used in this thesis to evaluate the mapped Socio-Technical conditions. The evaluation of conditions can be found in chapter 5.1. Identifying the specific needs of vulnerable households which falls under the category of recognition justice, is the main aspect of Just Transition and energy justice that is evaluated by comparing them against renovation priorities at an EU-policy level.

3.3 Vulnerability, Energy Needs, and Energy Poverty

The concepts of energy needs, energy or housing vulnerability and energy poverty are often used to discuss why and how we need to support households when decarbonising the existing building stock. Broad conditions of vulnerability and more acute experiences of energy poverty are influenced by household energy needs. Vulnerability can be discussed both in terms of housing and energy. The points at which energy and housing vulnerability converge are the focus of this thesis.

This thesis adopts Zhu et al. (2021, p12)'s definition of vulnerability as "the potential degree of exposure to risks of negative outcomes resulting from external risk factors, conditioned by an entity's ability to respond to the risks". This definition ensures that vulnerability is not solely attributed to specific socio-demographic characteristics like old age or unemployment but also to systemic factors. Therefore, this thesis investigates characteristics associated to vulnerability in the context of nation-specific definitions used in their long-term renovation strategies.

Energy poverty is often a defining feature of vulnerability measurement in policymaking with regards to energy renovations of residential buildings. Since the scope of this thesis is limited to 27 Member States of the European Union, the official definition of energy poverty in the EED will be used. The latest revision of the EED in 2024 (EU/2023/1791) adopted an EU wide definition of energy poverty and is as follows:

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 (European Parliament & Council of the European Union, 2023, p. 20)

This definition presents energy poverty in terms of the inability to meet energy needs such as adequate heating, hot water, cooling and lighting in relation to the national context and in terms of its driving factors which include unaffordable energy, low-income, high energy expenditure and poor energy efficiency. There is certain ambiguity in what could be considered "adequate" in terms of these needs. Since the definition calls for attention to national contexts, it is interpreted as the level required for households to meaningfully participate in society.

3.4 Decarbonisation and Carbon Neutrality

This thesis adopts the European Commision's definition of decarbonisation which is the complete transition of all buildings to zero emissions building. A net zero emissions building (NZEB) is a highly energy efficient building that uses renewable energy to meet any of the low energy needs (Ferreira et al., 2016; Maduta et al., 2023; Velten et al., 2023). The related concept of climate-neutrality describes the goal of zero net emissions that the process of decarbonisation aims to achieve.

Long-term renovation strategies (LTRS) mandated by the Directive (EU) 2018/844 are the main mechanism for the EU to monitor how Member States translate the Energy Performance of Buildings Directive (EPBD) [8] which deals with decarbonisation of the building stock, into actionable strategies adapted to local conditions. EU Member States are required to outline "renovation priorities" in their LTRS (European Union, 2020).

The European Commission also recommends that Member States should focus on cost-effectiveness, addressing market failures, split incentives, energy poverty, and worse-performing segments in terms of energy efficiency. Additionally, seismic activity and fire risks could also be addressed in the LTRS (Economidou et al., 2020). Through these guidelines, Member States are encouraged to plan and support energy renovations in a more holistic manner, tackling socio-economic concerns alongside energy-efficiency issues.

[8] The Energy Performance of Buildings Directive (EPBD) is the main EU law to achieve a net zero emissions building stock by 2050 by improving energy efficiency in this sector.
https://eur-lex.europa.eu/eli/dir/2024/1275/oj/eng

The Long-Term Renovation Strategies are part of the larger National Energy and Climate Plans[9] and have been reframed as Building Renovation Plans that member states are obliged to submit every 5 years. This revised version was adopted earlier in 2024 and requires member states to propose more concrete national targets instead of the previous indicative milestones.

3.5 Energy Renovations

Renovation, in general, can be defined as an umbrella term that encompasses any measure implemented to improve the stability, functionality, or aesthetics of an already existing building. Practices range from light touch measures of maintenance to resource intensive conversions. Meanwhile, energy renovations refer more specifically to renovation measures that improve the energy efficiency of a building. Energy renovation measures can be organised according to the energy efficiency pyramid (see Figure 3). It offers a comprehensive categorisation of the different types of measures needed to improve the energy performance of a building. Often, a combination of these measures is required to achieve adequate improvements.

Understanding a building's or household's energy consumption helps to identify areas of improvement in energy efficiency. Technical measures in this category primarily include smart meters which help to measure actual energy consumption. The energy conservation tier of the energy efficiency pyramid typically includes demand-responsive systems such as demand responsive heating and ventilation systems or automatic lighting. These measures do not necessarily improve efficiency directly but reduce the time that systems need to be in operation. The EU has adopted an energy-efficiency first principle (EU) 2021/1749) which prioritises reducing energy consumption before investing in renewable energy supply (EC, 2021). Reducing energy consumption through efficiency measures is also expected to put less pressure on infrastructure upgrades that are needed to switch to renewable sources. Typical measures that fall under this third tier of the pyramid range from passive interventions such as replacing windows or adding insulation to active interventions like installing ventilation systems with heat recovery. Decarbonising household energy consumption by switching to renewable energy sources is an important step in meeting carbon emission reduction targets agreed by the EU (EC, 2020). Commonly installed renewable energy systems include solar energy systems, heat pumps, and biomass boilers which rely on electricity to function. The electrification of final energy consumption is therefore recommended (EEA, 2023). ADEME, the French agency for energy transition, has summarised what the ideal order to carry out significant renovation works would be.

[9] National Energy and Climate Plans are strategic planning tool to attain EU climate goals. They outline how Member States plan to use investments for climate and energy transition, helping to mobilise private and public spending. https://energy.ec.europa.eu/strategy/energy-union/national-energy-and-climate-plans_en

They recommend starting with envelope insulation, followed by windows and doors, ventilation and finally the upgrade or replacement of heating and cooling systems (ADEME, 2021).

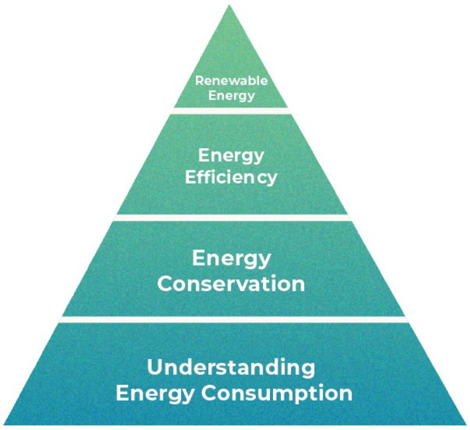

Figure 3 Energy Efficiency Pyramid. Source: Buffington, D. E. (2010, May). The energy pyramid. Mushroom News, 58(5). Retrieved from https://www.americanmushroom.org/ clientuploads/directory/mushroom_news/2010/2010_05.pdf

The definitions of key concepts used in this thesis closely align with how the European Commission or Member States define them. This is because the thesis seeks to understand how the concepts are operationalised rather than using a universally valid definition that comprehensively reflects lived realities. It reflects the pragmatic paradigm that shaped the research conducted. The adoption of a pragmatic paradigm and a mixed-methodology research design is elaborated on in the following chapter.

4. Research Approach

This chapter begins by outlining the reasons why a pragmatic paradigm was adopted for this thesis. A mixed-methods research methodology was chosen to align with the pragmatic paradigm, allowing for both a deeper conceptual understanding of renovations at the scale of national and European residential building stocks and the operationalisation of this knowledge through the analysis of quantitative data. The choice of databases and indicators used to characterise renovation needs and long-term renovation strategies as a data source to analyse renovation priorities are justified alongside the choice of hierarchical clustering analysis and qualitative content analysis are motivated.

4.1 Pragmatic Paradigm

A pragmatic paradigm was adopted due to the author's background in architecture. Research on a socio-technical process such as renovations, can be conducted through different disciplines ranging from engineering to social science. The choice of research discipline affects fundamental assumptions about the nature of the reality being studied (ontology), the methodology (the way knowledge is gained and interpreted) adopted and the nature of the knowledge (epistemology) produced and how it should be evaluated. The research that grounds this thesis is rooted in architectural and sustainability science disciplines, both of which have a tradition of borrowing methods from more established applied fields of research such as social science and engineering. They both tend to adopt a pragmatic research paradigm [10], aiming to solve a practical problem in the built environment in the case of architectural research and aiming to address climate change in the case of sustainability science.

The author's training as an architect has also greatly influenced the overall PhD aim of recommending context-appropriate renovation measures for vulnerable households, leading to a focus on identifying the technical renovation measures included in strategic renovation priorities. This disciplinary perspective risks privileging building-centred solutions over more fundamental determinants of housing vulnerability, such as welfare systems and income inequality. The focus on renovation measures also resulted in the adaptation of the concept of energy needs which are typically only expressed in terms of energy services needed by households, to include energy systems and building conditions.

[10] A *paradigm* is a theoretical framework which outlines a set of epistemological (nature of knowledge), ontological (nature of reality), and axiological (nature of value and how the values of the researcher can influence what is to be studied) beliefs that guide the methodology used.

A pragmatic paradigm focuses on the utility of any given theory over a rival theory rather than the objective truth or a constructed truth (Yvonne Feilzer, 2010). It is especially useful for shaping research design when the research questions call for a combination of epistemologically inconsistent methods. A socio-technical process such as renovations, grapples with positivist ideas of efficiency and optimisation of technical measures and constructivist ideas which question the objectivity of technical standards such as thermal comfort. Therefore, a pragmatic paradigm is applied and guided the choice of a mixed-method research methodology.

The pragmatic paradigm influenced the choice to use EU-level datasets and policy documents. While these sources provide comparable information across Member States, they also reflect institutional priorities regarding what constitutes relevant evidence and how housing vulnerability is measured. The findings should, therefore, be understood as an analysis of vulnerability and prioritisation as represented within European policy frameworks rather than a comprehensive account of households' lived experiences.

4.2 Research Methodology

"Overall, the triangulating investigator is left to search for a logical pattern in mixed-method results. His or her claim to validity rests on a judgment, or as Weiss (1968: 349) calls it, "a capacity to organise materials within a plausible framework." One begins to view the researcher as builder and creator, piecing together many pieces of a complex puzzle into a coherent whole." (Jick, 1979)

This thesis follows a mixed-methods research methodology, triangulating both quantitative and qualitative date following the convergence model whereby they are compared with each other and then synthesised into a common interpretation (Creswell et al. 2006). The first phase of the research involved conducting a series of hierarchical clustering analyses to characterise countries based on different dimensions of renovation needs (e.g. building, socio-demographic, and energy system conditions). The indicators chosen for these analyses were based on the conceptual framework of sociotechnical system of renovations introduced in Chapter 2, Figure 2. The second phase of the research involved using thematic analysis as proposed by Suddaby (2006) and qualitative content analysis as suggested by Mayring (2000) to study how vulnerable households are prioritised in the long-term renovation strategies of six Member States. The third phase involved triangulating the quantitative data on renovation needs with the qualitative data on priorities to understand the potential gaps (see Figure 4).

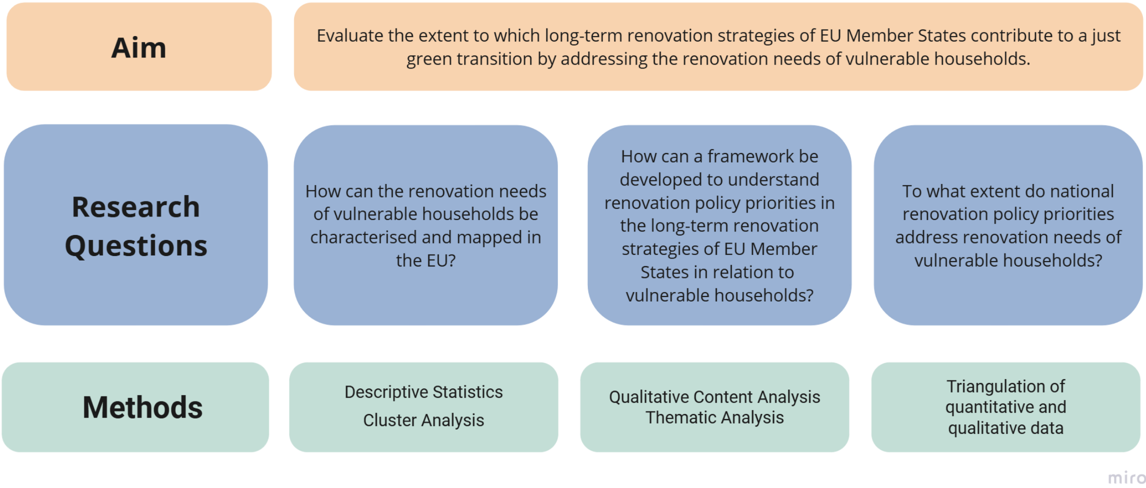

Figure 4 Research design

4.3 Characterising Household Renovation Needs in the EU

The process of characterising household renovation needs began with defining and quantifying the concept using indicators accessible through databases providing harmonised data for the 27 EU Member States. This allowed individual national profiles of household renovation needs to be made. Hierarchical clustering analysis was used to then describe the nature of household renovation needs at the national level in relation to other countries in the EU.

As mentioned earlier, the concept of renovation needs expands the concept of "energy needs", by shifting the focus to energy renovation measures that are required. It can therefore be defined as the building, and energy-system interventions required to sustainably satisfy those needs while improving housing conditions and reducing environmental impacts (see Appendix A, Section 2).

It is operationalised by a set of quantitative indicators that show the magnitude and nature of renovation that can be divided into 3 main components of conditions, outcomes, and renovations. Conditions include building, energy supply, and socio-demographic conditions. The second part of the profiling is on energy renovations implemented and the third part is on the outcomes in relation building energy consumption and household energy poverty. In the appended paper, the focus is more specifically on low-income households or households at risk of poverty (see Appendix A, Section 3.2)

Although energy efficiency and building emissions are often framed as a climate issue, the need to improve environmental performance is essentially a long-term requirement to sustain human life and can therefore also be considered an indirect or long-term "renovation need" for households. Reducing emissions from buildings becomes a more urgent need when they directly impact (i.e. direct emissions from on-site combustion) the living conditions of households.

Table 1 summarises available databases covering the EU27 Member States on energy, renovations, housing conditions, who they are managed by and the topics covered by them. Apart from Odysee-Mure which is managed by independent research organisations, the databases are managed by EU organisations. They are routinely updated as more data is gathered, countries correct previously submitted data, or when benchmark methods are revised. All data used in this research is open access.

Table 1 List of EU databases on energy, renovations, housing conditions

Database	Data Management	Topics Covered
European Statistics on Income and Living Conditions	Eurostat	Energy, Emissions, Renovations, Housing conditions
Building Stock Observatory	Directorate-General for Energy	Energy, Emissions, Buildings, Renovations, Energy Poverty
European Environment Agency	European Environment Agency	Energy, Emissions, Economy, Health, Nature
Energy Poverty Advisory Hub	Directorate-General for Energy	Energy Poverty
Odyssee-Mure	Enerdata, Fraunhofer ISI, IEECP	Energy, Emissions

The evolving nature of policy concerns has meant that data collected in established databases such as Eurostat has evolved to include new concerns and new databases such as the Energy Poverty Advisory Hub have emerged to cover the more recent concerns. Some of the indicators shown in newer databases are also derived from more established databases like Eurostat but in a format specific to its aim. This highlights the fact that standardised data collection at the EU level is a resource-intensive and collaborative process which is built over time through multiple research projects that complement or supplement established databases.

The EU Statistics on Income and Living Conditions (EU-SILC) [11] is a database containing results from a panel survey conducted in a standardised way across the EU which consistently monitors energy and housing conditions. The sampling frame for EU-SILC is all households or dwellings in

[11] The European Statistics on Income and Living Conditions is a survey on income, poverty, social exclusion, and living conditions. https://ec.europa.eu/eurostat/web/income-and-living-conditions

EU27 and candidate countries. The sampling strategy is a non-probability sampling method of stratified sampling conducted in two stages. In the first stage, small geographical areas (NUTS Level 3) are chosen using probability sampling. In the second stage, a sample of dwellings are also chosen using probability sampling. The surveys are longitudinal studies typically conducted on four-year rotations. One third of the households are swapped out for new households every four years.

The Building Stock Observatory (BSO) [12] presents a range of indicators that monitor progress on key energy policy goals including those related to energy poverty and energy-related greenhouse gas emissions. The data featured on this database is extracted from several other EU projects and databases such as the European Environment Agency [13], Eurostat [14], and the EU Comprehensive Study on Renovations [15]. The database is primarily targeted at policymakers, providing reliable information that lends itself easily to cross-country comparison. The table below summarises the indicators used by the Building Stock Observatory.

The European Environment Agency is a European organisation that consistently collects and validates energy and emissions related to data from Member States to support European environmental and climate policies. They also provide analysis of this data.

Energy poverty, which has gained a stronger policy focus in recent years is monitored primarily through the Energy Poverty Advisory Hub (EPAH) [16] which maps a wide range of indicators. The indicators used in the dashboard, however, are not the only indicators recommended by the advisory hub for use by municipalities in diagnosing and tackling energy poverty at the local level.

The Odyssee-Mure database monitors energy efficiency trends in multiple sectors including households as well as policies that support energy efficiency. The data is assembled from two databases, odyssee which focuses on energy efficiency trends and Mure which focuses on mapping policies across the EU. This is the only database of the selected ones that is jointly managed by independent research organisations and not directly by an EU agency. It was chosen because it presents energy efficiency data at the household or dwelling level and is also consistently updated.

[12] The Building Stock Observatory aims to provide reliable and transparent data on building and energy related topics. https://energy.ec.europa.eu/topics/energy-efficiency/energy-performance-buildings/eu-building-stock-observatory_en#objective
[13] The European Environment Agency is an EU agency that reports reliable data on the state of Europe's environment to support environment and climate policies. https://www.eea.europa.eu/en
[14] Eurostat is the official statistical office for the EU to support policy development and monitoring. https://ec.europa.eu/eurostat/web/main/home
[15] European Statistics on Income and Living Conditions https://ec.europa.eu/eurostat/web/income-and-living-conditions
[16] The Energy Poverty Advisory Hub (EPAH) was launched in 2021to support governments in alleviating energy poverty. It builds on the work of its predecessor Energy Poverty Observatory which was more research oriented. https://energy-poverty.ec.europa.eu/

Although research on energy systems and their adoption across the EU has been conducted through projects such as WeDistrict [17] and EU level market representatives such as the European Heat Pump Association [18], Eurostat provides a more consistent and comprehensive monitoring of such data and was therefore chosen over the individual projects. Meanwhile the concept of climate-neutrality has been monitored through the climate-neutrality observatory which tracks the EU's overall progress towards reaching climate neutrality by 2050. Buildings are a key component of this monitoring process. This database was, however, not used since it only presents data at the EU level.

The use of multiple indicators to operationalise a construct is an established method in quantitative social science research (Nardo et al., 2008). For instance, since energy poverty is usually described as a multi-dimensional phenomenon that is linked to other vulnerabilities like geographic location, and family composition, several studies use multiple indicators to quantify the phenomenon (e.g. Rakotomena & Ricci, 2025; Recalde et al., 2019a; Terés-Zubiaga et al., 2023). Although the multiple indicators used could have been assigned weights to create a single composite indicator that represents the construct of household renovation needs, the indicators are instead grouped under the different dimensions to be able to interpret the clustering results.

Hierarchical clustering analysis (HCA) is a descriptive technique used in statistics to analyse how datasets can be grouped based on mathematical similarities (Peña, 2002). The hierarchical method of clustering (as opposed to other types such as K-means) was used due to its suitability to a small sample size of 27 countries (Dou et al., 2026). The Ward.D2 method which is an algorithm to measure the numerical distance between variables was performed to categorise the 27 countries by considering the similarities in household renovation needs using the software Jamovi [19]. The results are presented through a dendrogram, a type of tree diagram that groups countries on multiple levels (see fig.10). Countries that share the most similarities are grouped together on the lowest level of the diagram, and in turn grouped with the next closest group of countries on the next level of the diagram. The visual length of the branches of the dendrogram which represent the mathematical distance of the data for each country determined the point at which the clusters were selected.

Renovation needs were then quantified through 7 categories of indicators which can be classified into 3 broader groups of indicators on underlying conditions (Building, Energy, Climate, and Sociodemographic), outcomes (Energy poverty, Energy consumption and Emissions), as well as implemented renovations. Each of the 7 categories consist of several indicators broken down in terms of "proportion of population" or ratios so that countries of different sizes can be compared. For instance, emissions are quantified by the ratio of direct to indirect emissions rather than absolute

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[17] WeDistrict is an EU-funded project…. https://www.wedistrict.eu/
[18] The European Heat Pump Association is an organisation which represents the heat pump sector in the EU… https://ehpa.org/
[19] Jamovi is a software that helps conduct statistical analysis based on quantitative data as input

quantities. This helps to understand the relative nature of emissions from buildings rather than its magnitude. The individual indicators were grouped so that a suitable number of indicators for a cluster analysis (varied enough to provide distinct groups and low enough to interpret the driving factors of the result) were used. This resulted in 9 separate cluster analyses, two each for building and energy conditions and one each for the rest of the categories. This implies that building and energy conditions had a larger effect on the ultimate result of 4 clusters which aligns with the dimensions that differentiate the concept of "renovation needs" from the concept of "energy needs".

In this thesis, an additional meta clustering analyses based on a correlation matrix counting the number of times each country ended up in the same cluster in the separate analyses is presented as a synthesis of the 9 separate analyses.

The indicators that were used to characterise household renovation needs across the EU are presented in the table 2 below.

Table 2 List of Indicators used in the Hierarchical Cluster Analysis. Reference Year 2023 unless otherwise specified.

Main Category	Dimension	Indicator	Database
Conditions	Building	Population living in dwelling with a leaking roof and/or damp ceilings, dampness in the walls, floors or foundations and/or rot in window frames and doors (%)	EU-SILC
		Degree of Urbanisation (%)	EU-SILC
		Dwelling Type (%)	EU-SILC
		Construction Year Cohort by Area (%)	BSO
	Energy Supply	Main Heating System (%)	EU-SILC
	Energy Supply	Household Fuel Mix by Consumption (%)	EU-SILC
	Climate	Heating Degree Days	Eurostat
		Cooling Degree Days	Eurostat
	Sociodemographic Factors	Risk of poverty	EU-SILC
		Inequality of income distribution	EU-SILC
		Aged above 65	EU-SILC
		Single-parent household	EU-SILC
		Single-person household	EU-SILC
		Unemployed	EU-SILC
		Chronic illness	EU-SILC
Renovation	Renovation	Energy Renovation Measures in the Last 5 Years (%)	EU-SILC
Outcomes	Energy Poverty	Inability to Keep Home Adequately Warm (%)	EU-SILC
		Inability to keep home adequately cool (%) (2012)	EU-SILC
		Arrears in Utility Bills (%)	EU-SILC
		Housing Cost Over Burden rate (%)	EU-SILC

	Energy and Emissions	Electricity Consumption per dwelling	Odysee-Mure
		Heat Consumption per dwelling	Odysee-Mure
		Direct and Indirect Emissions from Residential Buildings (%)	EEA

4.4 Developing a Framework for Renovation Priorities

Since national renovation priorities can be dispersed in different pieces of legislation under different governmental agencies across EU Member States, the 2020 long-term renovation strategies submitted to the European Commission were chosen as a relatively standardised source to analyse renovation priorities. They provide data that captures the country-specific transposition of priorities set at the EU level. They offer more comparable alternatives to rich, case-specific qualitative data that are resource intensive to analyse.

The requirement to submit plans for renovation began in 2014, with a revised version that was required to be submitted in 2017 (Economidou et al., 2020). According to the European Commission, these early versions of the national renovation strategies focused on plans for investment in the renovation of the national building stocks. The subsequent version was due in 2020 and required Member States to address additional concerns according to the 2021 revision of the EPBD which introduced the “Renovation Wave” and “Fit for 55” package. The national strategies follow the outline recommended by the European Commission to varying degrees. Since the focus of the thesis is on a just transition for households, the analysis focuses on sections related to residential buildings. Sections of the LTRS documents related to public buildings and public consultation were excluded (see appendix C).

The Long-term renovation strategies of 6 sample EU Member States were chosen for analysis as a proof of concept. The countries chosen were Austria, Denmark, Estonia, Hungary, Ireland, and Portugal. They each have different housing-welfare regimes and are geographically diverse. The analysis of the long-term renovation strategies began with close reading and thematic analysis, the details of which are presented in the appended paper (See Appendix A).

Priority setting in renovation projects is often heavily dependent on individual project conditions and resists generalisation on a larger scale. The European Commission’s requirement for the development of strategic plans, however, necessitates that renovation priorities are set on a national level. This creates a need for a more generalised or even theoretical explanations of what renovation priorities are, how they are formed and their implications. In general, the study of political priorities in academic literature related to climate and housing goals has highlighted conflicts between these goals and their unintended consequences on households (Tynkkynen et al., 2025; Von Platten et al., 2021). Normative stances are taken to recommend alternative ways of governance which reduce these tensions and negative impacts.

Document analysis of long-term renovation strategies conducted in other studies have focused more on quantitative aspects of the strategies such as climate targets (Castellazzi et al., 2022; Staniaszek et al., 2021) and indicators used (Beltrán Velamazán et al., 2021; Maduta et al., 2023). In this thesis, however, since the analysis also aimed to understand how Member States describe renovation priorities in relation to vulnerable households, a more open and qualitative approach was taken to develop a systematic understanding of these priorities. The initial thematic analysis resulted in an analytical framework that was used to conduct a more focused qualitative content analysis of renovation priorities in relation to vulnerable households. The analytical framework categorises priorities in terms of priority concerns, targeted segments, technical renovation measures, and supporting policies. Since the focus of the content analysis was on the priority concern of vulnerability, only the segments, measures, and policies related to this concern are presented in the licentiate thesis. The application of the full framework can be seen in the appended paper (Appendix A).

A similar approach was adopted by Bouzarovski et al. (2020), a report for the EU energy poverty observatory which analysed how energy poverty was defined in National Energy and Climate Plans. They assessed the extent to which energy poverty was considered in the NECPs based on 13 criteria, such as recognition and definition of energy poverty or the type and number of measures taken to address it. The qualitative content analysis began by establishing keywords that are related to vulnerable households in relation to renovations. These keywords were chosen based on an initial reading of sample Member States' LTRS, literature available, and an additional round of brainstorming synonyms or any related keywords which may have been missed. They fall under the categories of terminology related to vulnerability, poverty. Affordability, housing, energy, health, and policy targeting. These terms were searched in the long-term renovation strategies of the six Member States and relevant text that mentioned vulnerable households and how they will be addressed was organised into a table based on the analytical framework of renovation priorities.

Derived from military and navigation practices of using multiple reference points to determine the precise location of an object, triangulation in research is a process of using multiple research methods to study the same phenomena (Smith, 1975, p.273). It is used in social science research to validate findings from one method and/or to identify a divergence or variance in findings. It also provides the added benefit of more contextual and holistic understanding of a phenomenon (Jick, 1979).

Since the use of multiple methodologies is meant to compensate for method-specific limitations, statistical analysis of quantitative indicators was coupled with thematic analysis of qualitative strategy documents to two related phenomena of household renovation needs and national renovation priorities. Statistical analysis helps to understand the magnitude of the phenomena and find quantitative correlations in the data between different countries. However, since the indicators used to measure “renovation need” are based only on incidence, the intensity and variation in “renovation needs” is better understood by qualitative data that provides more descriptive and contextual explanations of the phenomenon.

The main challenge in designing the triangulation process was the lack of a systematic guide on how to compare two disparate sets of data. Not all statistical data had a directly comparable counterpart in the national strategy documents. Often, the strategic document was richer in data. For instance, the Portuguese strategy uses the country-specific classification of urban rehabilitation areas as a factor to target segments for policy support. This classification does not have a direct statistical counterpart in the aggregated EU-SILC statistics. In this case, the Portuguese strategy is interpreted to have an urban focus in its prioritisation which is then compared to the relative poverty levels in areas of different degrees of urbanisation. The detail comparison of statistical data to LTRS is presented in the appended paper (see Appendix A, Section 4)

5. Results

This chapter summarises the results from the hierarchical cluster analysis of quantitative indicators and qualitative content analysis of LTRS. The 9 hierarchical cluster analyses conducted have been synthesised in a meta hierarchical cluster analysis (See Figure 5) and a co-occurrence matric (See Figure 6) which aggregate the separate analyses to show more general patterns of similarity and difference in all the EU Member States. The results of the qualitative content analysis are summarised based on targeted segments (See Table 3), technical renovation measures and supporting policies (See Table 4). These results provide the basis for discussion on to what extent the strategies address the renovation needs of vulnerable households.

5.1 Country Clusters of Renovation Needs

The 9 cluster analyses conducted using indicators quantifying each of the above-mentioned categories, resulted in a range of 3 to 7 clusters. The number of clusters was determined by visually analysing dendrograms to identify the point at which the largest distances lie. Apart from energy poverty and socio-demographic indicators, all the analyses resulted in 1 or 2 outlier countries.

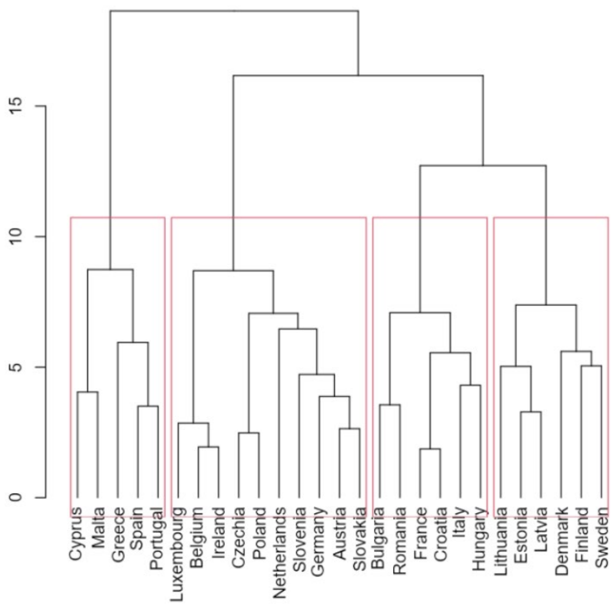

Figure 5 Meta Hierarchical Cluster Analysis of co-occurrences in 9 cluster analyses

The meta clustering analysis of co-occurrences of the 27 EU Member States in the 9 separate hierarchical clustering analyses resulted in 4 clear clusters (see Fig. 10). These clusters largely follow geographic patterns. Southern European countries (Cyprus, Malta, Greece, Spain, and Portugal) are in one cluster. Central European countries (Luxembourg, Belgium, Ireland, Czechia, Poland, Netherlands, Slovenia, Germany, Austria, and Slovakia) are grouped in a cluster. Meanwhile, Scandinavian and Baltic states (Lithuania, Estonia, Latvia, Denmark Finland, and Sweden) are grouped together. The fourth cluster deviates slightly from a geographic pattern with the Balkan states of Bulgaria, Romania, and Croatia grouped with Hungary, Italy and France. The meta clustering was conducted by assigning each of the 9 separate cluster analyses equal weight. Since more of the analyses were conducted for indicators related to energy systems, sources, and consumption patterns, it can be assumed that this is what drove the clustering primarily.

	BE	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU	HU	MT	NL	AU	PL	PT	RO	SL	SK	FI	SE
Belgium	9	1	4	3	5	2	7	2	1	2	2	1	1	3	1	7	3	1	2	5	4	1	2	4	5	2	2
Bulgaria	1	9	2	1	2	3	1	4	2	4	5	4	2	2	4	1	4	2	2	2	2	4	6	2	2	3	3
Czechia	4	2	9	5	4	3	4	0	0	6	5	4	1	3	2	5	5	2	4	6	8	1	3	5	5	4	2
Denmark	3	1	5	9	1	2	3	1	0	4	3	2	0	2	2	4	1	0	2	3	4	0	2	2	2	4	4
Germany	5	2	4	1	9	2	5	3	2	2	2	4	1	2	3	4	5	4	5	6	4	1	2	4	6	3	2
Estonia	2	3	3	2	2	9	1	1	1	2	3	2	0	6	5	1	2	1	1	2	3	3	2	2	2	4	4
Ireland	7	1	4	3	5	1	9	2	2	3	3	1	1	3	1	6	3	1	2	6	4	2	2	5	5	2	2
Greece	2	4	0	1	3	1	2	9	4	2	2	2	1	0	2	1	2	2	1	2	0	3	2	2	3	2	1
Spain	1	2	0	0	2	1	2	4	9	1	1	2	3	2	2	1	1	3	0	0	0	6	2	1	1	0	1
France	2	4	6	4	2	2	3	2	1	9	8	6	0	3	2	3	5	1	2	5	5	2	5	6	3	5	3
Croatia	2	5	5	3	2	3	3	2	1	8	9	6	0	4	1	3	5	1	2	4	5	2	6	5	3	4	4
Italy	1	4	4	2	4	2	1	2	2	6	6	9	0	2	2	2	6	2	4	2	4	2	5	3	3	3	4
Cyprus	1	2	1	0	1	0	1	1	3	0	0	0	9	0	1	1	1	6	2	1	1	3	2	2	1	0	0
Latvia	3	2	3	2	2	6	3	0	2	3	4	2	0	9	4	3	3	1	1	3	3	3	3	3	3	5	4
Lithuania	1	4	2	2	3	5	1	2	2	2	1	2	1	4	9	1	3	1	2	3	1	4	3	2	2	5	3
Luxembou	7	1	5	4	4	1	6	1	1	3	3	2	1	3	1	9	3	1	2	4	5	1	2	3	4	2	3
Hungary	3	4	5	1	5	2	3	2	1	5	5	6	1	3	3	3	9	3	6	5	5	2	5	5	6	4	1
Malta	1	2	2	0	4	1	1	2	3	1	1	2	6	1	1	1	3	9	3	3	2	2	0	2	3	2	1
Netherland	2	2	4	2	5	1	2	1	0	2	2	4	2	1	2	2	6	3	9	4	4	0	2	2	5	2	0
Austria	5	2	6	3	6	2	6	2	0	5	4	2	1	3	3	4	5	3	4	9	5	1	2	7	7	5	1
Poland	4	2	8	4	4	3	4	0	0	5	5	4	1	3	1	5	5	2	4	5	9	3	4	5	3	2	0
Portugal	1	4	1	0	1	3	2	3	6	2	2	2	3	3	4	1	2	2	0	1	1	9	3	2	2	1	1
Romania	2	6	3	2	2	2	2	2	2	5	6	5	2	3	3	2	5	0	2	2	3	3	9	4	2	3	3
Slovenia	4	2	5	2	4	2	5	2	1	6	5	3	2	3	2	3	5	2	2	7	4	2	4	9	5	4	1
Slovakia	5	2	5	2	6	2	5	3	1	3	3	3	1	3	2	4	6	3	5	7	5	2	2	5	9	4	1
Finland	2	3	4	4	3	4	2	2	0	5	4	3	0	5	5	2	4	2	2	5	3	1	3	4	4	9	5
Sweden	2	3	2	4	2	4	2	1	1	3	4	4	0	4	3	3	1	1	0	1	2	1	3	1	1	5	9

Figure 6 Co-occurrence matrix showing how many times countries were grouped in the same cluster

Looking at the co-occurrence matrix for Bulgaria, Romania, Croatia, Hungary, Italy and France. These countries are grouped in the same cluster in 4 to 8 of the 9 analyses. All these countries are in the same cluster for heating systems, climate conditions, and renovations recently implemented. France, Croatia and Italy have the strongest correlations, ranging from 6 to 8. In terms of energy sources, Hungary and Italy are in a cluster together and the other 4 countries are together in another cluster and all except Bulgaria are in the same cluster for energy consumption patterns. These countries diverge the most in terms of the age of the building stock.

5.2 Renovation Priorities in Relation to Vulnerable Households

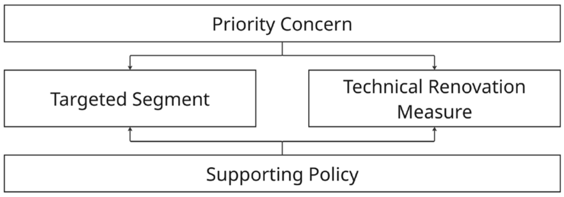

Figure 7 Analytical Framework to Understand Renovation Priorities

The long-term renovation strategies of six sample countries (Austria, Denmark, Estonia, Hungary, Ireland, and Portugal) were analysed using thematic analysis to understand how to form a systematic understanding of renovation priorities. This resulted in an analytical framework which breaks down the strategy documents into priority concerns, targeted segments, technical renovation measures, and supporting policies (see Figure 7). Although the initial thematic analysis showed that there are multiple priority concerns like climate mitigation and cost-effectiveness, the results of the thesis only focus on the priority concern of supporting vulnerable households.

Table 3 Vulnerable Segments Targeted in LTRS. Source: 2020 LTRS of Austria, Denmark, Estonia, Hungary, Ireland, and Portugal

Targeted Segments	*AT*	*DK*	*EE*	*HU*	*IE*	*PT*
Low-income	x	x	x	x	x	x
Energy Poverty	x			x	x	x
Dwelling Type	x		x	x		x
Tenure Type			x	x	x	x
Geographic Location			x	x		x
Energy Source/System				x		
Elderly		x		x	x	x
Chronic Illness					x	x
Household composition				x		

Of the targeted segments, low-income is mentioned the most. Four of the six countries target households by their tenure type and/or the type of dwelling they live in. Only three of the six countries target segments that are experiencing energy poverty. In the case of Denmark, this could be since energy poverty is not recognised as a type of vulnerability on its own and instead treated as part of general social hardship. Households in particular geographic locations were also mentioned in 3 of the 6 strategies. In Hungary and Estonia this referred to smaller settlements outside of large urban areas. In Portugal it referred to "degraded zones" or those classified under the urban rehabilitation area classifications (LTRS of Portugal p.61, 2020). The elderly were also specifically mentioned in three of the countries. Meanwhile, chronic illness and the type of energy source or system used were each only mentioned in one country's strategy. Since Hungary has a significant group of solid wood fuel users, it is reasonable that they have a special program for this group. A detailed description of the vulnerable segments targeted in the LTRS can be found in the appended paper (see Appendix A, Section 4).

Table 4 Renovation Measures and Supporting Policies for Vulnerable Segments. Data Source: 2020 LTRS of Austria, Denmark, Estonia, Hungary, Ireland, and Portugal.

Country	*AT*	*DK*	*EE*	*HU*	*IE*	*PT*
Efficient Energy Systems	x				x	x
Replace inefficient appliances	x					x
Switch Energy Source				x		x
Façade Insulation					x	x
Replace windows and other minor works					x	x
Subsidies, Bonuses and Allowances	x	x	x	x		
Energy Consultation	x					
Benefits for the Sponsor	x					
Renovation Programme					x	x
Fuel Distribution Programme				x		

Four countries provide some form of subsidy, bonus or allowance to cater to the renovation needs of vulnerable households. Only Ireland and Portugal highlight mention renovation programmes for vulnerable households, highlighting that the underlying poor building conditions are less favoured than temporary measures to ease household expenditure on energy. Energy consultations are included alongside subsidies, bonuses or allowances in Austria and Denmark. Reinforcing the emphasis on short-term solutions in relation to vulnerable households. In terms of renovation measures mentioned for vulnerable households, making energy systems (including ventilation) more efficient and switching energy sources are the two most common ones across the 6 countries. This is followed by replacing inefficient appliances and façade insulation. More minor works are only included in Ireland and Portugal's strategies.

6. Discussion

Characterising household renovation needs at a national level across the EU, investigating the renovation priorities of six EU Member States in relation to vulnerable households, and comparing them to each other highlight three main findings.

1. Countries with different socio-economic and geographic characteristics that are not typically grouped together show similarities in terms of building and technical energy conditions (France, Croatia, Italy, Hungary, Bulgaria, and Romania)
2. Considering targeted segments, renovation measures, and supporting policies together help reveal divergent approaches to addressing the needs of different vulnerable groups.
3. Addressing renovation needs of vulnerable households facing chronic illnesses in Estonia has been identified as a gap in policy

6.1 Addressing Research Questions

The main research question guiding the licentiate thesis is "To what extent do long-term renovation strategies of EU Member States align renovation priorities with the needs of vulnerable households?".

6.1.1 Characterising Renovation Needs of Vulnerable Households

Characterising household renovation needs in the EU through country clusters that position the needs in 27 Member States relative to each other is useful in understanding shared patterns of renovation needs that transcend conventional geographic and socio-economic groupings, enabling more context-appropriate comparisons and policy responses.

The research question seeks to characterise renovation needs in terms of "vulnerable households". The approach adopted in the appended paper focuses on households at risk of poverty in relation to conditions faced by the general population, showing the distinct needs of the households at risk of poverty (see Appendix A). While this approach characterises the needs of a segment of households that is undeniably vulnerable to energy poverty and poor housing conditions, it reduces "vulnerability" to a single dimension of income below 60% of national median income. Given that issues like an ageing building stock in the EU as well as energy poverty is becoming an increasingly widespread issue, Kikstra et al., (2021) calls for adjustive measures to create equitable outcomes for all members of society, regardless of their socio-economic status. The hierarchical clustering analyses, therefore, present a broader view of what kind of conditions households in different Member States are vulnerable to.

The standardised and consistent nature of the data collection allows for comparison both across countries and over time in most cases. However, since this data is based on aggregated indicators, they do not present an in-depth understanding of the severity of the issues being experienced do not help to identify vulnerable and target vulnerable households (Castaño-Rosa et al. 2020). Croon et al., (2023) critique the use of only headcount statistics to map energy poverty, highlighting that the omission of indicators that measure intensity and inequality means that the available data is only useful in evaluating the effectiveness of policies for households around the poverty line. Changes in the conditions of already poor households go undetected by indicators that only measure the incidence of energy poverty. A similar critique can be made of the incidence indicators measuring the number of renovation measures in the 2023 EU-SILC module on household energy efficiency. In the case of renovations, it is even more important to understand the "depth" of the measures or how much energy efficiency was improved as opposed to the number of renovation measures which can only serve as a rough proxy to understand improvement in energy efficiency. Therefore, multiple indicators need to be used to gain a holistic understanding of renovation needs.

While other similar studies cluster EU Member States in terms of levels of vulnerability, this thesis shifts the focus to clusters based on dominant qualities of renovation needs. Recalde et al. (2019) conduct a hierarchical clustering analysis of the 27 EU Member States according to "structural energy poverty" which they define through an index of indicators that quantify conditions such as long-term unemployment, annual electricity switching rate. Their study resulted in 4 clusters of countries that ranged from low structural vulnerability. Denmark, Netherlands, and Sweden were in the cluster with lowest structural vulnerability followed by UK, Ireland, Belgium, France, Finland, Austria, Germany, and Luxembourg in the second cluster with lower structural vulnerability. Bulgaria, Romania, and Greece were in the cluster with the highest structural vulnerability and the rest of the countries (which were from central and southeastern regions) fell into the last cluster. Their results largely align with geographic divisions and energy poverty levels. Kosowski (2025) conducts a similar study on 4 energy poverty-related indicators, ending up with 8 clusters that are also organised into level of risk. Key shifts include Poland's transition to a lower-risk cluster and Spain's move to a higher-risk group, while Southern Europe generally remains highly susceptible. Fernández Fernández et al. (2024) show in their clustering analysis that countries with lower inequality have higher energy efficiency but higher final energy consumption per capita. Halkos et al. (2025) find that northern countries show low convergence while southern countries show high convergence. The indicators they use to conduct the HCA are largely related to societal conditions and do not include factors like building age, energy systems, or energy sources. This could explain why the clustering results differ slightly to the clustering based on renovation needs.

Clustering of EU Member States have been investigated in the field of critical housing studies. Kemeny's (2006) welfare-housing regimes derived from Gøsta Esping-Andersen (1990) theory of welfare regimes. This clustering method alongside geographic locations, was used to sample the countries for studying renovation priorities for vulnerable households in the 2020 long-term renovation strategies. A more detailed discussion of how the results of the analysis relate to the housing-welfare regimes can be found in the appended paper (see Appendix A). The diverse conditions experienced by vulnerable households in addition to the diverse approaches to renovation policy priorities meant that the countries could not be categorised in terms of their housing and welfare regimes. This also implies that these results cannot be easily generalised to represent other countries with similar housing and welfare systems.

6.1.2 Framework for Renovation Priorities

A systematic understanding of renovation priorities requires considering not only which households are targeted but also the renovation measures and supporting policies associated with those groups. There are two main elements to the research question on forming a systematic understanding of renovation priorities in relation to vulnerable households. The first is identifying the renovation priorities in relation to vulnerable households and the second is forming a systematic understanding (as opposed to an ad-hoc one). Renovation priorities described in long-term renovation strategies in relation to vulnerable households are identified by focusing on parts of the strategy that explicitly mention vulnerability-related terms. Using comprehensive search criteria that included multiple dimensions of vulnerability such as energy and health related terms ensured that the analysis moved beyond a narrow focus on energy poverty.

Renovation priorities in relation to vulnerable households were identified by breaking down the segments that each of the studied six EU Member States targeted households. While income level was a factor in all the countries studied, often a combination of other factors such as dwelling, tenure, old age, household composition and in the case of Hungary, even the type of energy source and system were factors in how renovation strategies targeted vulnerable households (see chapter 5, Table 3). Fizaine & Kahouli, (2019) especially criticise the use of expenditure thresholds such as the one use in the Hungarian energy price cap programme. Weiner and Szép (2022) conducted a more detailed analysis and suggested that the inclusion of the programme in Hungary's LTRS was in part a tokenistic response to the European Commission's requirement that Member States identify measures to alleviate energy poverty. They proceed to show that the utility programme was indeed conflicting with the push for a fuel switch (encouraged through the socio fuel scheme) (Weiner & Szép, 2022). Therefore, identifying the policies used to support the implementation of the technical measures enables evaluation of how much the renovation needs of vulnerable households are recognised.

Although energy efficiency and building emissions are often framed as a climate issue, the need to improve environmental performance is essentially a long-term requirement to sustain human life and can therefore also be considered an indirect or long-term "renovation need" for households. Reducing emissions from buildings becomes a more urgent need when they directly impact (i.e. direct emissions from on-site combustion) the living conditions of households. This is why indicators on emissions were included in the quantification of household energy renovation needs.

The proposed analytical framework connects policy priorities with buildings, households and renovation measures, allowing comparisons across countries. It also applies the multi-level framework introduced in (see Chapter 3, Figure 2), to the case of energy renovations by tying together actions in the policy sphere to the physical building and energy systems, households, and renovation measures. Application of the framework shows which conditions in the current socio-technical regime hinder a just transition to a decarbonised residential building stock.

The second part of forming a systematic understanding involves having an EU level perspective that includes all Member States. Although the results show the specific priorities of the six EU Member States, they are aggregated and categorised in a manner that allows for comparison between countries, contributing to a systematic understanding. A systematic understanding implies knowledge not merely of specific instances of priorities but also a structured understanding of the different factors involved and how they compare across the EU. In this regard, the thesis has started forming a systematic understanding by developing a framework. However, the systematic quality of the conclusions would be further strengthened by extending the analysis to all 27 EU Member States.

On an EU level, Bertoldi et al., (2025) suggest 3 approaches to identifying housing segments to prioritise for renovation. The first approach is to focus on older building stock occupied by low-income households, and especially those owned by a single social housing provider to maximise the co-benefits of energy efficiency and energy poverty alleviation. The second approach is to identify other trigger points for renovation during which energy efficiency measures can be incorporated. The third approach is to identify areas where district-level renovations can be implemented. However, as shown in the state of the art, using broad criteria like social housing to implement large scale renovations can have unintended consequences on vulnerable households.

Several studies have investigated multiple criteria decision-making methods to choose renovation measures across different countries, tenure, and dwelling types showing different ways to prioritise the positive social impact of renovations. On a national level, Nicolas & Molina-Costa (2021) propose a framework of identifying homogenous buildings and similar socio-economic profiles of residents to undertake district renovations. Meanwhile Camporeale & Mercader-Moyano (2021) developed a GIS-based methodology prioritise buildings for district renovations based on potential for energy flexibility. These approaches are in line with recommendations from the European Commission and provide more nuanced prioritisation criteria that recognise specific conditions faced by households. On a portfolio level, Serrano-Jiménez et al., (2021) and Khadra et al. (2020) include social aspects related to the renovation process and not just its final impacts in their prioritisation framework but choose different aspects to focus on. While Serrano-Jiménez et al., (2021) consider rent increases, uncertainty in the process and the quality of information and communication plans, Khadra et al. (2020) consider factors such as relocation rate, noise and disruption levels. While long-term renovation strategies mention mitigating rent increases, they do not use such criteria to prioritise segments for housing renovation. Instead, measures aimed at vulnerable groups rely on the potential reduction of energy bills from reduced energy consumption and improved comfort to support the households. This is probably because at a larger national or EU scale, more granular identification criteria can be too resource intensive to apply and may rely on data that is not available.

6.1.3 Extent to Which Renovation Needs are Addressed

The comparison between statistical indicators and national renovation strategies (see Appendix A, Section 4) shows that targeting low-income households is a necessary but insufficient condition to identify vulnerable households and that vulnerability indicators should be used to understand different renovation needs rather than being solely as eligibility criteria.

The cases of Estonia and Portugal when compared to the Ireland reveal a policy dilemma between targeting hard-to-reach vulnerable groups and maximising renovation rates. Both Estonia and Portugal prioritise measures for a large portion of their building stock since they have relatively widespread issues of mould (Portugal) and ageing buildings (Estonia and Portugal) as seen from the clustering exercises (see Appendix B). They have therefore outlined the mobilisation of renovation across the national building portfolio that aim for fundamental and long-lasting change especially since the socio-demographic characteristics of households change more quickly than the conditions of buildings. Estonia has stated multi-family housing as its initial focus whereas almost all housing is included in Portugal's strategy.

The lack of renovation measures planned for housing occupied by vulnerable households confirms that the policies are often monetary or in the case of temporary fuel handouts to households in Hungary. Only Portugal and Ireland have renovation programmes. The subjective nature of comfort means that indoor environment quality is perceived differently by households than what standards determine. This acts as a barrier to undertake renovations which are seen as more disruptive and uncomfortable than a sub-optimal indoor comfort level (Essien-Thompson et al., 2026). Penna et al., (2015) also found that indoor environment comfort and energy efficiency can be conflicting when economic feasibility is required.

This could partially explain why financial assistance is favoured over comprehensive renovation programmes for vulnerable households but also raises the question of whether and in which cases renovations are a burden rather than a need. In Denmark, where the main issue is high costs (as shown by their relatively higher housing cost overburden rate), monetary assistance is the policy measure used to support vulnerable households. Their target group (pensioners) is also less likely to be willing to accept renovation measures due to the long payback times of measures which may exceed their lifetime. Therefore, in this case wouldn't monetary compensation be the best way to address their needs? The issue with this approach arises when the conditions that create vulnerabilities are not just tied to the income of a household but also to the heating system that is shared by all households in a building. Monetary compensation for high costs from gas-fuelled central heating systems which are more susceptible to global price hikes (especially, under current geo-political tensions between the US and Iran), act as disincentives for elderly from consenting to renovation projects. At the same time, a household that does not meet the criteria for heating assistance but still faces high costs is disadvantaged due to the split incentives. The resistance to renovation measures then has long-lasting consequences. An alternative could be to make the targeted monetary compensation dependent on participation in a renovation project.

The method used in this thesis to evaluate the alignment of renovation priorities and needs in relation to households is useful as a diagnostic tool. Even if vulnerable households are appropriately identified and targeted, the specific mechanisms of the targeting and types of policies differ and need to be discussed in depth to truly evaluate their fairness. The analysis would also be strengthened if it is extended to all 27 EU Member States and as was done in this discussion chapter, corroborated with more up to date information on policy implementation. The extent to which long-term renovation strategies contribute to a just green transition is analysed through a focus on how renovation needs of vulnerable households are addressed, in other words, the recognition justice aspect of a just transition. The analysis of statistics on renovation needs and long-term renovation strategies aims to describe and reflect on unfolding patterns of change in the conditions that create unjust renovations, following one of the just transition research approaches described by Loorbach et al. (2017).

6.2. Contribution of Research Findings

This thesis makes academic contributions to the fields of just transition research and renovation research. Furthermore, the findings contribute to policy by identifying areas that need to be addressed in different EU countries. Practitioners can also benefit from the insights on which technical measures are supported by policies, which housing segments they are targeted at as well as what the implication of the technical measures on households that experience vulnerability.

6.2.1. Academic Contributions

The thesis contributes to the field of energy justice by characterising household renovation needs through a set of quantitative indicators. The concept of renovation needs is used to expand the concept of energy needs to include building and energy systems. This reframes the issue from a purely social one to emphasise the role of technical systems (refer to Jason Hicks) in creating needs.

Similarly, showing which segments and measures are targeted by national renovation policy helps to ground abstract regulations in the material conditions and link it directly to the built environment. Such a framework provides a systematic understanding of renovation policy priorities at a national level in the six countries studied and a method to understand the priorities which can be applied to the other EU Member States. This provides researchers in the built environment a better understanding of which renovation measures will be more relevant to research in different housing segments or European contexts. Ultimately, these two contributions strengthen methods of evaluating the social sustainability of renovations which was identified as a gap by Jensen at al. (2018).

The thesis also contributes to the field of energy justice by identifying the specific areas in which the needs of households are not addressed by national renovation policies, highlighting aspects of recognition justice that can be improved in energy renovations.

6.2.2. Implications for Policy

This thesis also highlights the conflicts and gaps between national renovation priorities and household renovation needs in the six EU Member States.

Dedicated funds have been established from carbon tax revenues to reduce inequalities between EU countries and especially to support vulnerable households. By showing what the renovation needs are of vulnerable households in different countries, this research allows for evaluation of the just transition fund and the upcoming social climate fund.

The recently published affordable housing plan by the European Commission highlights four main priorities, which are protecting the most affected, boosting the supply of affordable housing, mobilising investment as well as support and reform policy measures. The housing task force, which oversees the affordable housing plan is currently collecting evidence to identify the areas of housing stress. Areas of stress are typically identified in general housing reform in terms of income, rental prices, and overcrowding but do not include building conditions.

Evaluation of the 2020 long-term renovation strategies sets a baseline for evaluation of the upcoming National Building Renovation Plans. The structured analytical framework of renovation priorities can be applied to the content of the National Building Renovation Plans even though its structure differs slightly from the long-term renovation strategies.

6.2.3. Implications for Practitioners

Practitioners involved in the planning of renovation measures can use the characterisation of renovation needs to better understand what technical measures would serve different housing segments. They can also use the framework of renovation priorities to grasp how the various levels of housing segment, renovation measure, and policy are interconnected in national building stocks. In other words, by linking policy, and housing segments to technical renovation measures, the analysis of long-term renovation strategies inform housing practitioners on how the renovations they plan are influenced by policies as well as how this may impact vulnerable housing segments. They also help identify housing segments that are overlooked by policies.

6.3 Limitations

This thesis relies predominantly on secondary data sourced from databases and strategic documents. The indicators presented in the databases are aggregated in ways that are generally useful for research on vulnerable groups and housing renovations. However, it is more limited than using primary data that is collected based on questions specific to investigating renovation needs. The series of cluster analyses conducted using the broad range of indicators demonstrate the areas of similarities and differences in renovation needs across the EU. The same renovation measures applied within a single cluster of countries will still result in varied outcomes for vulnerable households. However, by knowing the similarities and differences in different EU states helps clarify between which countries, certain renovation policies might be more transferable.

The renovation needs of households are shown through the chosen indicators. They are effective in showing incidence of these needs but do not show their intensity. Since the seminal contributions of Sen (1976), it is widely believed that poverty measurement should be decomposable into three orderings: incidence, intensity, and inequality. Not all needs can be operationalised using available data.

The long-term renovation strategies are also limited in providing insight into actual renovation conditions on the ground since they are official documents developed through consultation with a limited sample of experts. It is more useful in providing insights into the governance of building renovations on a national scale. There are also limitations in using a strategy document that was drafted before the more recent crises of the past few years, but the value of this analysis becomes stronger when it is compared to the recently submitted national building renovation plans. Moreover, the qualitative content analysis in this study, although it is documented to ensure replicability, is inevitably influenced by the author's interpretation. Since most of the author's background knowledge on renovation policies across the 27 EU Member States is derived from desk research, it is highly influenced by the European Commission's priorities and framing of the issue. To validate this interpretation, key informant interviews with representatives across the EU would be useful.

The method of qualitative content analysis used to study renovation priorities in the long-term renovation strategies is not a comprehensive or exhaustive method to identify gaps in addressing the household renovation needs of vulnerable households. Since the coding process is subjective to some extent, other researchers may not develop the same themes that were developed in this study.

7. Conclusions and Future Outlook

This thesis departs from the position that the largely disconnected nature of research on energy systems, socio-economic aspects of housing conditions and building renovations contributes to policies which have unintended consequences on the most vulnerable households. The thesis frames renovations as a multi-level issue that has immediate consequences for households and indirect implications on a societal level, especially considering the geopolitical events of the last 5 years that placed stress on energy systems globally. It shows how extensive research across the EU on mobilising renovations on a building stock scale has resulted in innovations in energy efficiency improvements, planning support, identification of cross-sectoral barriers and unintended consequences of renovations but still requires further research on systematically understanding the specific renovation needs of vulnerable households. Through a mixed-method methodology, combining hierarchical clustering analysis of indicators showing renovation needs and document analysis of long-term renovation strategies, it proposes analytical frameworks that show the nature of renovation needs systematically and help evaluate how well renovation priorities address these needs. The findings highlight that building and energy conditions are similar in countries with different socio-economic and geographic characteristics that are not typically grouped show similarities in terms of building and technical energy conditions (France, Croatia, Italy, Hungary, Bulgaria, and Romania), serving as a reminder that we should not default to typical geographic groupings when investigating the transferability of renovation policies. They also identify cooling measures, rural areas, and people facing chronic illnesses as overlooked aspects in long-term renovation strategies.

7.1 Future research

By profiling technical conditions (e.g. buildings, energy systems, climate) in relation to socio-economic factors associated with vulnerability in 6 EU Member States, this thesis provides evidence on the nature of renovation needs of vulnerable groups in these countries. This analysis should be expanded to all 27 countries. Analysis of long-term renovation strategy documents highlight in what way renovation needs of vulnerable groups are addressed. Through triangulation of both quantitative and qualitative data, the thesis highlights gaps between renovation needs of vulnerable households and national renovation priorities. The predominantly descriptive work conducted provides a valuable overview which can be used to identify housing segments potentially overlooked by policy and develop tailored renovation strategies for these segments that will contribute to both alleviating energy poverty and decarbonising the residential building stock.

As mentioned previously, gaining a systematic understanding of the priorities set in the 2020 LTRS, sets a baseline that is useful especially when compared to the latest strategy documents, the National Building Renovation Plans. Comparing the two documents using the framework of priority segments, measures, and policies, will help evaluate whether priorities have changed in relation to vulnerable households.

Moreover, the thesis introduced the analytical term “renovation needs” and operationalises it through the analysis of EU-level data. It also proposes an analytical framework of priority concerns, segments, measures, and policies to study long-term renovation strategies. Both the term and analytical framework could be further developed and validated in other contexts and using other data sources.

The two main methods that have been applied in thesis are statistical analysis and qualitative content analysis. Since the purpose of the statistical analysis was to characterise renovation needs, the descriptive statistics and cluster analysis were used. However, more focused studies on correlations between technical conditions such as energy systems, renovation measures carried out in recent years, building age and socio-economic factors such as high energy consumption and inability to keep home adequately warm could be conducted to understand the specific relationships between technical factors and energy poverty. In this study, only data from the year 2023 were used to simplify the harmonisation process required to profile national renovation needs. Analysis of the various factors over time could be better indicative of future trends and provide more future-oriented understanding of country profiles.

The data used for the statistical analysis was primarily based on aggregated statistics which limits how various housing segments that can be analysed. Micro-data can be used to analyse the various conditions mapped in this study in terms of tenure or dwelling type which may allow for more stream-lined clusters to be formed with clear segments to be targeted.

Other qualitative methods that could have provided insights into both the technical and socio-economic conditions faced by vulnerable households in the EU include meta-analysis of completed pilot renovation projects. Similarly, focus group sessions with representative housing practitioners across the EU could provide more first-hand perspectives of renovations for vulnerable households that are missed in official strategic documents such as the long-term strategies

While this thesis identifies renovation policy gaps across the EU, it does not recommend how to address these gaps. Further research is needed to investigate the possible strategies that could help address them. Targeted support for vulnerable households covered in the LTRS include, subsidised or completely free energy advice services, appliance replacement schemes, energy renovations. There is growing interest in new roles of specialised support such as energy coaches (Van Der Wal et al., 2025) and local energy champions (Ebrahimigharehbaghi et al., 2022). The impact of these emerging roles is yet to be studied in different national contexts.

The characterisation of household renovation needs in the EU can be further developed into typologies of renovation need. A typology is "a hierarchical system of categories used to organise objects according to their similarities and dissimilarities" (Mandara, 2003, p. 132). A preliminary typology of vulnerable housing segments was developed to illustrate patterns and groups from the rich and diverse data on renovation needs that was previously mapped. Typology development is commonly used in architectural research to group buildings according to common characteristics that guide how they should be handled for different purposes. In this case, although the Tabula [20] typology exists for the European building stock, it focuses on energy consumption and climate profiles to guide energy renovations from a purely technical perspective. It does not consider the households that occupy these buildings. On the other hand, analysis conducted on vulnerable groups tend to be based primarily on demographic characteristics such as age, gender or household composition. Some studies on vulnerable households using EU-SILC data distinguish between multi-family housing and single-family housing which considers the building type to some extent (Karpinska & Śmiech, 2024; Mangold et al., 2018). The aim of developing a new housing typology would be to further integrate the analysis of the physical buildings with both the energy systems that power them and the vulnerable households occupying them in relation to guiding renovation measures.

In the second stage of this thesis, there are some lose ends that remain open in the current studies including the preliminary hierarchical cluster analyses conducted that could be tied. More detailed sensitivity analyses would show how different factors influence clustering results. If more disaggregated data was available, the indicators analysed could focus on low-income or other vulnerable groups.

Another lose end to tie would be extending the analysis of long-term renovation strategies to 27 EU Member States and comparing them to the 2025 National Building Renovation Plans. The results from these analyses can then be used to conduct focus group sessions on addressing renovation needs with experts in several countries across the EU, potentially sampled from the most appropriate clusters from the clustering analyses conducted.

Based on the focus groups, tailored renovation solutions for vulnerable households through more in-depth studies of renovation programmes could be conducted. This would involve collecting primary data including both quantitative and qualitative data.

This thesis contributes to advancing the understanding of renovation needs by bringing together perspectives that have traditionally been studied separately. Through the development of analytical concept of renovation need, framework of renovation priorities, and empirical evidence, it demonstrates the value of integrating technical and socio-economic dimensions when assessing residential renovation priorities. It is hoped that this work provides a foundation for future research and supports the development of more tailored, just, and effective renovation policies across Europe

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