Updating the energy poverty and energy efficiency framework in rural areas across the EU

Deliverable 2.1

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About RENOVERTY

RENOVERTY will foster energy efficiency building upgrades in the Central and Eastern Europe (CEE), South-eastern Europe (SEE) countries, as well as Southern European countries (SE), by setting the methodological and practical framework to build renovation roadmaps of vulnerable rural districts in a financially viable and socially just manner.

Specifically, the project aims to deliver tools and resources to support local and regional actors to build and execute operational single or multi-household roadmaps for rural areas. A scalable model will also be created to ensure the wide geographical replicability and implementation of the roadmaps by different actors at the EU level. Strategically, the project will contribute to minimising logistical, financial, administrative, and legal burdens caused by a complex and multi-stakeholder home renovation process. Additionally, RENOVERTY will ensure that building retrofits consider the social dimension by incorporating security, comfort, and improved accessibility in the roadmaps to further improve the quality of life of vulnerable populations.

Over the project's three years, seven pilots located in Sveta Nedelja (Croatia), Tartu (Estonia), Bükk-Mak & Somló-Marcalmente-Bakonyalja Leader (Hungary), Zasavje (Slovenia), Parma (Italy), Coimbra (Portugal), and Osona (Spain) will implement the roadmaps, while wider integration of rural and peri-urban development is foreseen in the long run.

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List of Abbreviations

ANAH	Agence Nationale pour l'Amélioration de l'Habitat
AS	Accessibility Score
CCAS	Caisse centrale d'activités sociales
CDD	Cooling Degree Days
CEE	Central Eastern Europe
CE	Central Europe
CEPTI	Composite Energy & Transport Poverty Indicator
CSCO	Carbon Saving Communities Obligation
CWE	Central Western Europe
EC	European Commission
ECO	Energy Company Obligation
EPAH	Energy Poverty Advisory Hub
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificates
EPEEF	Environmental Protection and Energy Efficiency Fund
EPVI	Energy Poverty Vulnerability Index
ERESEE	Spanish Urban Agenda
EU	European Union
GDP	Gross Domestic Product
HDD	Heating Degree Days
HEEPS	Home Energy Efficiency Programs for Scotland
IDAE	Institute for Energy Diversification and Saving
INE	National Statistical Institute
JAC	Just a Change
LAU	Local Administrative Unit
MIS	Minimum Income Standard
NE	Northern Europe
NGO	Non-Governmental Organisation
OPAH	Opération programmée d'amélioration de l'habitat
PCE	Per Capita Expenditure
PREE	Aids Program for Energy Retrofit of Existing Buildings
REER	Rural Energy Efficiency Roadmap
RES	Renewable Energy Sources
SAS	Société par actions simplifiée
SE	Southern Europe
SEE	Southern Eastern Europe
SSC	Strompar Check
UK	United Kingdom
WE	Western Europe
WP	Work Package

Executive summary

Energy poverty is a complex and multidimensional phenomenon caused by various factors. It is defined as a situation in which households are unable to access essential energy services and products. Despite widespread recognition and discussion of the topic, there are still several gaps in knowledge and practice. One aspect of energy poverty that remains largely unexplored in Europe is rural energy poverty, receiving limited attention despite being more prevalent than in urban contexts. Additionally, in the pursuit of a clean and just transition, rural areas in Europe are often left behind, even though rural populations are at a significantly higher risk of facing poverty and social exclusion. This phenomenon is particularly pronounced in Central and Eastern Europe (CEE), Southern Eastern Europe (SEE), and Southern Europe (SE) countries, where populations are more susceptible to energy poverty.

This report follows a multi-step approach with the objective of addressing this gap and upgrading the framework on rural and peri-urban energy poverty. It consists of a summary of extensive desk research in which more than 80 relevant scientific and grey literature sources are analysed to review current knowledge and practices in energy poverty research and policy in rural and peri-urban areas. The outcomes of the literature review were utilised to formulate an online survey of relevant stakeholders to obtain broader insights into existing needs, barriers, and proposed solutions for the implementation of policies for energy efficiency in vulnerable rural and peri-urban areas. The acquired insights feed into the development of the Composite Energy & Transport Poverty Indicator (CEPTI) to provide a practical tool for identifying areas more highly exposed to energy poverty and offering an approximation of the experience of those affected by energy and transport poverty. Furthermore, a set of energy audits was conducted in the pilot regions of RENOVERTY to identify the distinct characteristics of dwellings found within rural and peri-urban areas of Europe.

This document presents the main outcomes of RENOVERTY activities which aim to provide a robust, holistic and up-to-date framing of rural energy poverty in the European Union (EU). This information informs relevant stakeholders regarding the specific characteristics of rural areas when it comes to energy efficiency and energy poverty and assist subsequent activities of the project that seek to enhance the uptake of energy efficiency and address energy poverty in rural contexts.

1 Introduction

In the latest European Commission (EC) recommendations, energy poverty is defined as a situation, in which households are unable to access essential energy services and products, thus affecting health, living standards and the levels of heating, cooling, and lighting of homes [1]. Moreover, energy poverty is a complex and multidimensional phenomenon, caused by various factors, such as low income, high energy and fuel prices and their volatility, inefficient buildings and appliances, geographic and climate factors, gender, family composition, health, household energy and transportation needs, etc.[1], [2].

While the subject of energy poverty is widely recognised and discussed, there are still several gaps in knowledge and practice [3]–[5]. These gaps are greater, particularly in the case of rural areas. Rural energy poverty has received limited attention within Europe, despite the fact that it is more prevalent than in urban contexts [6]–[8]. While relevant information on the overall levels of energy poverty in Europe is available via the European Union (EU) and national statistical agencies, there is limited data on the character and extent of end-use energy injustices faced by rural communities [9], [10]. Most policy actions and interventions to address issues of energy poverty, energy efficiency and building renovations in the housing stock have been concentrated in urban areas, where economies of scale (i.e., a decrease in the average cost of renovations when the number of renovations is increased) and economies of scope (i.e., a decrease in the average cost of a renovation when simultaneous interventions are implemented) can be achieved due to the greater concentration of people and housing [11]–[15].

Therefore, there is a substantive body of evidence to suggest that rural areas in Europe are left behind in the efforts to achieve a clean and just energy transition, even though rural populations are at a significantly higher risk of facing poverty issues. In addition, this situation is particularly pronounced in the case of Central and Eastern Europe (CEE), Southern Eastern Europe (SEE) and Southern Europe (SE) countries, where populations are highly exposed to energy poverty [16], [17].

In this context, this report aims to address this gap and update the energy poverty framework on rural and peri-urban energy poverty. The report provides a comprehensive overview of (i) the characteristics of rural areas, (ii) the status of energy poverty and its special driving forces in such contexts, (iii) the current relevant policy landscape at the European level, and (iv) the structural factors, which function as barriers to and solutions for the successful implementation of energy efficiency policies for the alleviation of energy poverty in rural areas. It serves as a basis for the development of a methodological framework that will support the identification of energy poor households in rural areas, mainly through the development of an indicator that captures effectively rural energy poverty.

To do so, a multi-method approach is applied by first conducting an in-depth review of academic and grey literature, followed by a European-wide survey to generate primary data on stakeholder needs and viewpoints for the development and implementation of energy efficiency policies, measures, and roadmaps in vulnerable rural and peri-urban areas in CEE, SEE, and SE. The first two steps are coupled with the development of the Composite Energy & Transport Poverty Indicator (CEPTI), which works as a tool for the identification of rural areas vulnerable to energy poverty and allows for the systematic assessment of energy poverty in rural areas across the EU. Finally, the last methodological step concerns the conduction of energy audits in real households exposed to energy poverty in seven CEE, SEE, and SE countries (i.e., Croatia, Estonia, Hungary, Italy, Portugal, Slovenia, and Spain) to gain a more detailed overview of the unique characteristics of dwellings in rural areas of differing geographies and climates.

Overall, this work aims to (i) set the ground for RENOVERTY activities which seek to foster energy efficiency building upgrades in CEE, SEE, and SE countries by setting the methodological and practical framework to develop Rural Energy Efficiency Roadmaps (REERs) for vulnerable rural districts in a financially viable and socially just manner, and (ii) provide key implications, which, if acted upon, could accelerate the deployment of energy efficiency policies and the alleviation of energy poverty in rural areas sector across Europe.

2 Methods

To upgrade the framework of energy poverty in rural and suburban communities, we use a multi-method approach based on extensive desk research, an online survey to collect data from a large sample of field experts, the development of an indicator to effectively identify areas highly exposed to energy poverty and a series of targeted energy audits to provide a comprehensive assessment of the specificities of rural dwellings, with a special focus on dwellings used by vulnerable population. The overarching methodology of this report is depicted in **Fig. 1.**

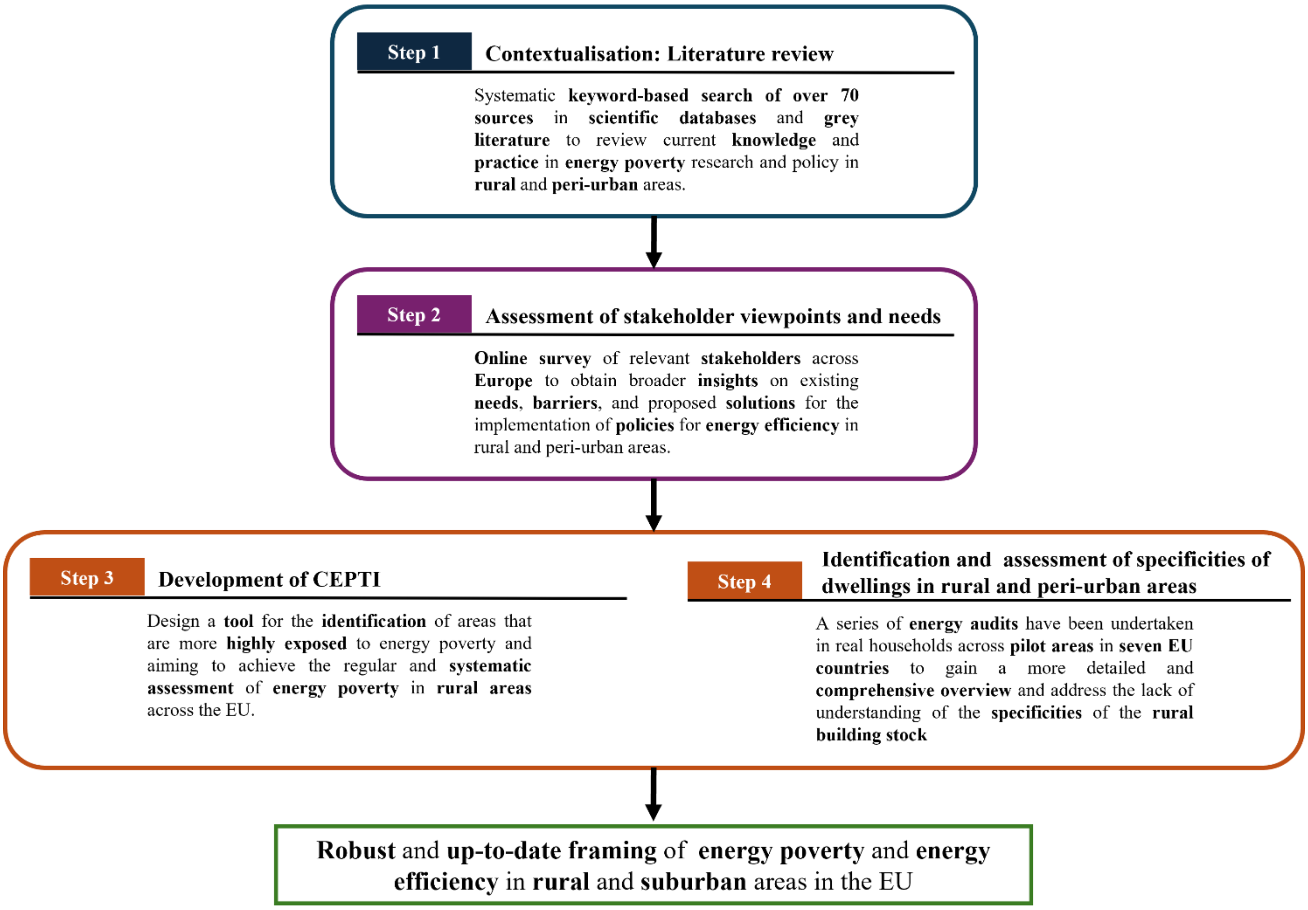


Fig. 1. Overview of the multi-method approach applied in the context of this study.

2.1 Step 1: Contextualising energy poverty and energy efficiency in rural and peri-urban areas

Extensive desk research of more than 80 relevant scientific and grey literature sources has been conducted to review current knowledge and practice in energy poverty research and policy in rural and peri-urban areas. To extract useful information from the literature, a keyword-based search of energy peer-reviewed journal articles in the "Science Direct" and "Google Scholar" databases was conducted, using relevant search keywords e.g., "energy poverty", "energy vulnerability", "energy efficiency", "policies", "barriers", "solutions", "rural areas", "rural specificities", "Europe", "European Union", "EU", etc., separately, or in different keyword combinations. For grey literature sources, the search was based on position papers and relevant technical reports. In the context of recording and assessing existing energy poverty and/or energy efficiency policies in rural areas, databases like "ODYSEE-MURE[1]" were used, while experts pertaining to the consortium were asked to provide their knowledge around relevant policies in the contexts of the project's countries. The findings of the desk research, which can be found in **Section 3**, allowed us to create the survey that was used in the next step and provided the foundation for the development of the methodological framework to identify rural energy poverty.

2.2 Step 2: Assessment of stakeholder viewpoints and needs

Between May to July 2023, an online survey of relevant stakeholders across Europe was conducted to validate our preliminary findings and obtain broader insights on existing needs, barriers, and proposed solutions for the implementation of policies for energy efficiency in vulnerable rural and peri-urban areas. The survey was titled "Survey on energy poverty and the implementation of energy efficiency policies in rural areas across the EU" and was divided into four sections, namely **A**, **B**, **C** and **D**. **Section A** focuses on gathering information about the participants' background and their affiliation. **Section B** explores the participants' experiences and opinions regarding energy poverty in rural contexts. **Section C** delves into barriers related to the implementation of energy efficiency measures in rural contexts. **Section D** focuses on recommendations about policies and measures to support energy efficiency investments and development in rural contexts.

We designed the survey following methodologies used in other EC-funded projects [18]–[21]. The survey was developed in the "EUSurvey[2]" platform as a semi-quantitative questionnaire, built on the preliminary findings of the desk research. The questionnaire contained mandatory and optional questions as well as independent questions that were based on previous responses. Depending on the topics addressed in the different survey sections, we applied a variety of question formats, from single and multiple choice (respondents chose between multiple given answers, e.g., select the most relevant or correct statement, etc.) to Likert-like scales (i.e.,

[1] https://www.odyssee-mure.eu

[2] https://ec.europa.eu/eusurvey

respondents had to rank the importance of the different challenges, e.g., from “not at all important” to “very important”) and free-text boxes. All responses were either quantitative (e.g., rating of importance of barriers identified, etc.) or qualitative (e.g., free-text questions regarding solutions to address barriers to energy efficiency and alleviate energy poverty in rural contexts) and have been anonymised.

The survey population was contacted directly by RENOVERTY partners aiming to gather responses from experts working in the RENOVERTY countries, but also indirectly, through social media posts and publications on the project’s communication channels to reach stakeholders that could provide insights from other geographical regions, presenting different cultural, socioeconomic and technological conditions. Nonetheless, these were differentiated in the very first phase of the survey so as to have a clear distinction between the two. Thanks to the already-established network of RENOVERTY partners in the fields of energy poverty and energy efficiency, a wide audience with relevant expertise was reached. Moreover, social media posts greatly increased the breadth and reach of the survey, with the main social media platform utilised for survey distribution being LinkedIn. The latter differentiates itself from other social media platforms as it is targeted to a professional audience sharing content often related to the working environment. Several rounds of dissemination of the survey, both on social media and via email to the consortium’s contacts, were performed.

RENOVERTY analysed survey results in two steps. First, responses were compiled and compared quantitative responses, after which, results were complemented based on stakeholders’ direct quotes (qualitative results). One interesting observation about the survey’s qualitative results is that a significant proportion of the respondents answered the free-text questions. The latter provided us with high-grade qualitative data from relevant stakeholders and field experts regarding solutions that governmental bodies at all levels could promote to address barriers to energy efficiency and alleviate energy poverty in rural contexts.

2.3 Step 3: Development of Composite Energy & Transport Poverty Indicator (CEPTI)

Following the review of relevant literature and the finalisation of the stakeholder needs assessment facilitated via the online survey, the acquired knowledge was utilised to formulate CEPTI in an attempt to design a tool for the identification of areas that are more highly exposed to energy poverty, while aiming to achieve the regular and systematic assessment of energy poverty in rural areas across the EU. The development of CEPTI includes four steps (1: ***Data Collection,*** 2: ***Standardisation of Data,*** 3: ***Customisation for Local Contexts,*** and 4: ***Guidelines for Implementation***) and encompasses four components (1: ***Per Capita Expenditure (PCE),*** 2: ***Accessibility Score (AS),*** 3: ***Energy Consumption*** and 4: ***Vulnerability)*** to offer our approximation on the experience of those affected by energy and transport poverty. An in-depth explanation of CEPTI and indicative outcomes of its use are provided in **Section 5**.

2.4 Step 4: Identification and assessment of the specific characteristics of dwellings in rural and peri-urban areas

To gain a more detailed and comprehensive overview and address the lack of understanding of the specificities of the rural building stock, a series of energy audits have been undertaken in households across pilot areas in seven EU countries – Spain, Italy, Portugal[3], Hungary, Croatia, Estonia and Slovenia. The chosen pilot areas have diverse economic, social, and cultural characteristics, aiming to encompass a wider variety of rural energy poverty manifestations to be identified and better understood.

An energy audit is a systematic inspection and analysis of energy use and energy consumption of a site, building, system, or organisation with the objective of identifying energy flows and the potential for energy efficiency improvements and reporting them [22]. In simpler terms, energy audits provide detailed information about the energy characteristics of a dwelling, its energy systems and energy sources and provide a list of measures identifying potential for improving overall energy efficiency.

This type of information is crucial to fully understand energy poverty in real areas, as well as to be able to address the identified contributing factors to its prevalence and severity and as a final result, to be able to successfully address them. Based on the results of energy audits, energy performance certificates (EPCs) are issued for each dwelling.

While the overall approach to EPCs and energy audits is defined in the Energy Performance of Buildings Directive (EPBD) and other legislative documents related to it, the member states' approaches to EPC schemes vary. Thus, for the purpose of the pilot studies within the RENOVERTY project, a unified methodological approach was developed, described in further detail in **Section 6**.

[3] The results from the audits conducted in Portugal will be included in an updated version of this document by mid-2024.

3 The status of energy poverty and energy efficiency in rural and peri-urban areas

3.1 Rural areas in Europe – a definition

Currently, there is no global method or international standard for the delineation of urban and rural areas. Therefore, cross-country comparisons are severely hampered by the wide range of various criteria used in national definitions of urban and rural regions, highlighting the importance of a harmonised definition of these areas [23].

In this respect, the EC has developed a methodology that allows statistics to be compiled by a degree of urbanisation at the local level. The degree of urbanisation classifies local administrative units (LAUs[4]) into the following three categories:

- cities otherwise referred to as densely populated areas;
- towns and suburbs otherwise referred to as intermediate-density areas;
- rural areas otherwise referred to as thinly populated areas.

According to this classification, each LAU belongs to only one of these three categories, based on a combination of geographical contiguity and population density, as determined by minimum population thresholds applied to population grid cells of 1 km^2. A population grid cell is the basis for the degree of urbanisation classification, and it is defined as a lattice composed of 1 km^2 grid cells overlaying a particular territory, for which information is collected relating to the number of inhabitants.

Following this approach, rural areas (thinly populated areas) are defined **as the areas where more than 50% of the population live in rural grid cells**, i.e., cells outside of urban clusters/centers. Urban clusters (or moderate-density clusters) are defined as contiguous grid cells (i.e., sharing a common border) of 1 km^2 with a population density of at least 300 inhabitants per km^2 and a minimum population of at least 5,000 inhabitants, while urban centres (or high-density clusters) are defined as contiguous grid cells with a population density of at least 1,500 inhabitants per km^2 and collectively a minimum population of 50,000 inhabitants [24].

[4] Local administrative units (LAUs): a system for dividing up a territory for the purpose of developing statistics at a local level. These units are usually low-level administrative divisions within a country, ranked below a province, region, or state.

3.2 General characteristics and key challenges of rural areas

Based on the abovementioned classification, 91% of Europe's surface is considered rural, resulting in 61% of Europeans living outside of urban areas, and around 25% in predominantly rural areas, highlighting the importance of these contexts in sustaining Europe's growth [25].

As shown in **Fig. 2**, when it comes to CE, CEE, SE, and SEE the proportion of people living in rural areas varies. On the one hand, in Croatia, Estonia, Greece, Hungary, Romania, Slovakia, and Slovenia more than 30% of the population lives in rural areas. On the other hand, in Italy, Portugal, and Spain this amount is limited to under 25% of the population.

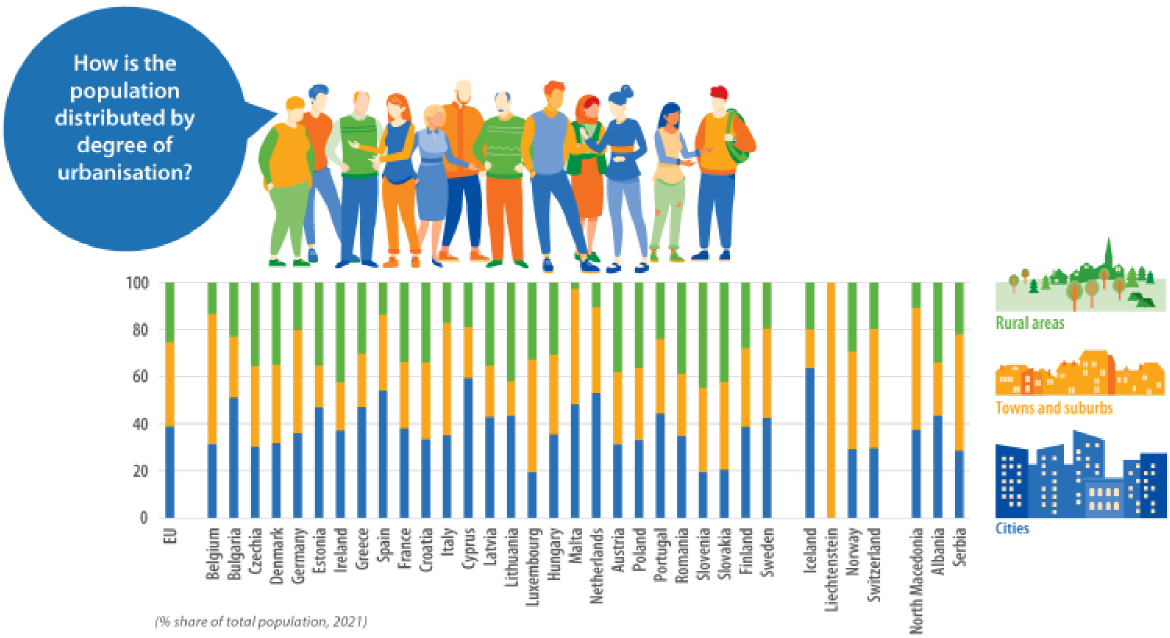


Fig. 2. The distribution of the population (%) by the degree of urbanisation in the EU [26].

Rural spaces in Europe have significantly evolved since the Second World War, and several areas show a good level of development, with limited economic lag with respect to urban areas. Nevertheless, rural poverty is still an important issue to address in terms of the economic and social growth of Europe, which is still dealing with both the problems of rural development and rural poverty [27].

As stated by the European Parliament in 2017, rural areas have not received enough attention in analysing the determinants and solutions of poverty. In the meantime, the general trend noticed in the EU Member States, is that the proportion of people at risk of poverty or social exclusion is higher in rural areas than in cities. Indicatively, in rural Romania and Bulgaria, the difference is as much as 20% [28].

The determinants of rural poverty in developed countries may be different, according to the specific condition of the country. The economic development, the infrastructural network, the extent and distribution of the population on the land, the topography and morphology of the land, the diffusion or concentration of towns and villages, and the tradition of anti-deprivation actions with respect to rural poverty are examples of very relevant factors that influence a country's rural poverty [27].

Nevertheless, the European Parliamentary Research Service has identified the main drivers of rural poverty and social exclusion that are more or less met in each European country. These are the [28]:

- **Specific demographic structures**: The rural population structure tends to include more elderly people (the share of people above 65 is usually higher than the national average), fewer people of working age and more young people aged 10 to 19. However, in many mountainous or peripheral regions of the EU, the local population has declined because of the outward migration of young people, thus presenting a greater emigration rate compared to cities.
- **Limited educational capabilities**: In many rural areas, access to education, at all levels, is less available than in cities. Many countries face a lack of preschool educational facilities for children. In addition, primary and secondary schools are frequently less accessible in terms of cost and daily commuting time. Characteristically, in the EU, **only 18.4 % of the rural population has completed tertiary education** (education for people above school age, including college, university, and vocational courses), which is around half of those that have completed it in cities.
- **Limited labour capabilities**: Generally, in rural areas, incomes are lower and there are fewer job prospects, within a narrower variety of activities, while unemployment is increasing. Young individuals, women, unskilled workers, and older people are especially at risk. Moreover, long-term unemployment rates tend to be greater in rural than urban areas.
- **Lack of infrastructure and services**: In many rural regions, certain demographic groups become more isolated as a result of inadequate transportation infrastructure, which also hinders access to jobs and the growth of social relationships. Furthermore, compared to city dwellers, rural communities are typically considerably farther away from major hospitals, as basic healthcare services are difficult to provide in regions with low demographic density.

3.3 Energy poverty in rural areas across Europe

Energy poverty is generally defined as the inability to afford socially and materially required levels of household energy services, which can affect health, social inclusion, environmental quality, mental well-being, and, productivity [29], [30]. In 2020, about 36 million Europeans were unable to keep their homes adequately warm, with the distribution of energy poverty being highly uneven, with CEE, EE and SE regions reporting the highest exposure to it [16], [17], [31].

At this moment the driving forces, aspects, and consequences of energy poverty in Europe are relatively well-known, and the EU has been addressing this issue in various legislative and non-legislative initiatives such as the Energy Efficiency Directive and EPBD, the Gas and Electricity Directives for the protection of vulnerable consumers, etc. [2]. However, this is not the case with regard to addressing energy poverty in rural areas across the EU, despite the fact that, even without considering the latest energy crisis, rural communities in many EU countries struggle with energy poverty issues to a considerably greater extent than the urban population.

Research on specific urban-rural disparities has found significant regional differences across Europe, with rural areas in CEE and Eastern Europe being traditionally much poorer and more excluded than urban contexts [32]. Southern European rural areas face similar problems. Those problems are escalated by the fact that economic differences at the urban-rural divide have been slow to decrease [33].

Given the latter, there is significant evidence to suggest that rural areas in CEE, Eastern Europe, and SE countries are significantly vulnerable to energy poverty. Sokolowski *et. al* (2020) state that multidimensional energy poverty is highest among rural households in Poland [34], while Bouzarovski and Herrero (2017) indicate that in the Czech Republic, Hungary, and Poland, there is a trend for energy poverty to be concentrated mostly in rural and peripheral regions [35]. In the case of Greece, Papada and Kaliampakos (2017) have shown that mountainous communities are extensively vulnerable to this phenomenon, mainly because of the cold climate and the generally low incomes of mountainous region residents [36]. Aristondo and Onaindia (2018) conclude that in Spain, rurality is a major factor of exposure to energy poverty [37], while according to a report by the "Future of Rural Energy in Europe" initiative, the percentage of the population that is unable to keep their home adequately warm in rural areas is greater than the national average [38]. Similar is the case of Italy, where the percentage of the population that is unable to afford to pay their energy bills in rural areas is also greater than the national average [39], while Karpinska and Smiech (2020) examine the exposure of several CEE countries (e.g., Lithuania, Estonia, etc.) to hidden poverty, verifying their significant exposure to it [7].

Nevertheless, despite these highlighted examples, scientific and policy literature poorly considers or addresses the particularities of rural areas across Europe when it comes to energy poverty alleviation. Consequently, the need for further research, investigating the specific characteristics of these areas that contribute to energy poverty, the current policy landscape regarding rural energy poverty and energy efficiency, as well as what prevents the design and implementation of energy efficiency policy measures in these contexts, is of utmost importance.

3.4 Specific characteristics of rural areas that contribute to their exposure to energy poverty

To better understand energy poverty in rural areas and investigate ways to address it, there is a great need to examine the specific characteristics of rural areas that contribute to energy poverty. Across the board, several specific characteristics of rural areas that contribute to energy poverty have been found. Physical isolation, limited economic diversity, and high rates of vulnerable populations due to lower incomes and higher poverty rates, combined with lower educational and employment opportunities and an ageing population are some of the characteristics that increase the vulnerability of rural communities [40]. Furthermore, rural households are more likely to be energy-poor, also due to the **nature of the housing stock** as well as the more **limited choice of energy sources**.

In most European countries, the rural housing stock is old and inefficient compared to the urban buildings, as it was built before the first thermal regulations that were established during the 1970s [41], [42]. For example, in France, 69% of the oil-heated rural properties are built before 1975, in Germany, 73% of the building stock is built before 1978, while in Sweden 64% of homes are built before 1971.

Moreover, most European rural homes still extensively rely on coal and other high-carbon fossil fuels for heating when compared with urban ones. In France and the United Kingdom (UK), clear differences exist between the energy mix used by households in rural and urban areas. Rural households in these contexts rely more on biomass, coal, and heating oil than in urban areas, where more natural gas is used [42]. Similar is the case in Portugal where the use of biomass is particularly widespread among the vulnerable rural population [43]. In Poland, coal is the most consumed fuel for heating (50% of the final energy consumption), while in Ireland and Belgium heating oil accounts for 36% and 35% of the final energy consumption, respectively. Finally, in the Netherlands, gas provides 86% of the final energy consumption for rural heating.

Another important special characteristic of rural areas across Europe is that 40.7 million European households located in rural areas are **not connected to the gas grid** [44], which can lead to higher prices given the limited choices [8]. Indicatively, according to Roberts *et al.* (2015), in the UK, rural areas have a high percentage of households off of the gas grid due to distance from the gas network and, therefore, rural consumers are more likely to use non-mains gas heating fuels. Nevertheless, connection to the **gas grid does not necessarily lead to lower costs**, as it is the most criticised fuel as a key culprit to the energy price and energy security crisis. Furthermore, in the Central and Eastern Europe region, heating with firewood and other solid fuels is more widespread than in the Western and Northern parts of Europe, while being especially widespread in rural and suburban areas [34].

Additionally, Drescher and Janzen (2021) provide evidence from Germany which shows that living in rural areas is linked to **expenditure-based energy poverty**, mainly due to the **higher energy costs faced by households in rural areas**. This energy cost price differential can easily be attributed to the **differences in grid access feed**, due to the lower population density, meaning that grid costs are spread over fewer inhabitants. Moreover, even though the EU power grid is in general consistent, remote areas such as rural ones may have **limited grid services** provided. The latter increases exposure to energy poverty while hampering environmentally friendly ways to alleviate it, such as the production of micro-renewable electricity [45].

In the case of Poland, single-family dwellings in rural and low-density areas are one of the two major archetypes that characterise the Polish residential building stock, and they are highly exposed to energy poverty on the basis of the objective Low-Income High Costs measure [34], [46]. According to Świerszcz *et al.* (2019), what characterises the Polish rural population, apart from their low incomes, are their **old and small houses**, the **outdated thermal insulation**, heating with **old coal-fired stoves** in poor technical condition, as well as the **inability to carry out thorough renovations** on their own [47].

Finally, consumer behaviour in rural ecosystems indicates significant differences in the **usage of energy** in various forms. Consumer preference towards any given energy service is a function of **geographical situatedness**, **local customs**, **traditions** and **tastes** including local weather conditions. Eventually, the rural flavour of energy poverty has a **distinctive micro-character** which can understood be understood in terms of the **sociocultural behaviourism** of an energy consumer [48], [49].

3.5 Current state of energy poverty and energy efficiency policies in rural contexts across Europe

This section records and assesses existing energy poverty and/or energy efficiency policies targeting rural areas. The primary objective is to concisely review a diverse range of policies, extracting implications and identifying the current state of measures and interventions. Consequently, this review sheds light on common challenges and deficits within the current policy landscape.

It is important to note that this review does not provide a detailed analysis of the aforementioned policies and does not claim to include every existing past or ongoing policy. Instead, its purpose is to trace distinct characteristics and key patterns in the implementation and design of policies targeting energy-poor households in rural areas. Policies were identified based on publicly available, non-confidential, and non-personal information. Given the rarity of actions specifically targeting rural areas, no additional criteria were applied other than the existence of support for rural areas, without requiring special emphasis and criteria that consider their specificities. Consequently, the collection of initiatives, programmes, and policies gathered was highly diversified. The list is enriched by the contributions of experts within the RENOVERTY consortium, where each pilot region contributed policies implemented in their respective countries.

This chapter is structured into two sections. Firstly, the collected measures are reviewed based on various criteria, such as the implementing authorities, the target of the policy, as well as the scope in both geographical and temporal terms, the type of actions performed, etc. Following that, key trends are provided based on the analysis of the policies in line with the discussed criteria, identifying key challenges and strengths.

3.5.1 General description of the identified policies

In total, 25 policies and initiatives from European countries are gathered and analysed. These policies are listed in **Table 1**, along with hyperlinks, the operating country, and a short description.

Table 1. List of the gathered energy poverty and/or energy efficiency policies targeted in rural areas across Europe.

Policy name	Operating Country	Short Description	Rural focus
State Housing Plan 2018-2021 Extra info	Spain	The objectives of the 2018-2021 State Housing Plan were to increase the rental housing stock and promote urban and rural renewal and regeneration. This Plan was implemented through the following strategic areas: special attention to the most vulnerable people; improved building quality, in particular, energy efficiency and environmental sustainability, and improved access to (rental) housing for young people.	National policy, which allows for the inclusion of rural areas, without targeting specifically on them.
Programmed Operations to Improve Dwellings (ANAH-OPAH) Extra Info	France	Grants are managed on a geographical basis, in close cooperation with local authorities. One of the goals of those grants is to improve the energy performance of dwellings (grants distributed can concern the replacement of windows, maintenance or installation of a new heating system). There are several types of OPAH.	National policy, which focuses on rural areas via the Opah-RR (Rural Revitalisation) section, and that aims to rehabilitate devitalised rural areas.

Aids Program for Energy Retrofit of Existing Buildings (PREE)	Spain	PREE, a programme coordinated by IDAE (Institute for Diversification and Saving of Energy), is responsible for monitoring the aids, managed by the Autonomous Communities, direct beneficiaries of these aids. The program aims to boost the sustainability of the existing building through actions on the thermal envelope, and thermal and lighting installations. PREE offers additional funds through social criteria. For example, for actions carried out in areas characterized as eligible to the "Rural Regeneration and Renovation Areas" criteria, additional aid is granted.	National policy, which foresees extra funding for retrofit actions performed in rural areas.
Aids Program for Energy Retrofit of Existing Buildings in demographic challenge municipalities (PREE 5000)	Spain	The Aids Program for Energy Retrofit of Existing Buildings in demographic challenge municipalities (PREE 5000) is aimed at boosting the sustainability of existing buildings through actions on the thermal envelope, and thermal and lighting installations. Specifically for municipalities under 5,000 inhabitants.	National policy, which aims at the promotion of retrofit actions performed in rural areas. It targets specifically municipalities under 5,000 inhabitants.
ECO (Energy Company Obligation)	UK	The Energy Company Obligation (ECO) is a set of statutory obligations on energy suppliers with over 250,000 domestic customers and delivering over a certain amount of electricity or gas to make reductions in carbon emissions or achieve heating cost savings in domestic households.	National policy which focuses specifically on rural areas via the Carbon Saving Communities Obligation (CSCO) which targets low-income, rural, or deprived areas.
Lumină pentru România (Light for Romania)	Romania	Light for Romania is a social campaign dedicated to families who live without electricity and light. The project discovers people in need via document analysis and fieldwork. It also installs	National policy, which mainly benefits rural areas, as these are mostly

		photovoltaic systems that provide free electricity to almost 250 families.	exposed to access to electricity issues.
Fényhozók Alapítvány (LightBringers Foundation)	Hungary	The Ligthbringers Foundation aims to transform Baks into a model village of an energy community involving low-income households. The project wishes to develop a distributable and adaptable model targeting lower-middle-class families in the region. To reach this goal and tackle energy poverty, the project provides renewable energy solutions to households in need in Baks. The project provides solar panels for households affected by energy poverty that have no access to electricity, affecting, thus, mainly rural areas.	Regional policy, that particularly targets a small village in Hungary.
Winterization Solutions for the most vulnerable families in the South Caucasus and the Balkans	Romania	The project aims to offer support for insulating and heating houses, complemented by educating families about proper heating solutions in order to improve children's health status, as well as investing in the development of new skills, which allowed beneficiaries to find a jobs in the county of Vaslui, one of the poorest counties in Europe, where most of its inhabitants (~60%) live in rural environments.	Regional policy which targets a specific county where most of its inhabitants live in rural contexts.
Financial Education and tackle Energy Poverty for families (Educación Financiera Familiar y Pobreza Energética)- EFFyPE	Spain	The Financial Education and tackle Energy Poverty programme took place in the year 2019. The initiative was focused on the economic empowerment of families, income management for households, investments, basic supplies, debt, over-indebtedness and housing. The use of clean energy and responsible consumption are part of the main objectives of the programme targeting	Regional policy, which allows for the inclusion of rural areas, without targeting them specifically.

		vulnerable groups and rural areas (among others).	
Transition Point Extra Info	Portugal	The project aims to support the construction of an innovative model that implements outreach actions in two municipalities of the District of Setúbal to support the most vulnerable families in improving the energy performance of their homes while taking into consideration the special needs of the areas included (also rural). The Transition Point provides the following services to local populations: advice on electricity and gas bills, information and advice on obtaining financing for the energy renovation of homes assistance in completing application forms, and free home energy assessments.	National policy, which allows for the inclusion of rural areas, without targeting them specifically.
Energy for All - LIGAR	Portugal	LIGAR brings together a multifaceted team of experts to develop an inclusive and comprehensive approach to tackling energy poverty, starting with the identification and mapping of hotspot regions, rural or not, for energy poverty vulnerability, followed by direct and in-person engagement with vulnerable consumers in selected regions to understand their situation and what can be done to better it, and finally conducting local actions in vulnerable homes for increased awareness and support through energy efficiency strategies.	National policy, which aims to map energy poverty including the special characteristics of the targeted areas (rural or not).

Just a Change (JAC) Extra Info	Portugal	Just a Change is a non-profit association that rebuilds homes for people in need in Portugal and mobilises volunteers to work on the rehabilitation of houses in precarious conservation states, improving the quality of dwellings in rural areas.	National policy, which allows for the inclusion of rural areas, without targeting them specifically.
Stromspar-Check Extra Info	Germany	Stromspar Check (SSC) advisers consult low-income households in their homes all over Germany free of charge on how to save energy and water and on further issues like heating and how to include climate protection actions in their everyday lives. In order to better reach rural areas, the SSC develops and implements new offers based on experience gained from networking in the neighbourhood approach and extends the use of channels for consultations.	National policy, which allows for the inclusion of rural areas, without targeting them specifically.
Hauts-de-France Pass Renovation	France	The project supports owners, landlords, individuals or collective housing by providing turnkey technical support coupled with an all-inclusive financial solution. The mechanism encompasses all the phases of the renovation project from information and advice to maintenance, including the identification of financial solutions in the Haus-de-France region (including rural areas).	National policy, which allows for the inclusion of rural areas, without targeting them specifically.
Nomad'appart	France	"Le Nomad'Appart" is a mobile educational apartment project on the theme of savings and comfort in housing as well as energy renovation in accordance with the principles of eco-construction. The vehicle will also be offered to actors supporting people in poverty (CCAS, SAS, social landlords) in	National policy, which allows for the inclusion of rural areas, without targeting them specifically.

		order to train them in energy efficiency and specific support procedures for households in fuel poverty affecting among others the rural areas of that region.	
Fuel Insecurity Fund SCO	Scotland	The Scottish Government's Fuel Insecurity Fund includes provisions for households on any tariff type and using any type of fuel, taking into account the generally higher costs of living, when it comes to remote and rural communities.	National policy, which includes both rural and urban areas. In the case of rural ones, it considers the higher cost of living in them.
Home Energy Efficiency Programmes for Scotland (HEEPS): area-based schemes	Scotland	These area-based schemes are designed and delivered by councils with local delivery partners, mainly targeting rural areas or areas with special needs. They fund local authorities to develop and deliver energy efficiency programmes (mainly solid wall insulation) in areas with high levels of fuel poverty. This funding is blended with Energy Company Obligation funding, owners' contributions and funding from registered social landlords who may choose to insulate their homes at the same time.	National policy, which involves local communities when designing area-based schemes targeting rural areas.
Public call for encouraging renewable energy sources in family homes (EnU-2/22)	Croatia	Within the framework of this call, projects for the use of renewable energy sources for self-consumption are co-financed, i.e. measures for the installation of systems for the use of renewable energy sources in existing family houses, in accordance with certain technical requirements. The definition of a family house implies that it is a building that has a valid building permit or other appropriate	National policy, which allows for the inclusion of rural areas, without targeting them specifically. Rural parts of Croatia are in the majority and among all counties, only the City of Zagreb, with approx. 20% of the total population of Croatia, is classified as a

		act that proves legality. The house must be energy-certified.	predominantly urban area.
Program of energy renovation of family houses (Energy retrofits of family houses)	Croatia	This programme targets the renovation of 10,000 family houses, simultaneously supporting energy renovation measures of family houses, as well as horizontal measures (implementation of accessibility elements, measures of installation of elements of green infrastructure, urban sustainable mobility and electromobility).	National policy, which allows for the inclusion of rural areas, without targeting them specifically. Rural parts of Croatia are in the majority and among all counties, while only the City of Zagreb, with approx. 20% of the total population of Croatia, is classified as a predominantly urban area.
Program of energy renovation of multi-apartment buildings	Croatia	This programme targets the renovation of 300 residential buildings, simultaneously supporting energy renovation measures of family houses, as well as horizontal measures (implementation of accessibility elements, measures of installation of elements of green infrastructure, urban sustainable mobility and electromobility).	National policy, which allows for the inclusion of rural areas, without targeting them specifically. Rural parts of Croatia are in the majority and among all counties, while only the City of Zagreb, with approx. 20% of the total population of Croatia, is classified as predominantly urban areas.
Program of measures for the reconstruction of buildings damaged by earthquake	Croatia	Up to 80% of the actions done as part of this program will be co-financed for increasing the thermal protection of the envelope, as well as installing some of the RES systems.	All counties of the program, except the City of Zagreb, can be classified as rural areas.
Program for tackling energy poverty which includes the use	Croatia	Support is provided to buildings in assisted areas and areas of special state concern. The target of the program is the renovation of 413	National policy, which allows for the inclusion of assisted areas and areas of special state concern.

of renewable energy sources in residential buildings in supported areas and areas of special state concern until 2025.		buildings until 2025 Assisted areas are the most rural parts of Croatia and economically underdeveloped areas.	These areas are predominantly rural areas.
Program for Energy Renovation of Family Houses	Croatia	This program aims at the renovation of 1.000 family houses - alleviating energy poverty by implementing energy renovation measures as well as measures to improve structural and non-structural elements in family houses.	National policy, which allows for the inclusion of rural areas, without targeting them specifically. Rural parts of Croatia are in the majority and among all counties, while only the City of Zagreb, with approx. 20% of the total population of Croatia, is classified as a predominantly urban area.
Spanish Urban Agenda (ERESEE 2020)	Spain	The Spanish Urban Agenda defines the long-term strategy to support the renovation of its national stock of residential and non-residential buildings (ERESEE 2020), both public and private, transforming them into energy-efficient and decarbonised building stock by 2050, facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings.	National policy, which allows for the inclusion of rural areas, without targeting them specifically.
National Strategy Against Energy Poverty (2019-2024)	Spain	The Strategy has been prepared by the Ministry for Ecological Transition. The Strategy establishes a definition of the situation of energy poverty and vulnerable consumers, diagnoses the situation in Spain, determines lines of	National policy, which allows for the inclusion of rural areas, without targeting them specifically.

		action and sets targets for reducing this social problem that affects more than 3.5 million inhabitants.	

3.5.2 Spatial and temporal extent of policies-inclusion of rural areas

All of the 25 policies collected are measures, initiatives and actions performed in Europe. The majority, i.e., **62.5%** of the policies are implemented at the **national level**, while the rest are implemented at the regional level, with the one exception of the *"Fényhozók Alapítvány (LightBringers Foundation)"* programme, which is implemented in a local community in Hungary.

The analysed policies do not necessarily have a special focus on rural areas. Of the national policies recorded, only half of them particularly address rural areas. Only two of the policies implemented at the national level that had a special focus on rural areas are targeting them exclusively, and not among others. In addition, some policies are added, due to the demographic situation of the areas they are implemented in.

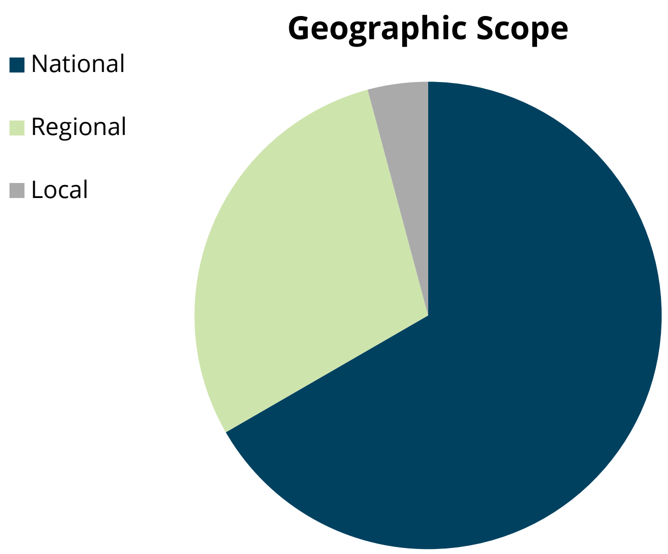


Fig. 3. Geographical scope of the gathered energy poverty and/or energy efficiency policies targeted in rural areas across Europe.

In addition, most of the policies analysed are implemented in countries of Western Europe (WE) and SE, while less than half of them is identified in CE and Eastern Europe, which are EU regions with increased figures in energy poverty issues. A classification regarding the European regions of the identified policies and the list of the operating countries of the policies are shown in **Fig. 4** and **Table 2**, respectively.

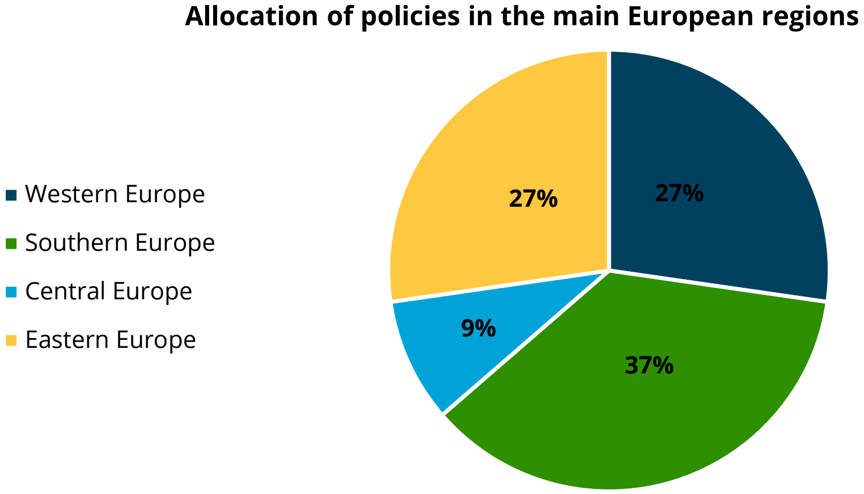


Fig. 4. Allocation (%) of the collected energy poverty and/or energy efficiency policies targeted in rural areas in the main European regions.

Table 2. Operating countries of the gathered energy poverty and/or energy efficiency policies targeted in rural areas.

Country	Number of policies
Spain	6
Portugal	3
France	3
Scotland	2
Romania	2
United Kingdom	1
Germany	1
Hungary	1
Croatia	6

Most of the policies are measures and initiatives that started after 2013 with the oldest starting in 2008. This comes as no surprise as the subject of the needs of those areas is not widely recognized and represented in policy decision-making.

3.5.3 Implementing authorities – measures included

An interesting finding is the variety regarding the implementing authority of the identified policies/initiatives. **Although the majority of implementing authorities are government bodies, a significant portion of initiatives is carried out by private funds and charities**. In some cases, authorities further partnered with Non-Governmental Organisations (NGOs) and local organisations to deliver the policy, or subcontracted local suppliers and providers to implement the works in the case of retrofits and installations. Such an example is the "*Just a Change (JAC) Pass Renovation"*, a non-profit association that rebuilds homes for rural people in need in Portugal, and mobilises volunteers to work on the rehabilitation of houses in precarious conservation states. Different partners and third parties will be able to notify and detect potential beneficiaries, deploy support, and mobilise local businesses, contributing also to the need for a sustainable local market for the implementation of energy efficiency measures, as well as the creation of job opportunities.

The actions proposed and implemented in most cases revolve around two main axes. The first is an array of **financial and technical measures** aiming to increase the energy efficiency of houses in the targeted areas through direct implementation and financing of the actions, or by subsidizing the cost of the performed actions for the beneficiary. The second category of initiatives has an **advisory/educational role** for those communities, including information campaigns and workshops about energy efficiency. Some projects include actions from both categories, like "*Hauts-de-France Pass Renovation"*, which not only incentivises its partners to perform the actions, but also provides advisory services for the technical and financial aspects of the project. **It is worth stating that 60% of the policies with a regional scope have advisory characters exclusively**. Moreover, technical measures of the programmes mainly concern the improvement of the building envelope and secondly, the installation or upgrade of the heating/cooling system. Nevertheless, in some cases like the "*State Housing Plan"* programme in Spain, the installation of Renewable Energy Sources (RES) and the improvement of electrical systems (lighting) is foreseen.

3.5.4 Discussion of the identified policies

By collecting and describing energy efficiency and/or energy poverty policies targeting rural areas, we seek to provide an initial analysis of the current relevant policy landscape, which is particularly understudied. By doing so, we aim to identify the main challenges of the implemented policies, actions, and initiatives. A first interesting observation is that even **when policies aim to focus on rural areas, most of them fail to describe or implement frameworks tailored to their unique characteristics**. This could be attributed to the fact that most of the policies focusing on rural areas are recent, and have not particularly considered rural particularities, highlighting the need for further focus and research. Indicatively, this is the case with the "*State Housing Plan"* and other nationwide initiatives, which aim to provide grants or subsidies without special discrimination for rural areas. Due to the latter, such programmes may face challenges when reaching out to the beneficiaries.

Nevertheless, there are specific examples of policies that focus on rural special characteristics. For example, the "*OPAH*" initiative (France) foresees local communities – which have a better overview of the local needs – to post a request to the National Energy Agency of France and contact the beneficiaries, establishing the foundation for them to act. The "*Fuel Poverty Act"* of the Scottish Government, which started in 2019, defines energy poverty using MIS (Minimum Income Standard), considering the generally higher costs of living in Scotland's remote, rural and island communities as a parameter. Additionally, the "*Lumină pentru România (Light for Romania)*" project is aimed towards rural regions with limited access to electricity, by installing photovoltaic systems to provide them free electricity. Technical guidance is also provided to the beneficiaries, as well as monitoring systems for the photovoltaics installed.

Another interesting case is the UK government's "*ECO programme*", which imposes several obligations to large gas and electric utilities. One of them is the Carbon Saving Communities Obligation (CSCO) which obligates suppliers to promote primary measures (roof and wall insulation) and connections to district heating systems, in low-income, rural, or deprived areas. Carrying out these measures is the complete responsibility of the energy providers, which in the case of rural areas addresses severe challenges regarding their geographic isolation.

Furthermore, a wide **lack of monitoring/evaluation of the performed actions** has been identified, leading to a limited understanding of the effectiveness of the policies. In the case of policies that aim to achieve certain benchmarks like the improvement of the energy efficiency of the dwelling or the decrease of emissions, only preliminary studies were conducted.

Our analysis also identifies that the policies focused on advisory/educational measures are mainly comprised of two objectives. The first is **the identification and mapping** of energy poverty as well as the in-person engagement of vulnerable groups, while the second is the **provision of information and consultation services** for the groups involved. This is in some cases a two-step procedure, like with "*Energy for All – LIGAR*", which developed a quantitative analytical method, the "*Energy Poverty Vulnerability Index (EPVI)*", to assess and map vulnerability to energy poverty for specific regions, including rural areas. On the other hand, in some policies, only one of the above-mentioned objectives is included. Indicatively, the "*Stromspar-Check*" offers individual meetings with households having difficulties related to their housing, which may impact their living conditions (energy/water bills, etc.).

In many cases, the measures implemented as part of the discussed policies are exclusive or mainly financial. An interesting observation is that most of the policies implemented on a national level are exclusively financial aids for house retrofits. An example of such a policy is the "*Program of energy renovation of family houses"* implemented in the country of Croatia, where the objective is the renovation of 10,000 family houses and the support of energy renovation measures for family houses. This is accomplished by the financing of up to 80% of the eligible costs.

An additional issue raised by the experts from RENOVERTY pilot areas, especially in CEE, SEE and SE regions, is the eligibility for receiving financial assistance as part of policies. For an applicant to be eligible to receive financial aid, it must be confirmed that the building undergoing renovation is legally registered, which can prove difficult, especially for buildings constructed before 1990.

3.6 Barriers to designing and implementing energy efficiency policies to alleviate energy poverty in rural contexts

The "energy efficiency gap" or "energy efficiency paradox" broadly describes the situation when energy efficiency products and services are slowly adapted despite their economic benefits ([50]–[52]). MacDonald *et al.* (2019) indicate that when this happens to rural areas, residents face a distinct set of energy efficiency adoption barriers that create a market failure called the "rural efficiency gap" [53]. This term describes the seemingly slower uptake of energy efficiency improvements in thinly populated rural communities even when implementing these improvements is more cost-effective due to the higher energy costs and energy burdens.

The rural efficiency gap exists in many rural places because the barriers to accessing energy efficiency, such as access to appropriate financing mechanisms, and skilled contractors, geographic isolation, and the general awareness of energy efficiency programs, often differ from those experienced in more populated areas. Indicatively, one of the most important barriers to energy efficiency, the so-called split incentive problem (where one party invests in energy efficiency, while the benefits produced are received by another) is less present in rural areas, as there are more owners-occupiers than renters [54].

According to Tahsildoost and Zomorodian (2020), the barriers that specifically affect energy efficiency in rural areas can be grouped into three main categories: financial barriers, geographic barriers, and awareness and access barriers [55].

3.6.1 Financial barriers

Across the board, financial barriers are considered very important in regard to the implementation of energy efficiency measures [3]. According to Blomqvist *et al.* (2022) and Kaya *et al.* (2021), when it comes to rural contexts, ***lack of capital*** combined with the ***high upfront costs*** of energy efficiency effectively discourages its uptake [56], [57]. The renovation of rural dwellings is frequently more expensive and does not necessarily result in an adequate increase in the energy efficiency rating [58]. In the meantime, out-of-pocket costs for energy efficiency services are also a challenge for rural households, which are already more exposed to low incomes, particularly when they are exacerbated by the additional costs associated with travel to remote areas [53]. Moreover, rural households are also exposed to ***lower median incomes*** and ***higher energy burdens*** which are also challenging the ability of residents to invest in energy efficiency. The average income is 21% to 62% lower in rural areas, with this phenomenon being accentuated in Eastern Europe countries [54]. Consequently, even when subsidies are provided, rural residents are still likely to choose traditional biomass energy (e.g., straw, firewood, scattered coal, cow dung), which has almost no costs, instead of using more energy-efficient products/services [59]. Finally, other important financial barriers identified are related to ***credit access*** and ***debt aversion***. Many rural residents are unable or unwilling to take on debt to finance efficiency, limiting their participation in standard loan programs, while alternative financing mechanisms such as on-bill financing are often not available in rural areas [53]. Moreover, tax incentives may have limited appeal, due to the fact that small low-income household tax payments and write-offs are likely to be negligible [57].

3.6.2 Awareness and access barriers

As already mentioned, rural areas suffer from low educational capabilities. Due to this, several awareness barriers can hinder the implementation of energy efficiency measures in these contexts. For example, ***lack of technical knowledge*** and ***information*** about energy efficiency aspects and options are met more in rural contexts than in urban ones [56]. Moreover, residents of small towns and rural communities often rely on word-of-mouth recommendations from neighbours and trusted messengers. Therefore, the limited experience within rural residents' social network, combined with their scepticism of assistance programs and a preference to "*do it yourself*," often limit rural residents' knowledge of and interest in accessing energy efficiency programs, leading to a widespread **lack of awareness** or **scepticism of existing resources** among the rural population [45], [53], [60]. Therefore, greater efforts to build on local and traditional knowledge and experience as well as finding ways to better integrate local and scientific knowledge are needed. Moreover, according to Blomqvist *et al.* (2022), **lack of time or other priorities** also work as a significant barrier in rural areas [56]. Finally, the **lack of access to traditional marketing channels** also hinders the implementation of energy efficiency interventions in rural contexts. The success of traditional marketing strategies, particularly those online, may be limited in rural areas due to factors such as limited access to reliable broadband internet [60].

3.6.3 Geographic barriers

As identified in literature, the geographic nature of rural areas affects severely the quality of life of inhabitants. This also leads to several geographic barriers to implementing energy efficiency measures in these contexts. More specifically, rural areas are characterised by ***geographic isolation***. Due to the latter, rural residents' access to financing, incentives, and professional services necessary for the implementation of energy efficiency projects is hindered by the physical distance from resources (e.g., financial, human, etc.), which along with the lack of economies of scale, characterize rural communities [61]. Moreover, the geographic characteristics of rural areas often cause difficulty in hiring qualified local energy efficiency workers to serve rural areas, due to the **shortage of local energy efficiency workers** and **lack of expertise** [62], [63]. For this reason, implementers may sometimes need to source contractors from the nearest urban center rather than supporting the local rural economy directly.

3.6.4 Regulation barriers

In addition to the financial, awareness and access, and geographic barriers, across the literature, **regulation barriers** are also identified. **Unsupportive and inconsistent policy setting** is a major regulatory barrier faced by rural communities that significantly hinders the uptake of energy efficiency measures[64]. When it comes to energy efficiency in buildings, rural areas face higher disadvantages, which have not yet been fully recognised by policymakers, who still give higher priority to cities [54]. Whilst in most developed countries there are central government policies and commitments that include reference to the desirability of energy efficiency developments, they **lack strong sub-national territorial components** and indeed are often **poorly articulated** with regional and rural policymaking [65].

4 Survey: Assessment of stakeholder needs and viewpoints

This section describes an assessment of the needs and viewpoints of relevant stakeholders and local actors (e.g., households, developers, local community representatives, energy agencies, NGOs and social service providers, municipalities, representatives of ministries such as climate, finance, agriculture, EU such as the Energy Poverty Advisory Hub (EPAH), and local businesses for heat pumps, installers, construction companies ad networks of installers on the local level) to validate our preliminary findings (i.e., literature review findings) and obtain broader insights on the status of energy poverty and energy efficiency in the rural contexts of CEE, SEE, and SE. Emphasis is given to the existing needs and barriers for the development and implementation of roadmaps for energy efficiency in vulnerable households in rural and peri-urban areas in CEE, SEE and SE. Indicative topics to be answered by stakeholders (according to their field of expertise) include:

- Information about the special socio-economic status of rural populations (depopulation, outmigration, limited access to education, labour dynamics, remoteness, etc.), as well as their exposure to energy poverty.
- Specificities of energy poverty and energy efficiency policy implementation.
- Classification of barriers to and drivers for the development and implementation of energy efficiency renovation roadmaps in the rural context.
- Prioritisation of suggested actions/measures.
- How energy poverty alleviation can be tied to rural development and social inclusion.

4.1 RENOVERTY stakeholder survey on energy poverty in rural areas

The RENOVERTY survey regarding stakeholder views on energy poverty and energy efficiency in rural areas provides important insights into how relevant institutional actors and stakeholders see the drivers and implications of rural energy poverty. ***To the best of the authors' knowledge, this survey is the only such statistical instrument that has been developed to date***. The survey was composed following an extensive literature review of relevant research on the topic (to identify relevant gaps in knowledge), as well as detailed consultations, piloting, and testing with all partners within the RENOVERTY consortium.

The survey begins with a welcome message and introduction, explaining the background and objectives of the RENOVERTY project. It highlights the importance of investigating energy poverty in rural contexts and understanding the barriers and potential solutions for implementing energy efficiency policies to alleviate rural energy poverty.

The main survey questions are categorised into sections labelled **A**, **B**, **C**, and **D**. **Section A** focuses on gathering information about the participants' background and their affiliation with stakeholder groups or sectors. It includes questions about the participants' specialisation, working sector, country/region of operation, and their interaction frequency with various types of organisations related to energy efficiency.

Section B explores the participants' experiences and opinions regarding energy poverty in rural contexts. It asks about common challenges faced by rural households, such as higher energy bills, transport costs, poor housing conditions, and inadequate access to the electricity grid. Participants are also asked to assess the importance of different factors contributing to these challenges. In addition, information is requested regarding the diffusion of emerging technologies in rural areas.

Section C delves into barriers related to the implementation of energy efficiency measures in rural contexts. The participants are asked about potential obstacles, including financial, awareness and access, geographic, and regulatory barriers. They are also asked to rank the importance of these barriers based on their region.

Section D focuses on policies and measures to support energy efficiency investments and development in rural contexts. It includes questions about the participants' awareness of relevant policies, the importance of different policy scales (EU-level, national, regional, and local), and suggestions for improvement by EU institutions, and national, regional, and local governments.

The survey gathered a total of 130 responses distributed across different sectors within 24 countries. All answers came from European countries excluding one received from Zambia. Nonetheless, the latter was excluded for geographical simplicity, and the answers were subdivided across five different regions of Europe. These were Northern Europe (NE), which includes answers from Estonia, Ireland and the Netherlands, CEE, which includes answers from Austria, Germany, Hungary, Poland and Slovakia, SEE, which includes answers from Albania, Bosnia & Herzegovina, Bulgaria, Croatia, Cyprus, Greece, Northern Macedonia, Romania, Slovenia and Turkey, SE, which includes answers from Italy, Portugal and Spain, and Central-Western Europe (CWE), which includes answers from Belgium and France. As a whole, there was a relatively wide geographical distribution of answers, with the exception of NE and CWE (**Fig. 5**).

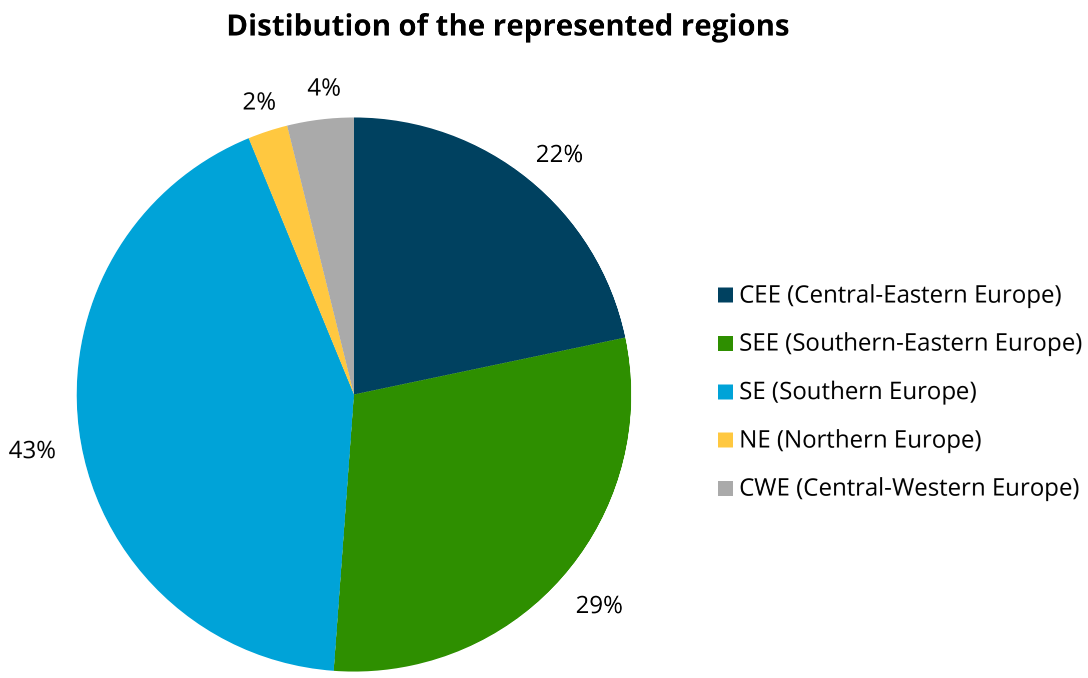


Fig. 5. Distribution of regions represented by respondents to the survey.

Respondents were also subdivided according to their field of expertise: governmental bodies (including local, regional and national ones), the private sector (including the construction and business industry, energy companies, private businesses and trade unions), the research sector (including both academia/research institutions and policy organisations/think tanks), and the third sector (including both community organisations and non-governmental organisations). Overall, the private sector was slightly under-represented, at the expense of the third sector (**Fig. 6**).

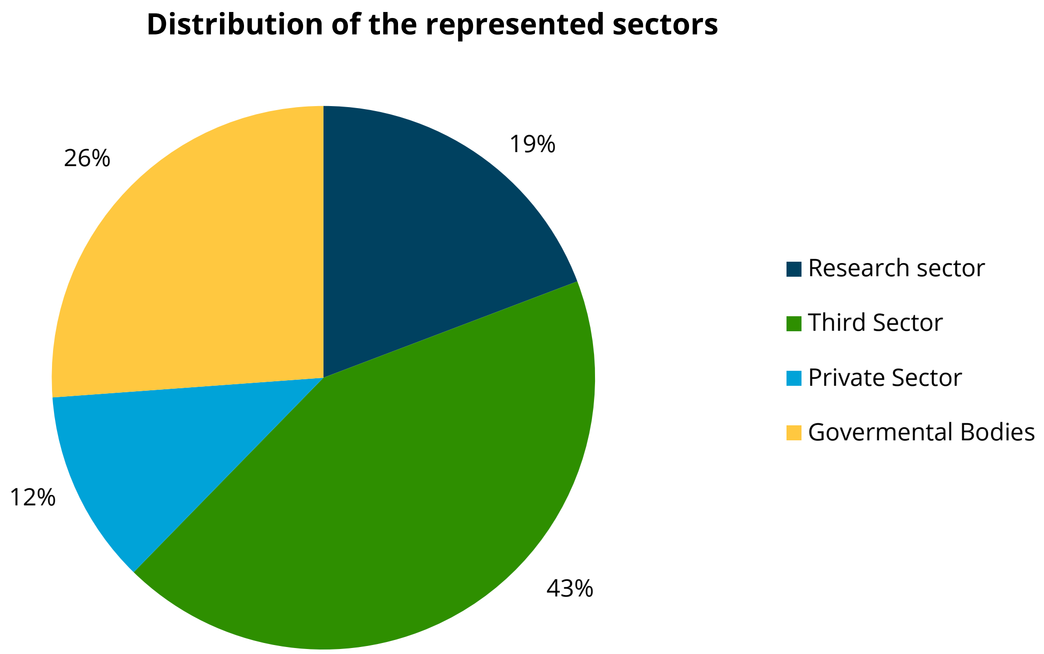


Fig. 6 Distribution of sectors represented by respondents to the survey.

Lastly, it must be noted that 42% of the answers were from RENOVERTY pilot areas.

4.1.1 Familiarity of respondents with energy poverty

The respondents were asked if they were familiar with the notion of energy poverty and if so, if they were directly involved in helping reduce energy poverty or social vulnerability among rural residents. According to the responses, most of the respondents indeed were involved in such activities. **Table 3** and **Table 4** illustrate how the answers to the postulated question varied among regions and sectors. As can be seen, SEE had in fact a lower than average percentage of respondents involved in such activities. On the other hand, when considering the different sectors, only respondents from governmental bodies had a higher percentage of involvement in energy poverty activities than average.

Respondents who answered positively to the previously mentioned question were thereafter asked to specify if they took part in any specific activities. For example, it was asked whether they undertook activities aimed to help improve access to public transport and cycling among rural residents. **Table 5** and **Table 6** summarise the answers to this question. When subdividing among regions and sectors, the majority of respondents answered negatively to this question, especially respondents from CEE and the Research and Third sector. This signals a low level of interest in this issue from the two sectors and the CEE region. On the other hand, CWE respondents and those from governmental bodies and the private sector seemed to be more interested (which was expected as public transport is ensured by governments and provided by the private sector).

Table 3. Respondents' involvement in energy poverty alleviation activities per region.

Region	No Answer	No	Yes
CWE	25%	0%	75%
NE	0%	0%	100%
SE	15%	16%	69%
SEE	34%	21%	45%
CEE	18%	18%	64%
Average	18%	11%	71%

Table 4. Respondents' involvement in energy poverty alleviation activities per sector.

Sector	No Answer	No	Yes
Governmental bodies	27%	6%	68%
Private sector	27%	20%	53%
Third sector	23%	14%	63%
Research	4%	40%	56%
Average	20%	20%	60%

Table 5. Respondents' involvement in activities aimed at improving access to public transport and cycling among rural residents.

Region	No Answer	No	Yes	Partly
CWE	0%	0%	67%	33%
NE	33%	33%	33%	0%
SE	24%	39%	29%	8%
SEE	6%	41%	35%	18%
CEE	17%	56%	22%	5%

Average	16%	34%	37%	13%

Table 6. Respondents' involvement in activities aimed at improving access to public transport and cycling among rural residents per sector.

Sector	No Answer	No	Yes	Partly
Governmental bodies	22%	26%	35%	17%
Private sector	13%	38%	38%	11%
Third sector	20%	49%	26%	5%
Research	14%	50%	29%	7%
Average	17%	41%	32%	10%

4.1.2 Energy poverty challenges in rural areas

All respondents were asked whether the listed energy poverty challenges were indeed faced in rural areas. Once again, the answers were subdivided into regions and working sectors. **Fig. 7** illustrates how the three most common energy poverty challenges faced in rural areas are higher transport costs compared to urban households, a greater likelihood of living in a poorly insulated house, and lower incomes compared to urban households. Interestingly, the answers did not differ depending on whether the geographical or employment perspective was considered. In fact, **Fig. 7** and **Fig. 8** are rather similar.

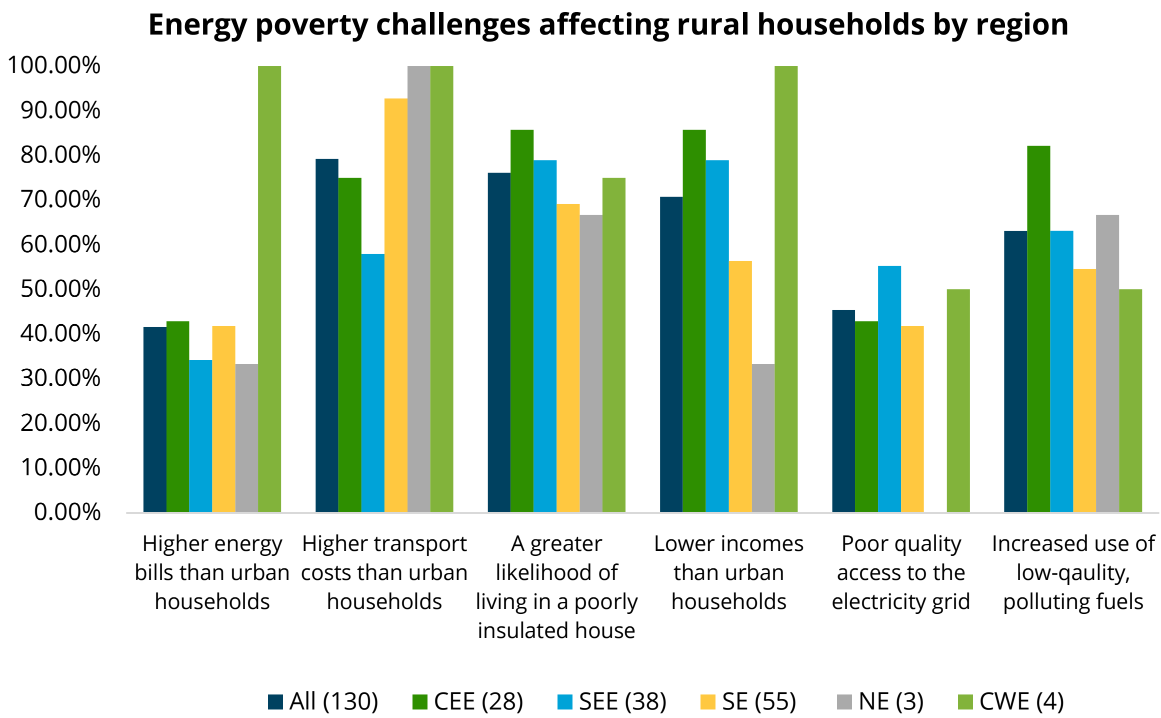


Fig. 7. Energy poverty challenges faced by rural households subdivided by region.

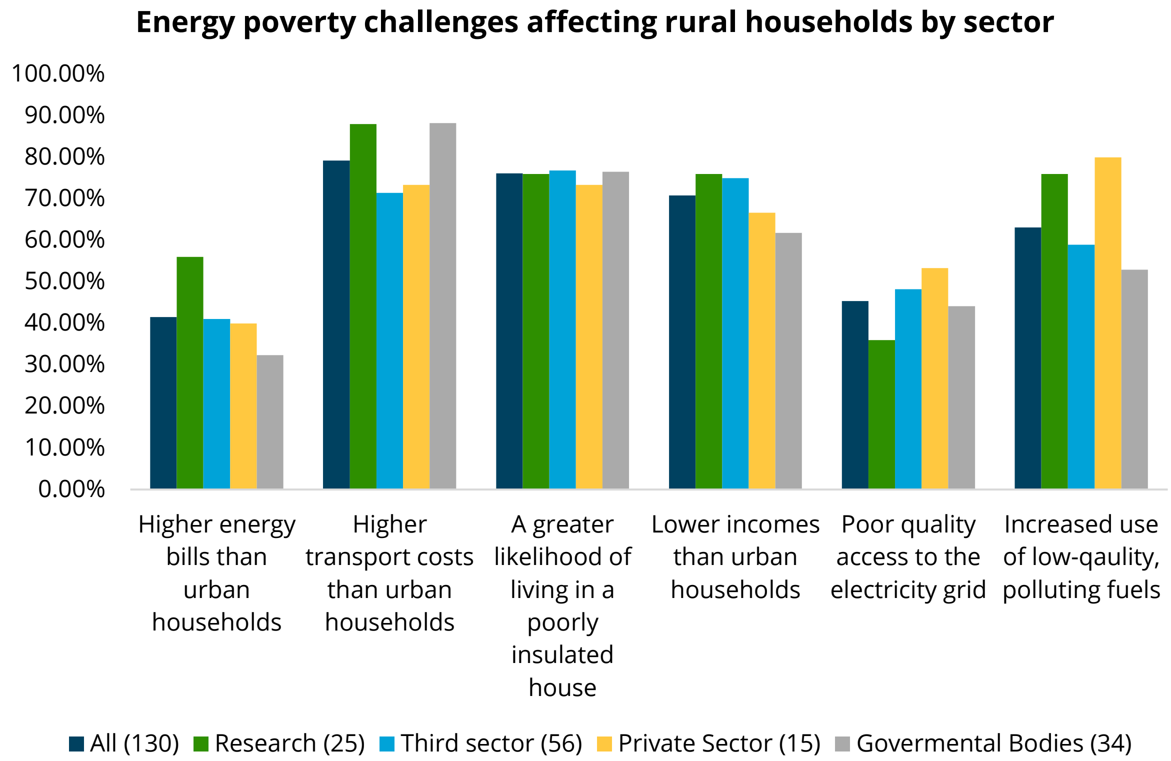


Fig. 8. Energy poverty challenges faced by rural households subdivided by working sector.

4.1.3 Drivers of energy poverty

Similarly, to the previous question, respondents were asked which drivers of energy poverty they would deem to be more important. They were asked to rate eight different drivers of energy poverty as either: “not important at all” (value of 1), “unimportant” (value of 2), “neutral” (value of 3), “important” (value of 4), “very important” (value of 5). **Fig. 9** shows the results when considering all answers, without distinguishing per region or affiliation. Very interestingly, **the most important driver of energy poverty was deemed to be poor public transport access**. This remains the case also when categorising the respondents both by region and affiliation (**Fig. 10** and **Fig. 11**). The prevalence of transport poverty in rural areas is well documented in the relevant literature (as supported by the previous sections of this report) and it is clear that stakeholders also recognised its relevance. In CWE, the transport driver even scored an average value of 5, however, this skewed due to the low number of respondents from the region (only four). Nonetheless, this was deemed the most important factor also in SE and Northern-Europe (NE). On the other hand, underinvestment in rural areas was seen as the main driver in SEE, whereas poor quality of housing was seen as the main driver in CEE.

When comparing answers from the different sectors, all sectors found poor public transport access to be the main driver of energy poverty; except the third sector, which identified underinvestment in rural areas as the main one.

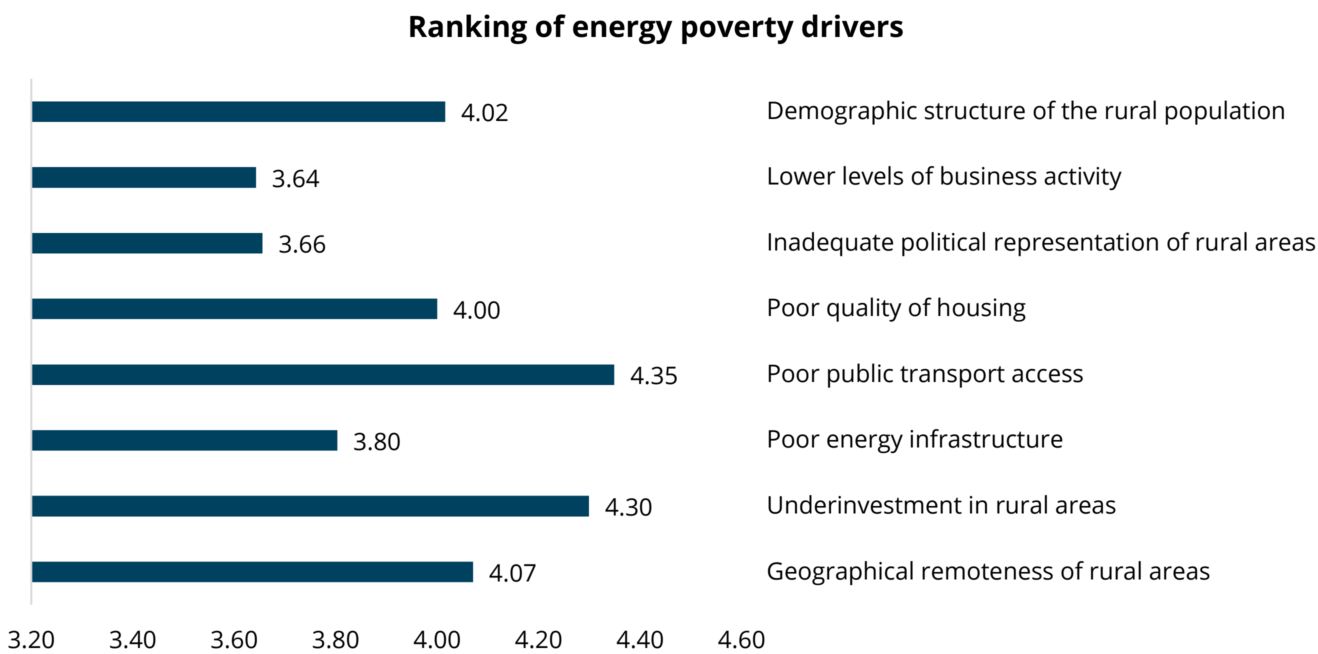


Fig. 9. Energy poverty drivers ranking.

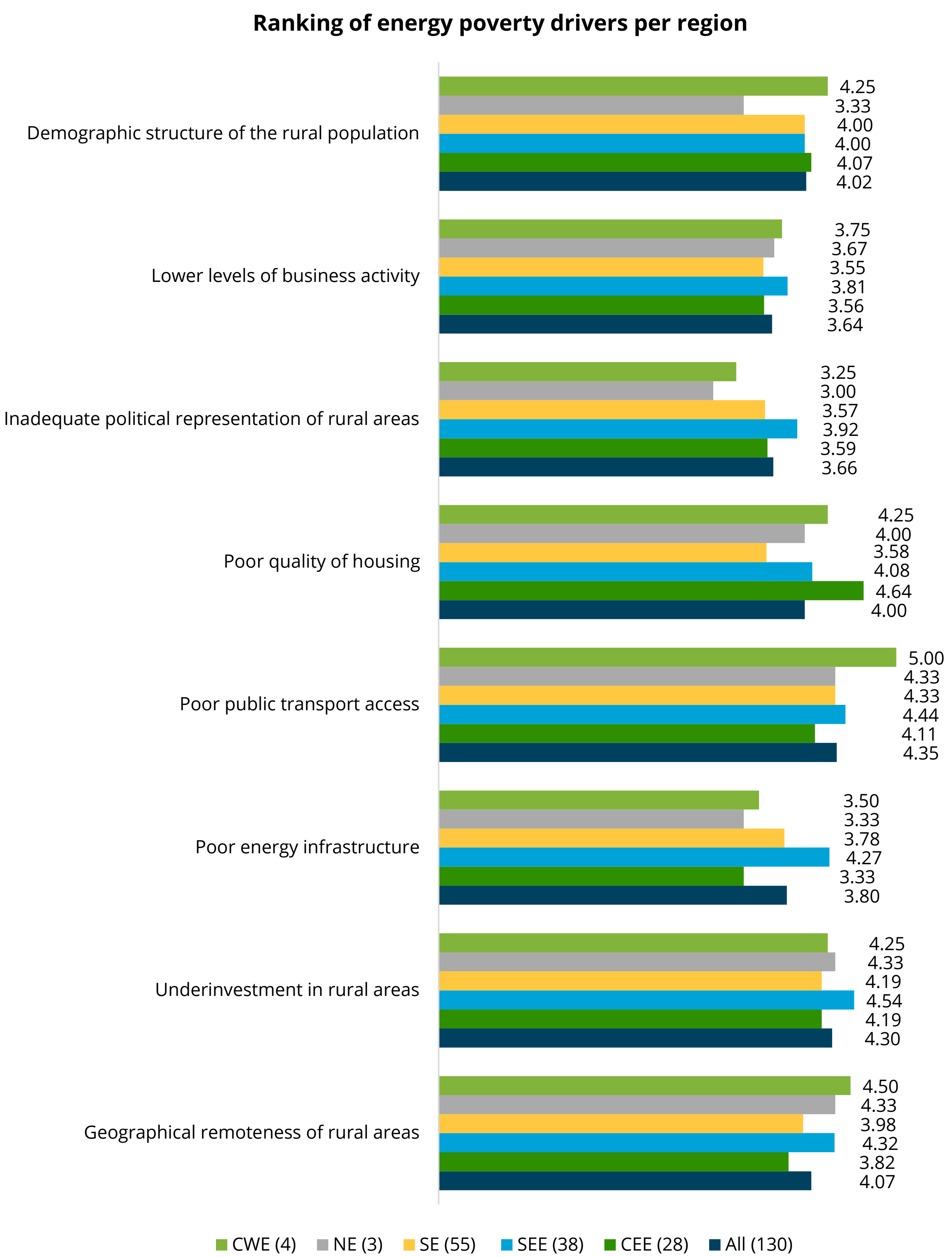


Fig. 10. Energy poverty drivers ranked and categorised per region.

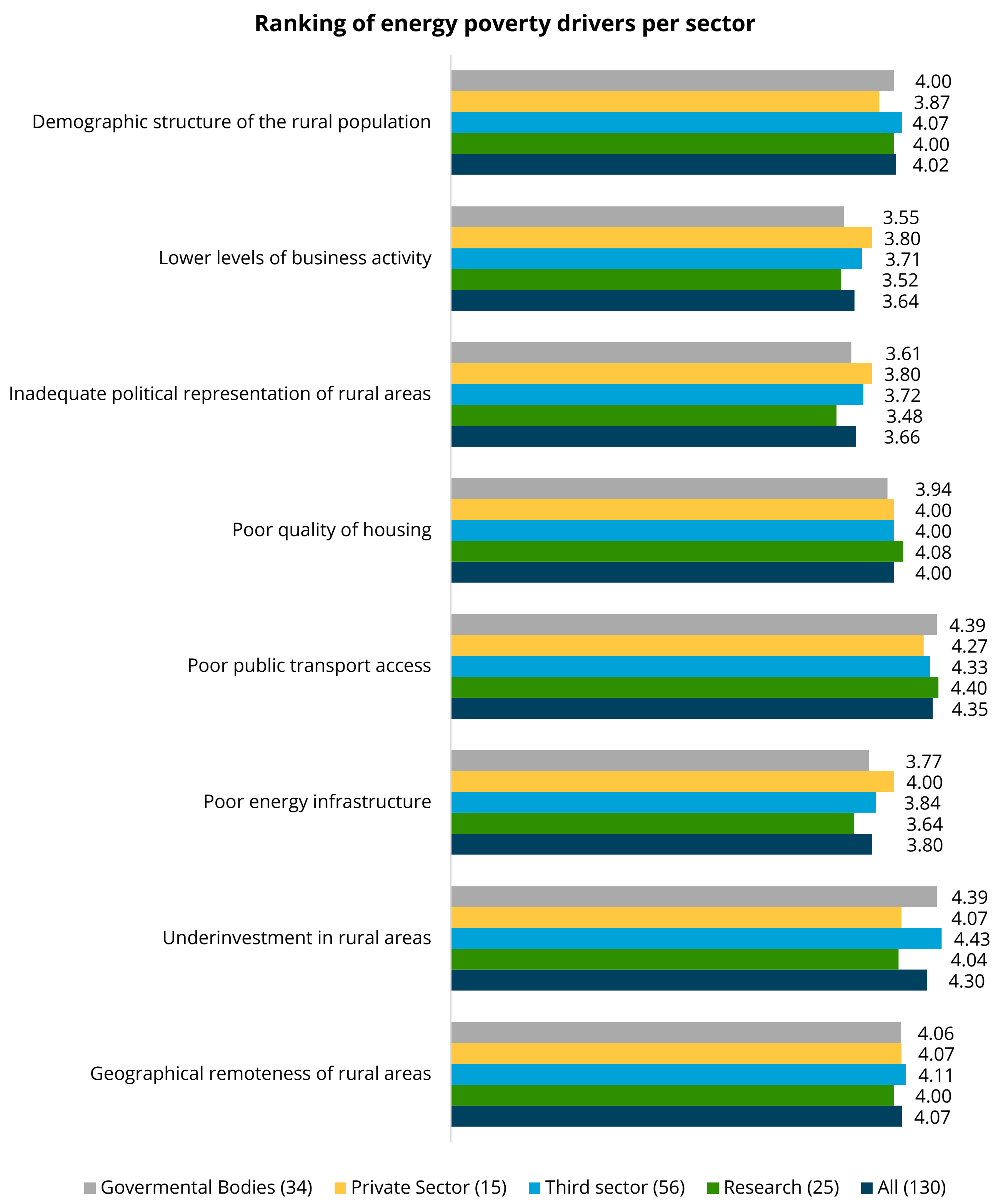
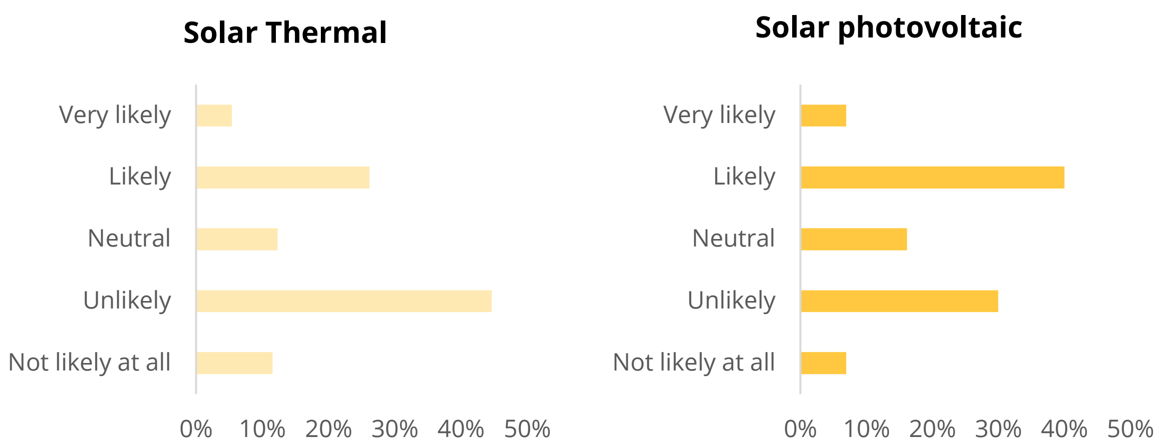


Fig. 11. Energy poverty drivers ranked and categorised per working sector.

4.1.4 Utilisation of renewable energy/electrification technologies in rural areas

Respondents were asked to answer how likely they saw the utilisation of four different types of renewable energy/electrification technologies in rural areas. The four investigated forms of renewable energy/electrification technologies were solar thermal, solar photovoltaic, domestic heat pumps and electric vehicles. In **Fig. 12**, it can be seen how each technology was ranked from "not likely at all" to "very likely". Electric vehicles were seen as being either unlikely or not likely at all to be employed in rural areas, with 0 out of the 130 respondents seeing this type of technology as very likely to be employed in rural areas. Domestic heat pumps were found to be the second most unlikely form of technology to be employed in rural areas – a disappointing finding given the deployment potentials of this form of energy in rural areas. Solar thermal was rather ambiguous, as it was the second most "likely" and "very likely" technology to be employed, but also the most "unlikely" one and the second most "not likely at all". On the other hand, solar photovoltaics were definitely seen as the most likely type of technology to be employed in rural areas when considering all respondents together. They are clearly a well-established and well-recognised technology.



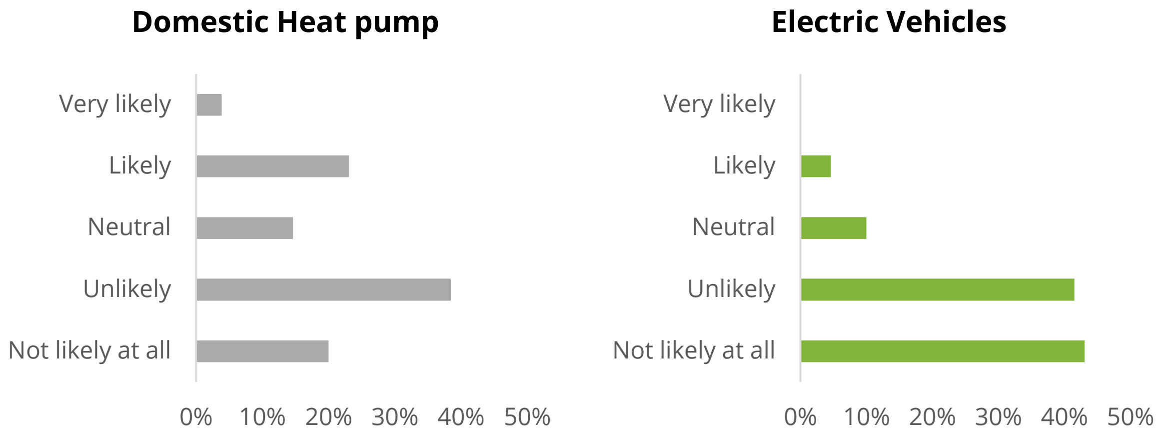


Fig. 12. Likeliness of different renewable energy technologies being employed in rural areas.

To gain more insights into the data, a score from 1 (“not likely at all”) to 5 (“very likely”) was given to every option. Thereafter, the research examined how every individual technology performed, categorising the answers per region. **Fig. 13** shows how solar photovoltaics were seen as the most likely form of technology to be implemented in CWE, CEE and SE; however, performed poorly in the other two regions. In NE, the domestic heat pump was surprisingly found to be the best solution. On the other hand, SEE illustrates a pessimistic picture, as no technology scored an average value higher than 3, with the best performing technology being solar thermal with a score of 2.89. This illustrates a low level of social expectation in SEE regarding the efficacy of renewable energy technologies in rural areas. Lastly, it should be noted how electric vehicles were once again not seen as a solution in rural areas, with only NE scoring an average value of 3 (however skewed by the low number of respondents from the region).

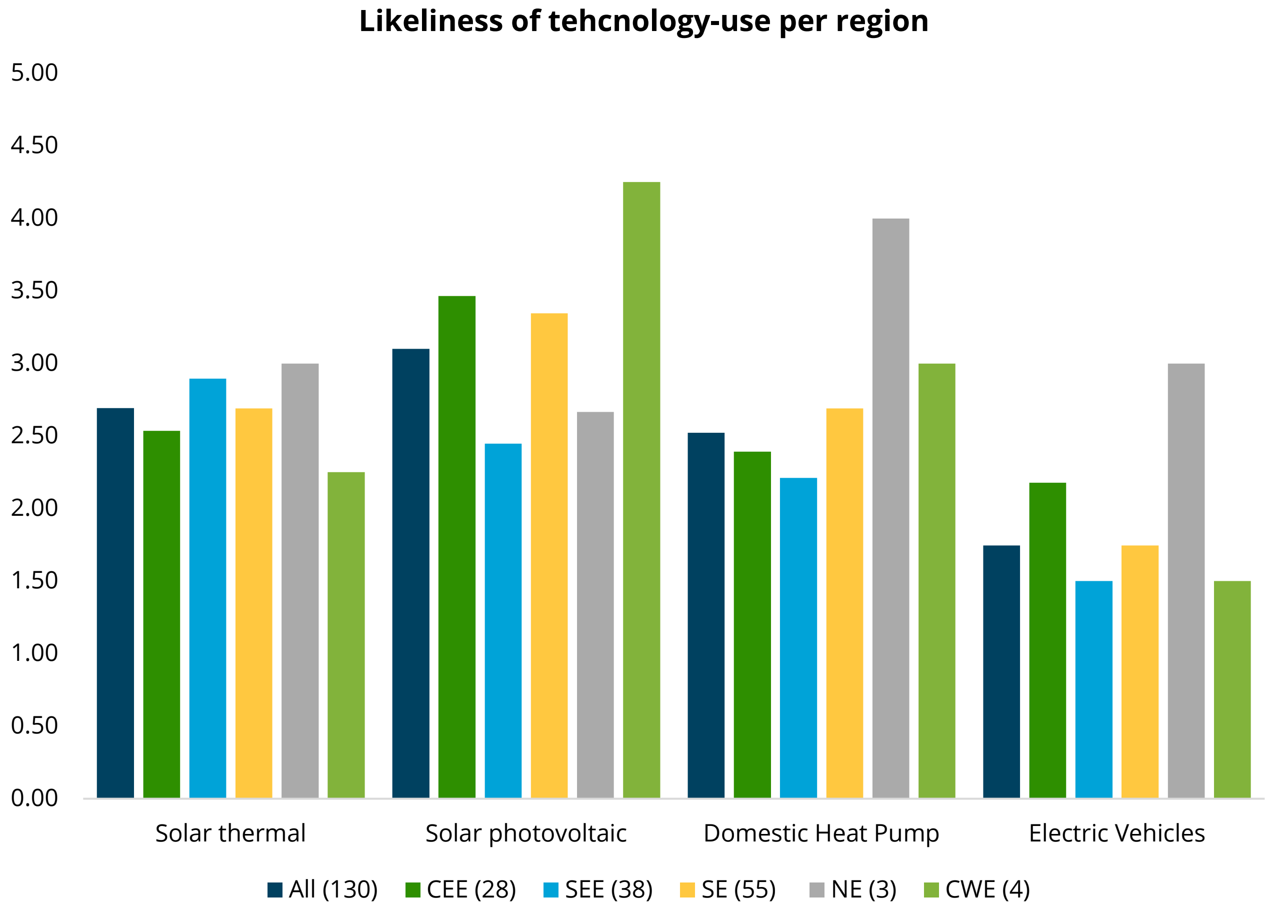


Fig. 13. Likeliness of different technologies being employed in rural areas categorised per region.

4.1.5 Existence of barriers to energy efficiency improvement in rural areas

Respondents were asked whether they were involved in helping improve the energy efficiency of rural households and if so, which barriers they found. Five categories of barriers were given to the respondents to choose from: financial barriers, awareness access barriers, geographic barriers, regulatory barriers and “other” types of barriers. The answers to this question are visualised in terms of all general answers (**Fig. 14**) and per region **(Fig. 15**, **Fig. 16**, **Fig. 17**). No major differences were found between the four graphs. In fact, financial barriers resulted as the most prominent ones in all cases, followed by awareness access and regulatory barriers (with the latter two being lower in CEE compared to other regions). Geographic barriers were partly seen as a barrier.

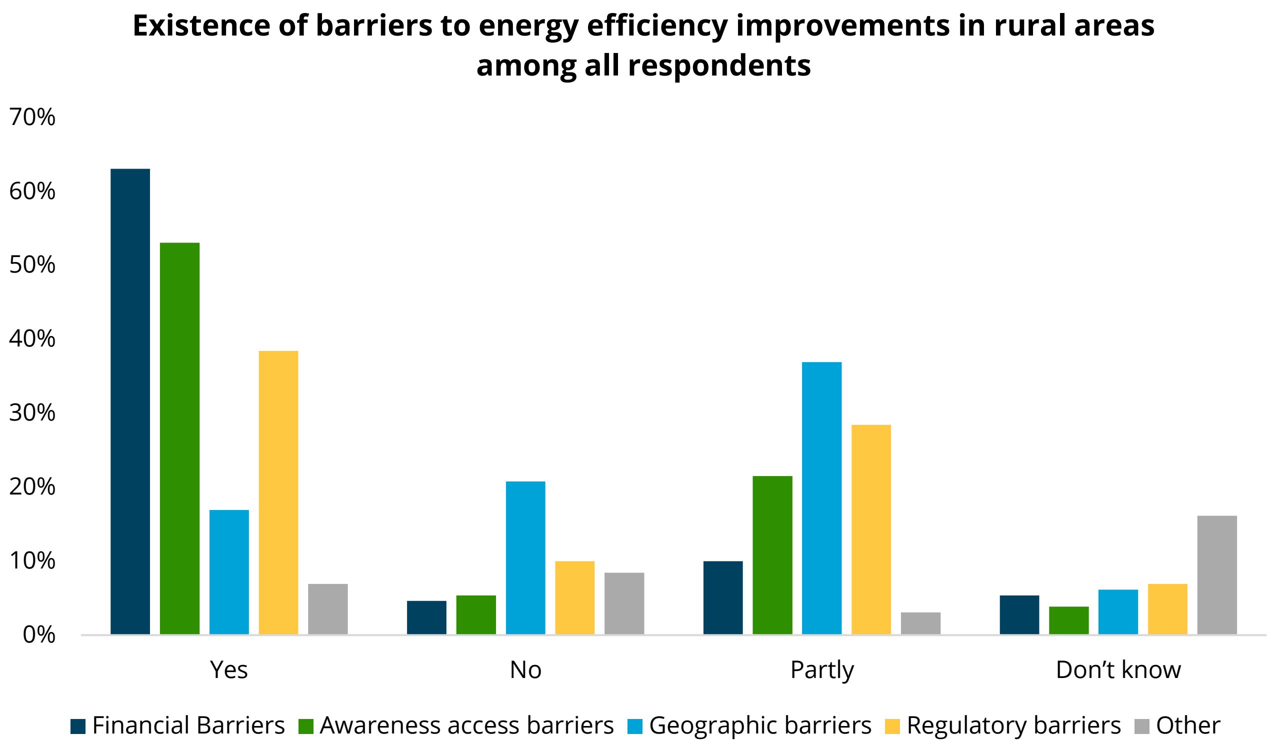


Fig. 14. Existence of barriers to energy efficiency improvement in rural areas among all respondents.

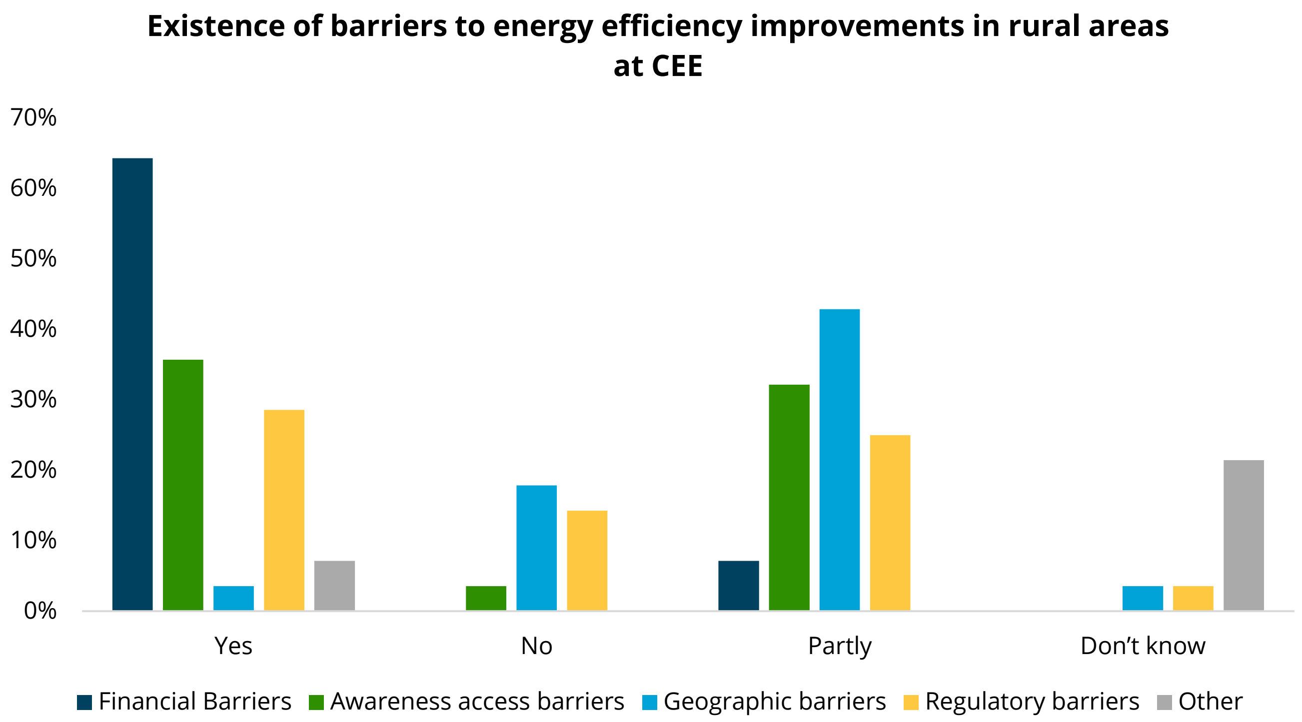


Fig. 15. Existence of barriers to energy efficiency improvement in rural areas among CEE respondents.

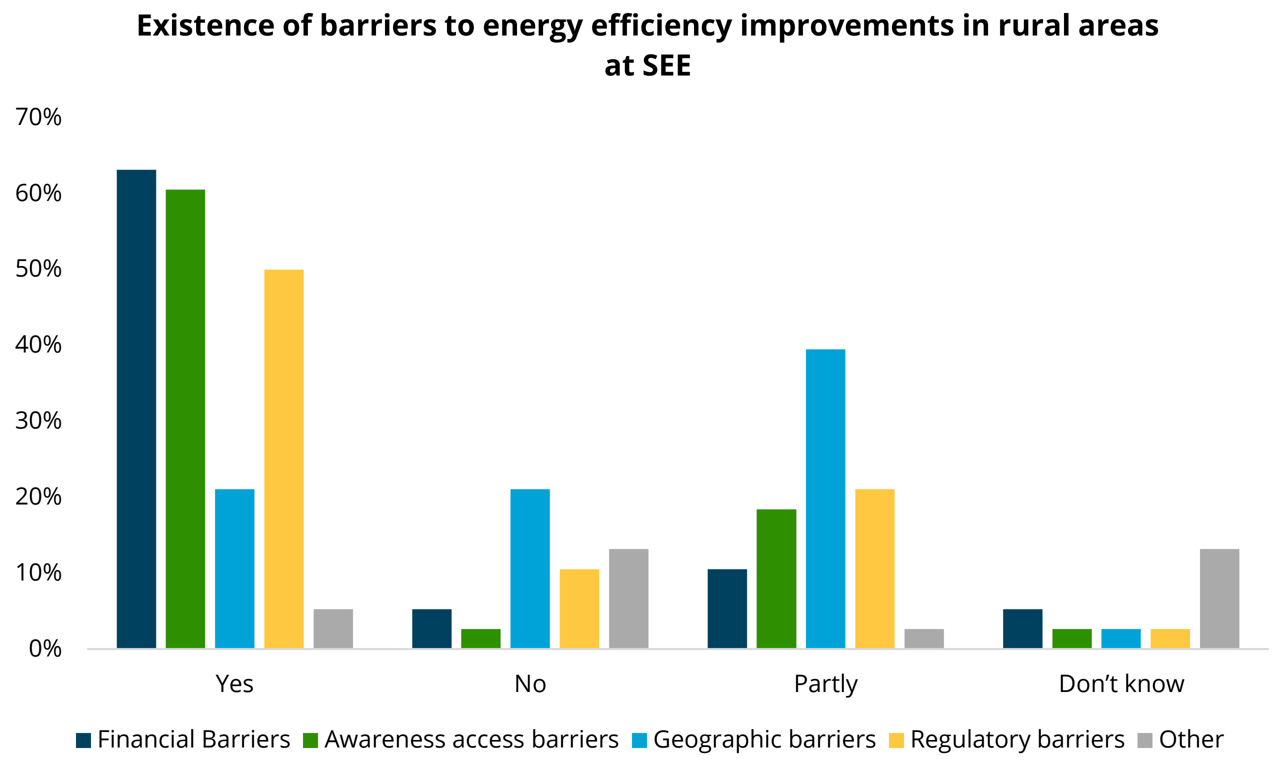


Fig. 16. Existence of barriers to energy efficiency improvement in rural areas among SEE respondents.

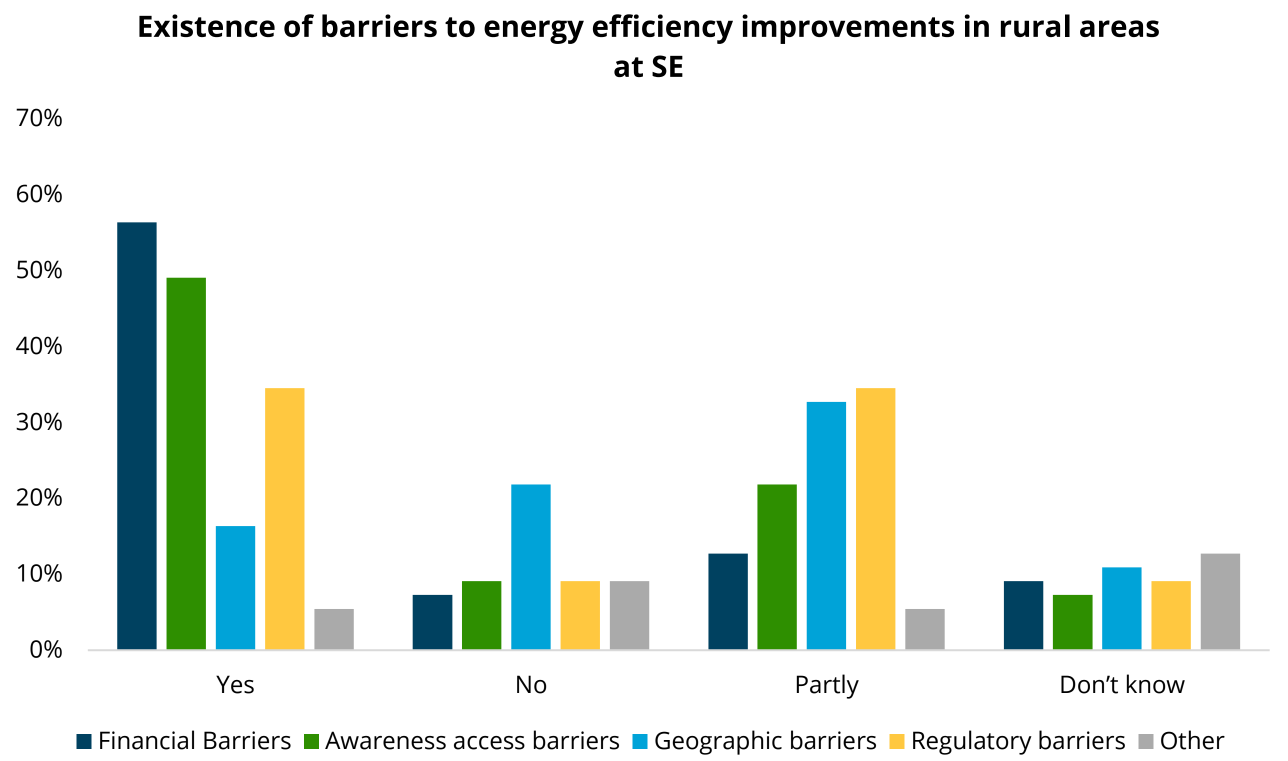


Fig. 17. Existence of barriers to energy efficiency improvement in rural areas among SE respondents.

4.1.6 Importance of barriers per affiliation

The importance of different aspects related to each barrier was also asked. Once again, the respondents were asked to rank the importance of each aspect of one barrier from "not important at all" (with a value of 1) to "very important" (with a value of 5). Hereby, we show the importance of each aspect per barrier per affiliation, as this provides greater insights than when categorising such answers per region. In fact, as shown in the previous section, the differences per region related to barriers to energy efficiency improvements in rural areas were not substantial.

When analysing the importance of different aspects related to financial barriers, the lack of capital/high upfront costs was found to be the most important factor in general, especially among governmental bodies. As expected, the higher energy burdens and credit access/debt aversion/return on investment were deemed as important factors more prominently by the private sector (**Fig. 18**).

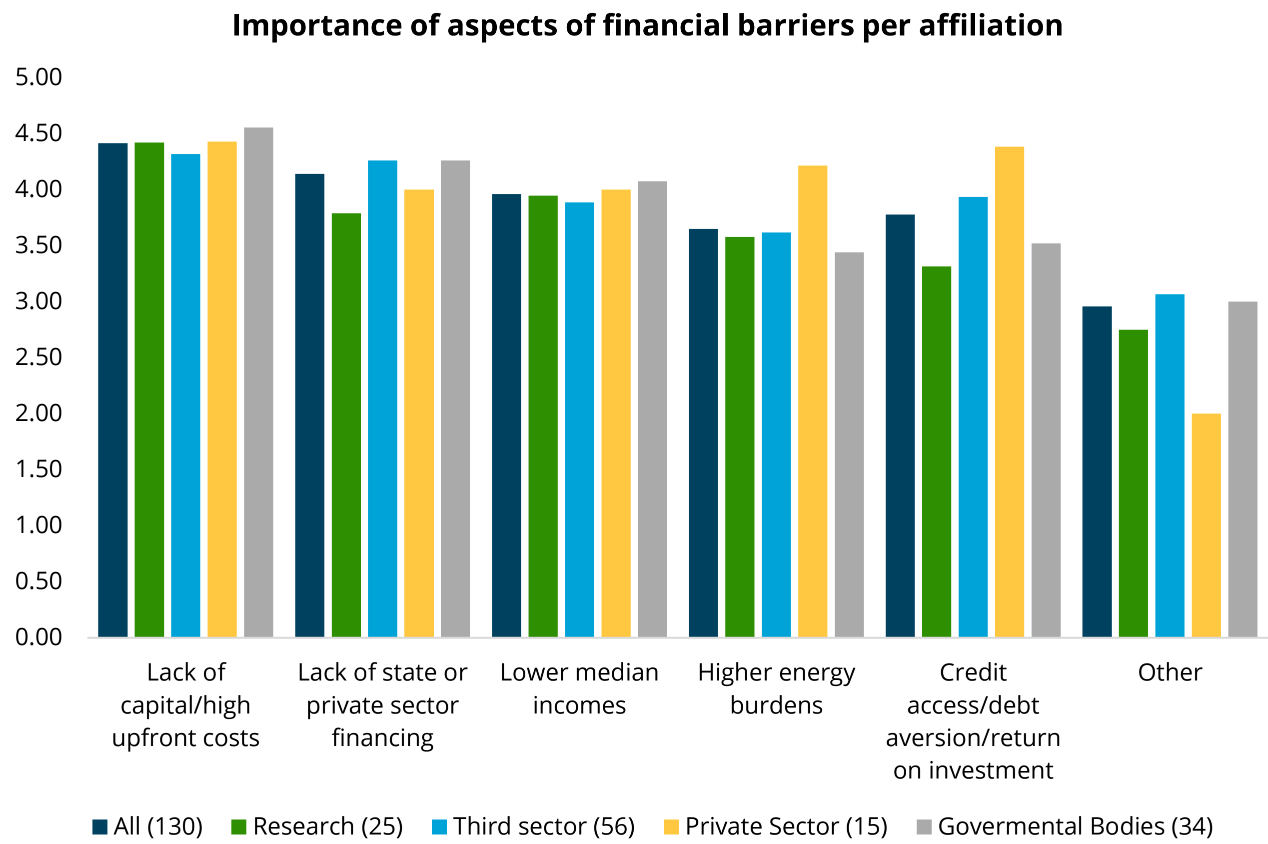


Fig. 18. Importance of different aspects related to financial barriers per affiliation.

The factor deemed most important when tackling awareness/access barriers was the lack of technical knowledge and information throughout all affiliations. The private sector, however, also deemed the lack of awareness/increased scepticism as an equally important factor. As expected, the lack of time/other priorities was deemed more important by governmental bodies, whereas the lack of access to traditional marketing channels/financial mechanisms was more important for the third sector (**Fig. 19**).

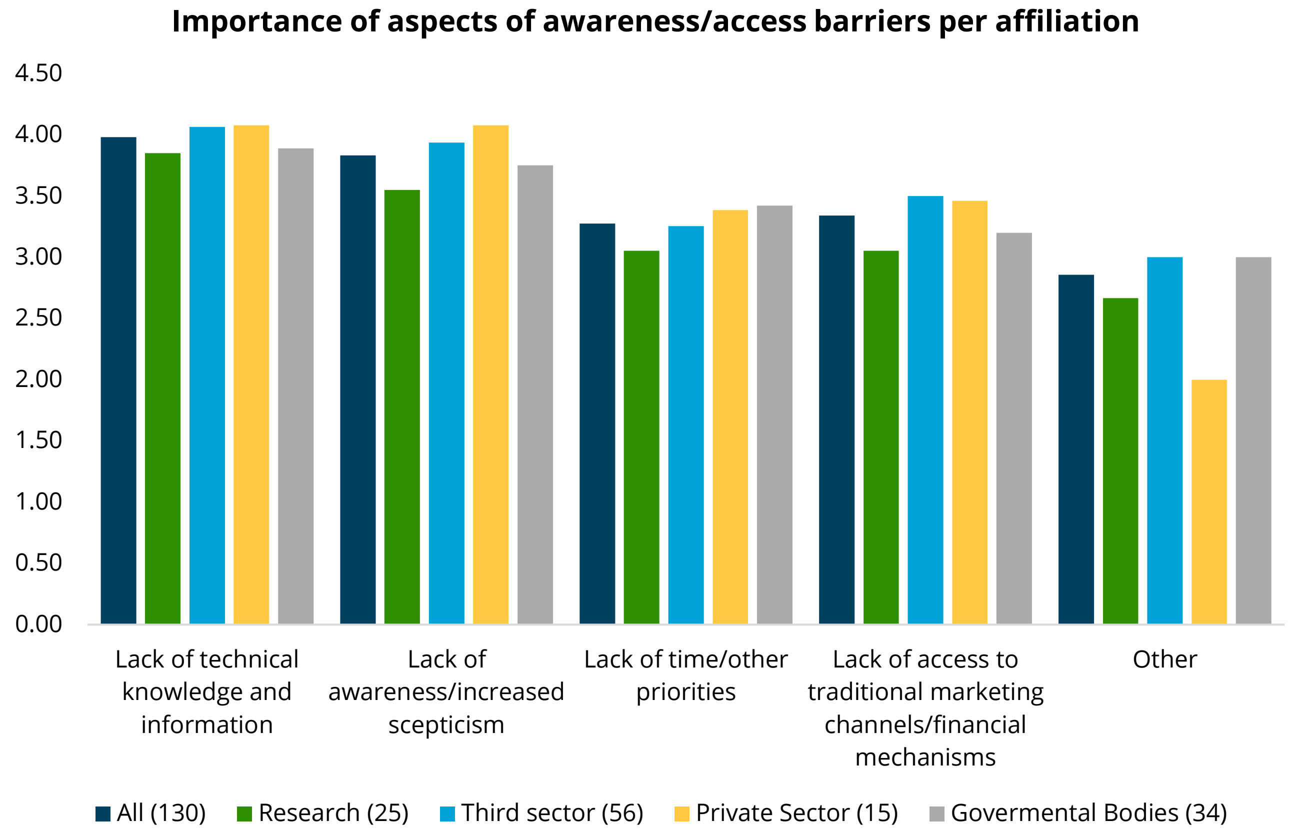


Fig. 19. Importance of different aspects related to awareness/access barriers per affiliation.

The shortage of local energy efficiency workers/lack of expertise was found to be, in general, the most important factor related to geographic barriers, especially by the private sector. However, the third sector identified geographical remoteness as equally important, whereas stakeholders from governmental bodies found "other" factors to be the most important ones (**Fig. 20**).

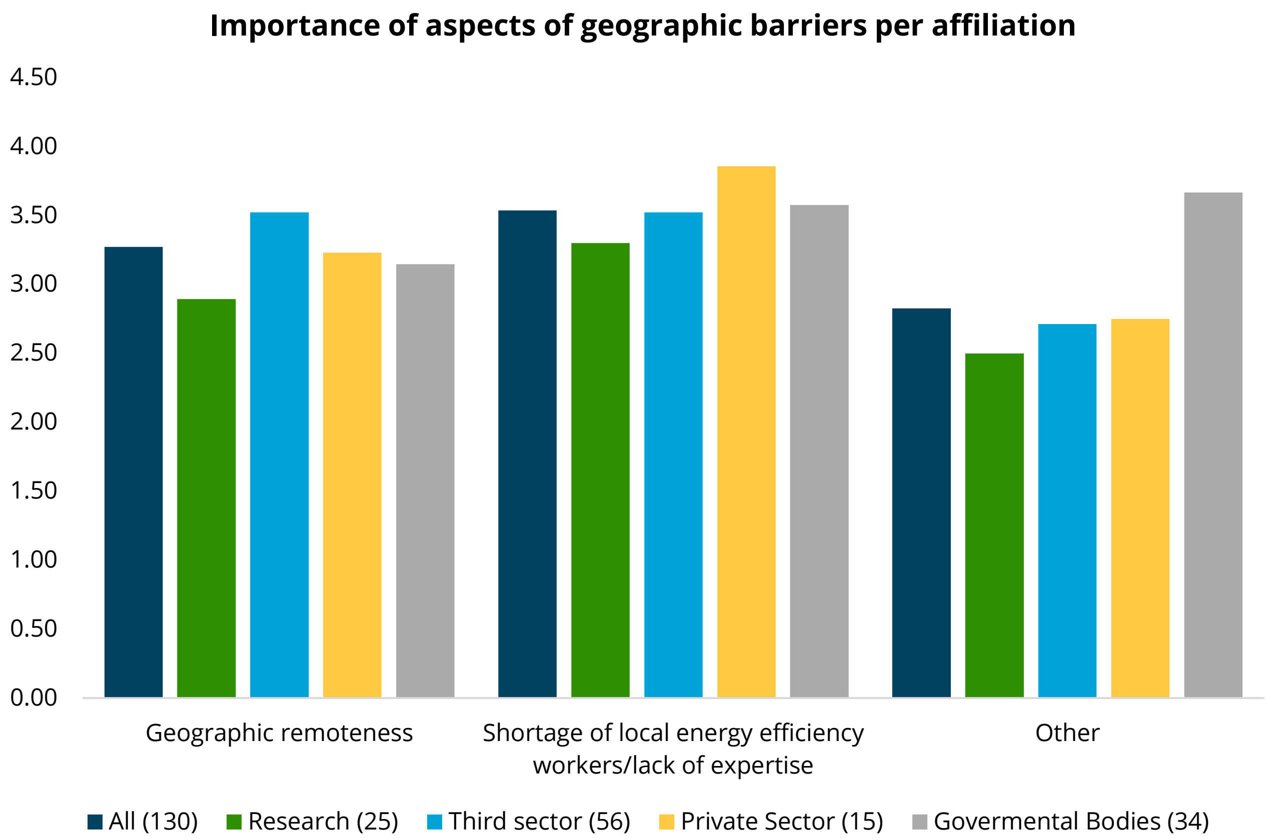


Fig. 20. Importance of different aspects related to geographic barriers per affiliation.

Lastly, when analysing the different factors related to regulatory barriers, it can be seen that an unsupportive and inconsistent policy setting was found to be the most important factor in general, however by a small degree. In fact, whereas the third sector found inadequate law and policies equally important, the private sector found the latter as the most important one. At the same time, governmental bodies found the lack of regional/local focus on national policies as the most important factor (**Fig. 21**).

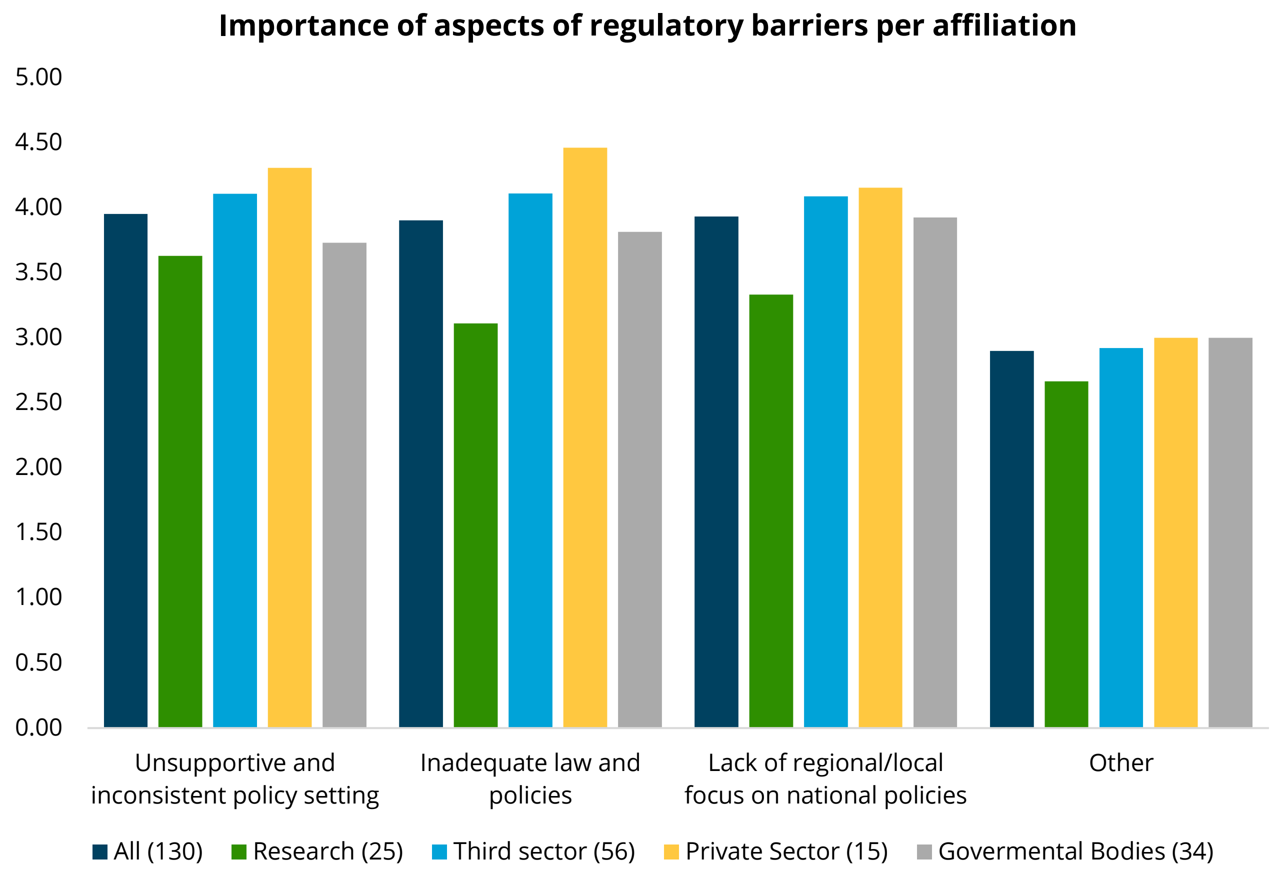


Fig. 21 Importance of different aspects related to regulatory barriers per affiliation.

4.1.7 Importance of barriers to micro-renewable energy in rural areas

All respondents who stated that they were involved in activities related to helping improve access to micro-renewable energy in rural areas were subsequently asked to evaluate – in the same manner used in the previous section – which barriers were the most important ones to tackle. Again, the answers were categorised per affiliation. In general, financial barriers were once again found to be the main culprit to the missing improvement of access to micro-renewables. Nonetheless, as expected, the private sector found regulatory barriers to be equally important. Additionally, as seen before, governmental bodies found "other" barriers, for example, the unreadiness of electrical distribution networks, to be more important compared to all other affiliations (**Fig. 22**).

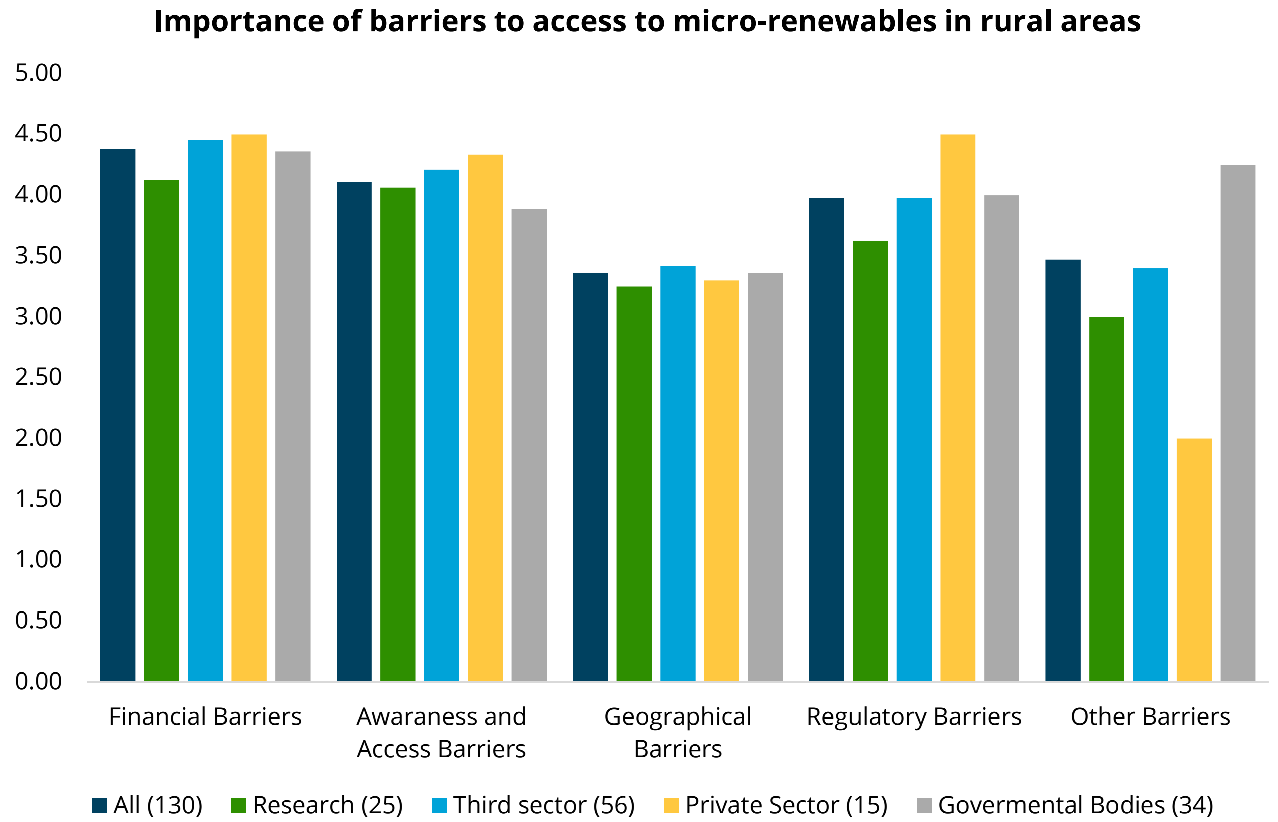


Fig. 22. Importance of different barriers to helping improve access to micro-renewables in rural areas per affiliation.

4.1.8 Importance of different policy levels in addressing energy poverty in rural areas

As a final quantitative question, every respondent was asked to rate the importance of the different policy levels to enhance the uptake of energy efficiency measures for the alleviation of energy poverty in rural contexts. The levels of importance were asked and evaluated utilising the same logic as in previous sections. When considering all of the received answers, at a general glance, the national-level policies were deemed as the most important ones to combat energy poverty in rural areas (**Fig. 23**). The results do not change greatly when categorising per region, with the majority still finding the national level policies to be the most impactful ones. Nonetheless, it must be noted that the regional level policies were found to be the most impactful in SE, in comparison to local level ones in CWE (however maybe due to the lower number of respondents in CWE) (**Fig. 24**). On the other hand, all working sectors found the national level policies to be the most impactful ones (**Fig. 25**).

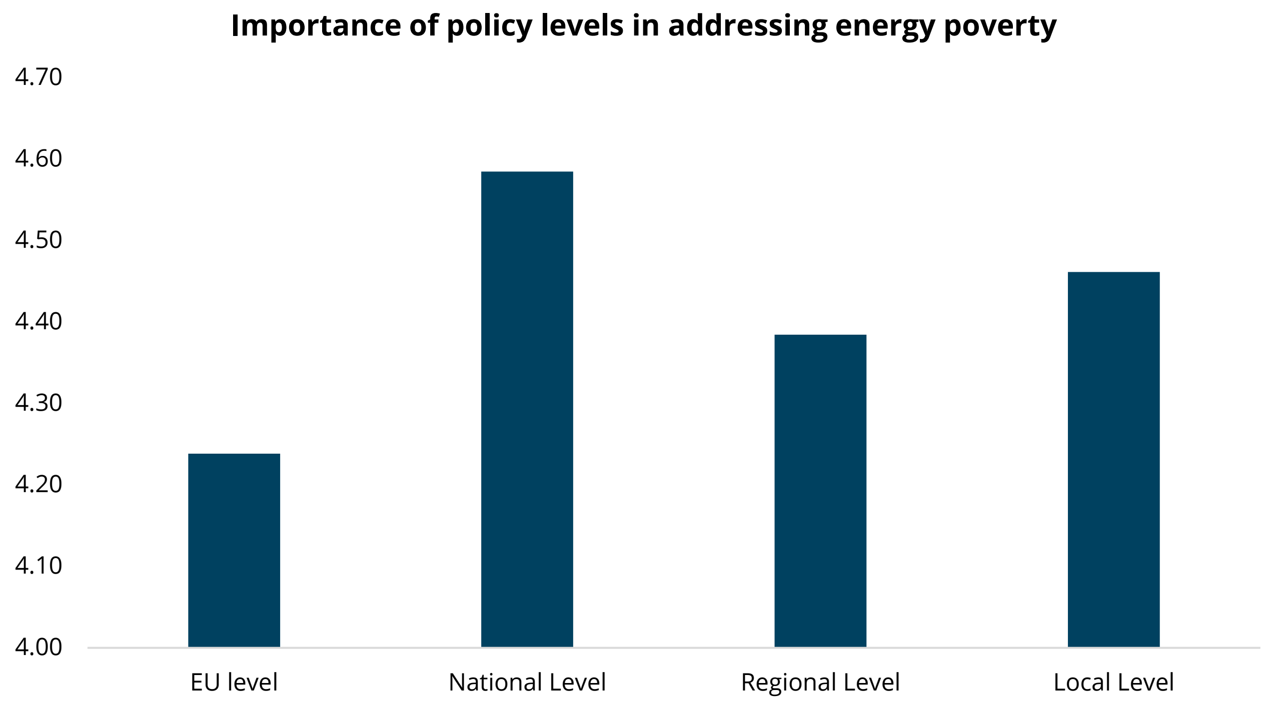


Fig. 23. Importance of each policy level when combating energy poverty.

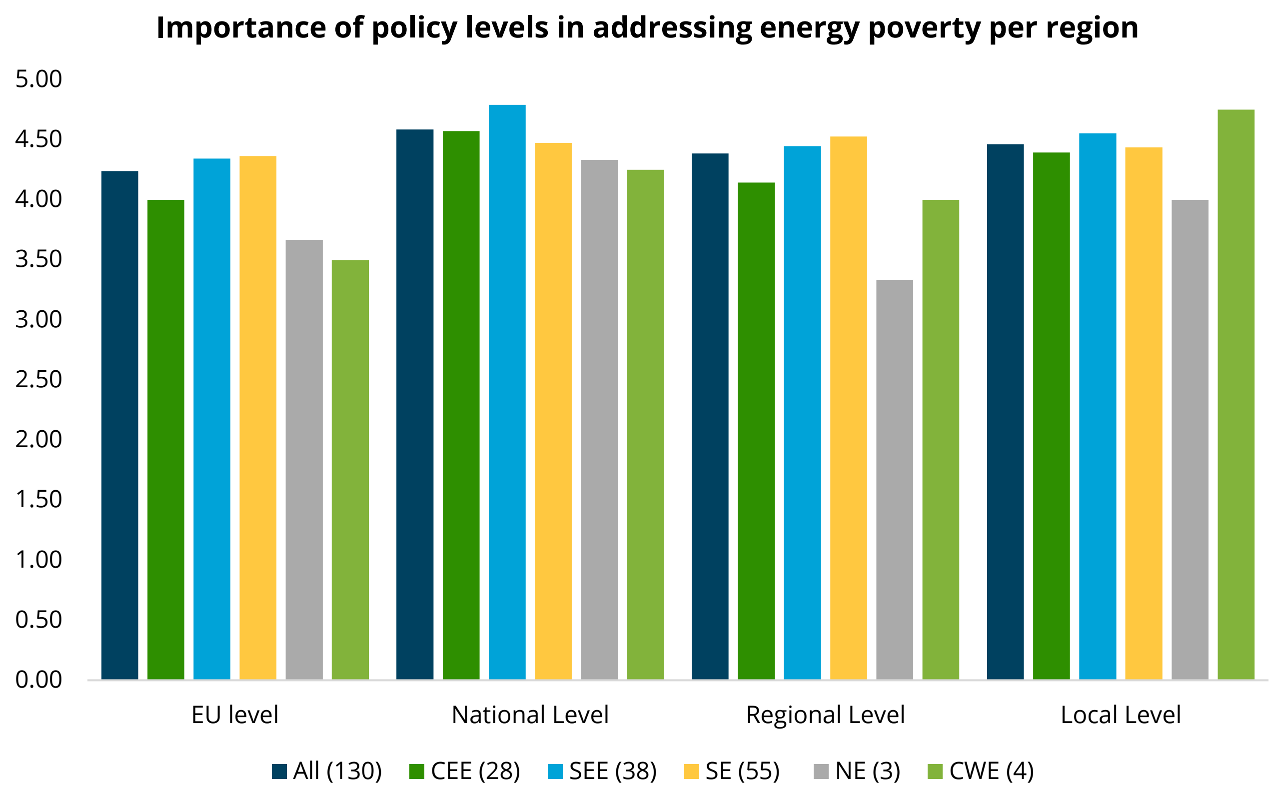


Fig. 24. Importance of each policy level when combating energy poverty per region.

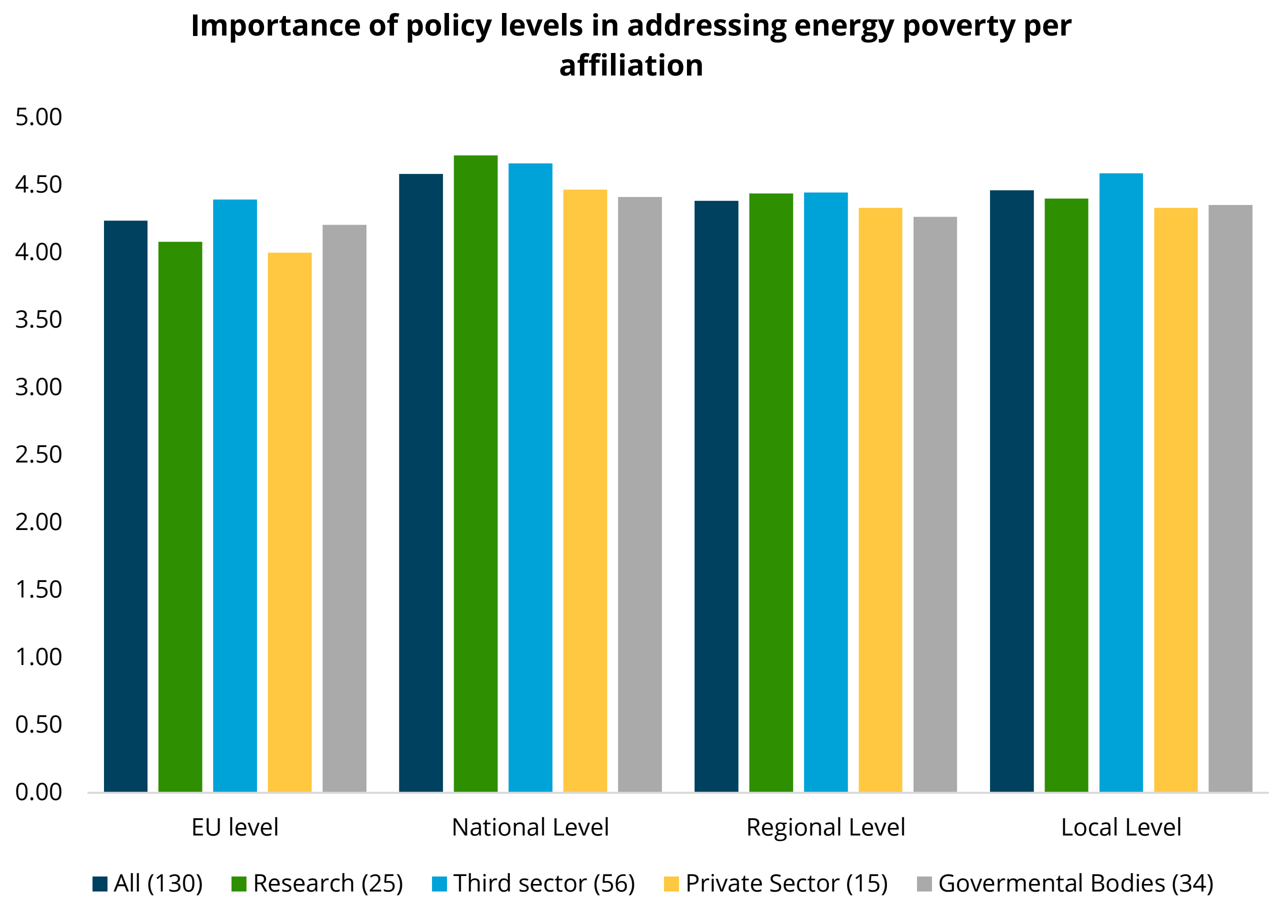


Fig. 25. Importance of each policy level when combating energy poverty per affiliation.

4.1.9 Narrative answers on prospective policies

Within the survey, there were several questions where participants were asked to provide narrative and concrete insights on practical solutions to overcome ongoing challenges. The participants in the survey offered insights into various actions that **governmental bodies at all levels (i.e., EU, national, regional, and local)** can implement to address energy efficiency and energy poverty in rural contexts.

In the case of EU governmental bodies, the statements made by the respondents suggest that they should focus on education and awareness, advocate for policy changes and funding, adopt a regional approach, engage stakeholders, and ensure financial support to effectively address energy efficiency in rural contexts. Several recurring themes emerge from the survey:

1. **Policy transformation:** A key theme is the introduction of policy changes in the existing legal and policy framework, including setting targets for energy efficiency and energy poverty reduction in rural areas. EU institutions can work to develop policies that support the implementation of these targets, enabling effective energy-efficient projects. In this sense, many statements highlight the importance of strategic, regulatory and legislative

changes specifically tailored towards rural areas. Institutions are urged to push for policies that consider the unique challenges and dynamics of rural contexts.

2. **Financial mechanisms and support:** Financial resources emerge as a central theme. There is a need for new funding mechanisms and financial support for energy-efficient initiatives, making projects feasible and sustainable in rural settings.
3. **Stakeholder engagement and collaboration:** Collaboration is emphasised as a crucial aspect. EU institutions should engage with all relevant stakeholders, including governments, communities, and institutions, to collectively address energy poverty.
4. **Education and awareness building:** EU institutions can initiate large-scale outreach programmes such as workshops, training programmes and public campaigns to enhance awareness and understanding of energy poverty issues within rural communities. This involves sharing knowledge about energy-efficient measures and solutions to empower residents.

In terms of **national governments**, the survey participants collectively identified three clear steps that relevant administrations can undertake in terms of tackling energy efficiency and energy poverty challenges in rural contexts. To some extent, these mirror the perception of necessary changes at the EU level:

1. **Policy design and implementation.** A prevalent theme is the need for well-designed policies that specifically address energy issues in rural areas. Relevant authorities should propose plans and strategies that consider the unique challenges faced by these communities. This includes creating subsidies, monitoring mechanisms, and legislation that encourages energy efficiency improvements. Organisations should empower local governments and communities to take action tailored to their specific needs, whether through decentralisation, community-based initiatives, or partnerships with local stakeholders.
2. **Financial support and incentives:** Financial support is a recurring theme, with suggestions ranging from dedicated funding for rural regions to tax incentives and subsidies for energy-efficient upgrades. Providing clear and accessible financial mechanisms is seen as crucial for encouraging rural energy efficiency projects.
3. **Access to information, training, and financing:** Many statements emphasise the importance of providing rural communities with access to information, training, and financing. This includes informing residents about energy efficiency measures and benefits, offering workshops, and facilitating financial support for implementing energy-saving solutions. Raising awareness about energy poverty and energy efficiency is also highlighted as essential. National governments should implement nationwide campaigns, educational programs, and community outreach efforts to disseminate information about available resources, technologies, and the benefits of energy-efficient practices.

As for **regional governments**, several key themes collectively emerge, providing insights into the development of a novel and comprehensive approach to address energy poverty and foster sustainable development in rural areas.

1. **Empowerment and customised strategies:** Respondents stress the significance of region-specific policies. They advocate for the creation of custom-built regional plans, leveraging local characteristics and resources. This entails empowering local governments, communities, and stakeholders to actively engage in decision-making processes. Efforts should extend beyond urban-oriented strategies, enabling the development of unique solutions for rural challenges. Once again, regional-level education and awareness campaigns are pivotal in conveying the benefits of energy-efficient practices to the population.
2. **Financial support and accessibility:** Financial aspects play a critical role in alleviating energy poverty. Recommendations encompass supplying financing, subsidies, and support mechanisms. Stakeholders highlight the importance of clear, accessible subsidy programs that cover a significant portion of costs, especially for marginalised communities. Long-term funding, innovative financing tools, and partnerships with financial institutions can ensure sustained investments in energy efficiency projects. Funding should be directed at areas with higher energy poverty prevalence.
3. **Collaboration and advocacy:** Effective collaboration between local, national, and European entities is essential. This involves cooperation with national stakeholders to improve rural-specific plans and policies. Advocacy for changes at higher levels, including harmonising regulations and access to incentives, is crucial. Partnerships with various organisations, industry players, and NGOs can bolster resources and expertise. Furthermore, the emphasis on lobbying and leveraging political influence reinforces the need for comprehensive and coordinated efforts.
4. **Inclusive infrastructure and innovation:** Infrastructure improvements are integral to rural development. Initiatives include enhancing public transportation connectivity, upgrading energy systems, and promoting sustainable building practices. Innovation is essential, especially in transitioning from dormitory villages to vibrant, self-sufficient rural communities. Supporting initiatives that utilise local resources, such as biomass or micro-generation, can bolster economic growth and energy security.
5. **Data-driven planning and accountability:** It is argued that effective policies rely on accurate data. Survey respondents state that identifying areas with higher rates of energy poverty, and crafting data-driven interventions is paramount. It is argued that governments must allocate resources to support data collection, analysis, and monitoring. The creation of dedicated departments to oversee local government activities can ensure

accountability in implementing plans. Moreover, facilitating collaboration between various stakeholders in data sharing can lead to more informed decisions.

The themes that emerge from the statements provided by the survey respondents regarding potentially relevant **local government** action can be summarised as follows:

1. **Financial support and funding allocation:** A significant focus is placed on new financial mechanisms and vehicles for vulnerable populations and energy efficiency initiatives. Statements suggest that local governments should allocate funds for retrofitting buildings, implementing energy-saving technologies, and supporting energy-poor households. There is also an emphasis on the targeted allocation of funds based on the specific needs of different regions.
2. **Local policy development:** Many statements acknowledge the unique challenges of rural areas, and call for contextualised local solutions to the greatest extent possible. Municipal authorities are urged to prioritise the energy challenges faced by rural regions within their remit, facilitate access to technical expertise, and develop specialised plans. The role of local governments in providing support to the most remote and vulnerable communities is also highlighted, particularly in relation to the reduction of transport poverty.
3. **Local engagement and participation:** Co-producing policy with local stakeholders, in addition to supporting energy communities, is also highlighted. Statements advocate for the involvement of rural residents in the decision-making processes, encouraging their participation in local energy projects, and establishing local energy communities. The need for communities to take ownership of the energy transition comes up frequently.
4. **Co-ordination and collaboration with higher levels of government:** The need for collaboration between local and regional governments, to implement national policies effectively, is also highlighted. Local governments are encouraged to work closely with authorities at other governance scales to overcome structural barriers and adapt policies to the local context. Local governments are seen as intermediaries to communicate the specific needs of their areas.

Overall, the survey responses point to a clear need for proactive engagement by public authorities to inform, empower, and financially support communities in tackling energy poverty and improving energy efficiency, with a strong emphasis on the local context and collaboration across different levels of government. It frequently emerged that addressing energy poverty in rural areas necessitates bolstering local communities through tailored strategies and targeted financial support. Collaboration between stakeholders, advocacy for policy changes, and inclusive infrastructure development, can all drive sustainable change. Finally, respondents highlighted that innovation, data-driven planning, and accountability measures strengthen efforts to support socially-equitable and energy-efficient rural environments.

5 Composite Energy & Transport Poverty Indicator (CEPTI)

CEPTI is an innovative tool designed to identify potential areas of concern and challenges of energy and transport poverty, particularly in understanding the complexities in European rural areas. In fact, its primary objective is to provide a more inclusive and nuanced perception of how energy and transport poverty intersect and impact households, especially in regions where traditional indicators may not fully capture the complexities of these issues. This is achieved by integrating various socio-economic and demographic factors into a singular, coherent framework.

The relevance of CEPTI to the RENOVERTY scope and objective lies in its ability to work as a methodology for the identification of vulnerable rural areas, and, thus, contribute to the identification and alleviation of energy poverty in such contexts. CEPTI draws inspiration from the work described above, aimed at the upgrading of the energy efficiency and energy poverty framework in rural and peri-urban areas. As identified from the aforementioned literature review and survey, as well as some specific characteristics of rural areas, such as the spread of population, lack of basic services, lack of territorial connectivity, etc., may make it more difficult to identify vulnerabilities, and specifically those associated with energy. Moreover, the stakeholder survey indicated poor public transport as the main driver of energy poverty, followed by underinvestment, demographic structure, geographic remoteness, and inefficient housing stock. Furthermore, CEPTI's approach aligns with RENOVERTY's emphasis on sustainable development and social equity. By considering a range of available data, including household expenditure on energy and transport, regional Gross Domestic Product (GDP), and socio-economic factors, CEPTI provides a holistic overview of poverty.

Overall, CEPTI offers a comprehensive analysis of energy and transport poverty, seeking to contribute to the overall RENOVERTY goals, which concern the effective identification, localisation, and tracking of vulnerable households, the alleviation of the specific needs and challenges, and the enhancement of living conditions in rural settings.

5.1 CEPTI Methodology

The methodology of CEPTI is determined by its robust data integration and a strong emphasis on replicability and comprehensive data utilisation. Indeed, a fundamental aspect of CEPTI's methodology is its replicability, ensuring that this framework can be consistent and comparable when implemented across different regions, times, and socio-economic conditions.

The CEPTI methodology includes the following steps:

1. <u>Data Collection</u>: Utilising widely available data sources, such as regional GDP and household expenditure surveys, to ensure ease of access and comparability.

2. Standardisation of Data: Implementing procedures to standardize data, allowing for consistent analysis across different regions, namely normalization of components between 0 and 1.

3. Customisation for Local Contexts: It is possible to adapt the indicator to other countries, and when microdata might be more wisely available, to local conditions, while maintaining the core methodology, ensuring relevance and applicability in various settings.

4. Guidelines for Implementation: Providing detailed guidelines for implementing the indicator in new regions, including exact data, analysis methods and processing, and interpretation of results.

As CEPTI leverages diverse data sources, including regional GDP figures, household expenditure surveys, and socio-economic indicators, it uses the proportion of household expenditure on energy and transport, contextualised within the broader economic conditions indicated by regional GDP, to understand the influence of economic factors on energy and transport poverty.

The four main components taken into account are:

1) **Per Capita Expenditure (PCE)** at the NUTS3[5] level to quantify how much a household spends on energy and transport services.

2) **Accessibility Score (AS)** at NUTS2[5] level, quantifying the number of average vehicles per household, as well as railway network passenger intensity and multimodal potential accessibility of a region.

3) **Energy Consumption**, which is assessed, and compared to the backdrop of the previous two components as well as Heating[6] and Cooling[7] degree days (HDD/CDD).

4) **Vulnerability** is assessed from the percentage of people at risk of poverty or social exclusion.

While primarily quantitative, CEPTI values the depth added by qualitative insights from the social practice theory (SPT) perspective, which views behaviours not just as individual choices but as

[5] NUT levels: NUTS 1: major socio-economic regions, NUTS 2: basic regions for the application of regional policies, NUTS 3: small regions for specific diagnoses.

[6] Heating Degree Days (HDD) index: the severity of the cold in a specific time period taking into consideration outdoor temperature and average room temperature (in other words the need for heating).

[7] Cooling degree days (CDD) index: the severity of the heat in a specific time period taking into consideration outdoor temperature and average room temperature (in other words the need for cooling). *i*

part of broader social routines. This theory considers the interconnected roles of materials (infrastructure and technology), competences (skills and knowledge), and meanings (cultural norms) in shaping energy and transport usage. Through this approach the indicator can offer a better approximation of the experiences of those affected by energy and transport poverty.

5.2 Preliminary findings for Croatia and Italy

Preliminary findings of the CEPTI in Croatia and Italy, two of the pilot counties of RENOVERTY, reveal significant insights into the dynamics of energy and transport poverty in these countries, particularly in rural areas.

5.2.1 Croatia

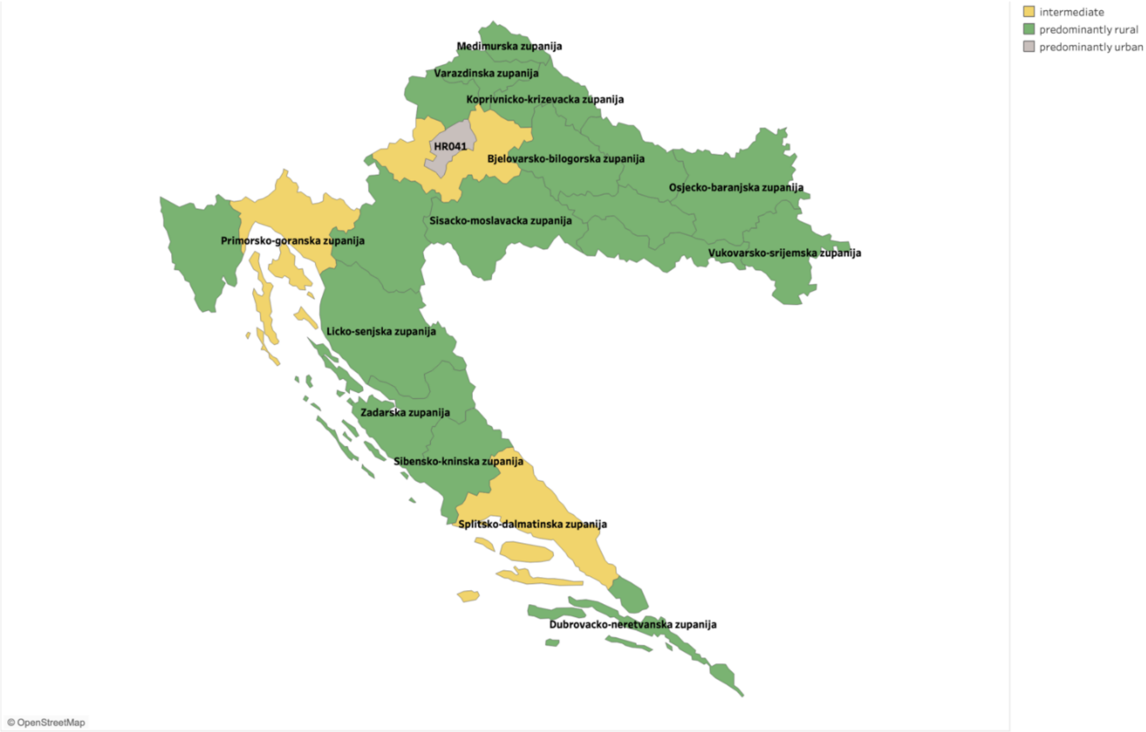


Fig. 26. Division of NUTS 3 Regions by Rural-Urban Typology in Croatia.

In Croatia, as shown in **Fig. 26** the majority of NUTS3 regions fall under the 'predominantly rural' category, with regions like Bjelovarsko-bilogorska zupanija, Brodsko-posavska zupanija, and Dubrovacko-neretvanska zupanija exhibiting lower PCE values. This indicates limited household expenditure on transport and energy, likely due to a combination of factors such as limited transportation options, economic constraints, and reliance on traditional, non-commercial modes of transport. The higher risk of poverty in regions like Brodsko-posavska Zupanija underscores the challenges faced by residents in accessing or affording efficient transportation. Zagreb, as a predominantly urban region, contrasts sharply with high PCE values and lower risk of poverty, reflecting its diverse transportation options and efficient energy use.

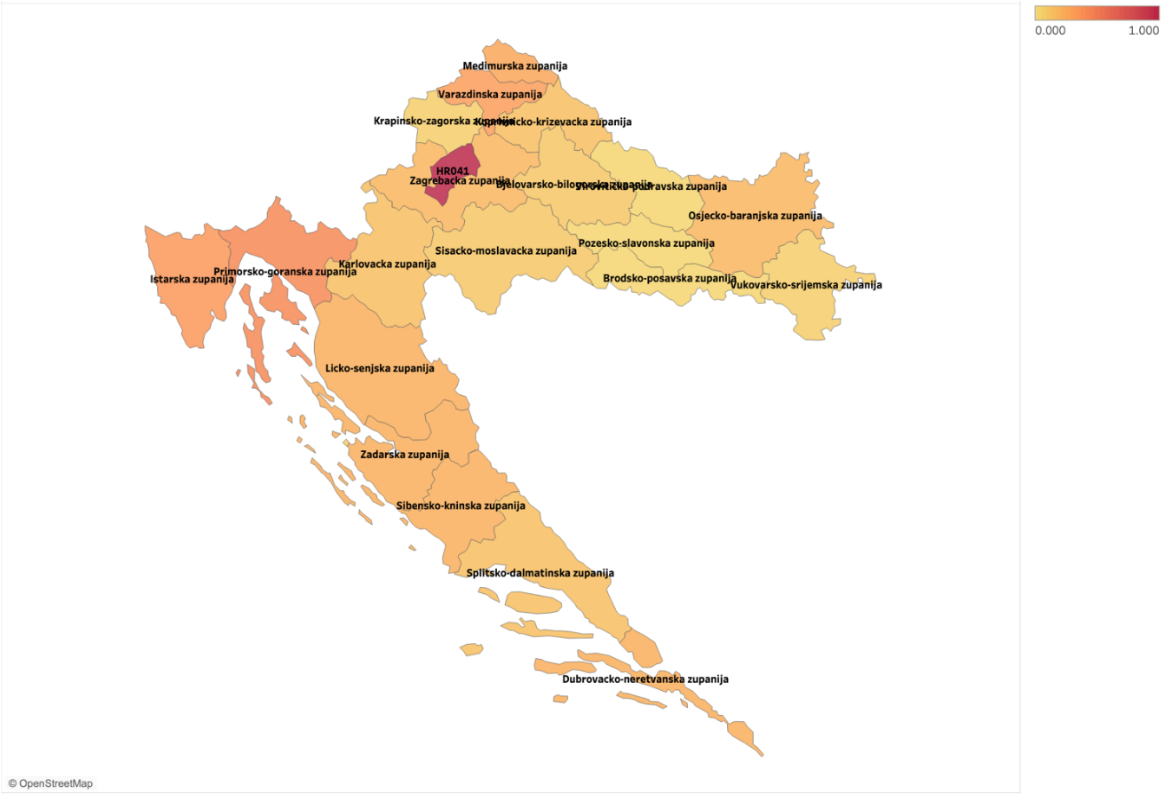


Fig. 27. PCE on Energy and Transport in Croatia, NUTS 3 level.

Fig. 27 depicts the PCE on Energy and Transport in Croatia. **Low PCE Regions**[8] **(PCE < 0.1)**, meaning the lowest expenditure on energy and transport services observed, align with the primary economic activities in these regions: agriculture and forestry, alongside which limited infrastructure, economic challenges, or efficient energy usage might contribute to the low PCE values. Then, **moderate PCE Regions**[9] **(0.1 ≤ PCE < 0.3)** have a balanced expenditure on energy and transport services. Some regions, especially in eastern Croatia, have faced challenges due to past conflicts, which might impact the current economic and infrastructural state. Lastly, **high PCE Regions**[10] **(0.3 ≤ PCE < 0.5)** regions, especially those along the Adriatic coast, have higher PCE

[8] Viroviticko-podravska zupanija, Pozesko-slavonska zupanija, Brodsko-posavska zupanija, Krapinsko-zagorska zupanija.

[9] Bjelovarsko-bilogorska zupanija, Osjecko-baranjska zupanija, Vukovarsko-srijemska zupanija, Karlovacka zupanija, Sisacko-moslavacka zupanija, Licko-senjska zupanija, Zagrebacka zupanija.

[10] Primorsko-goranska zupanija, Splitsko-dalmatinska zupanija, Istarska zupanija, Medimurska zupanija, Varazdinska zupanija, Koprivnicko-krizevacka zupanija.

values possibly influenced by tourism activities, as the influx of tourists requires the provision of more energy and transport services. Uniquely, as an outlier, Zagreb the capital city, exhibits the **highest PCE value (1),** attributable to its urbanized nature, diversified economy, and the presence of major infrastructures.

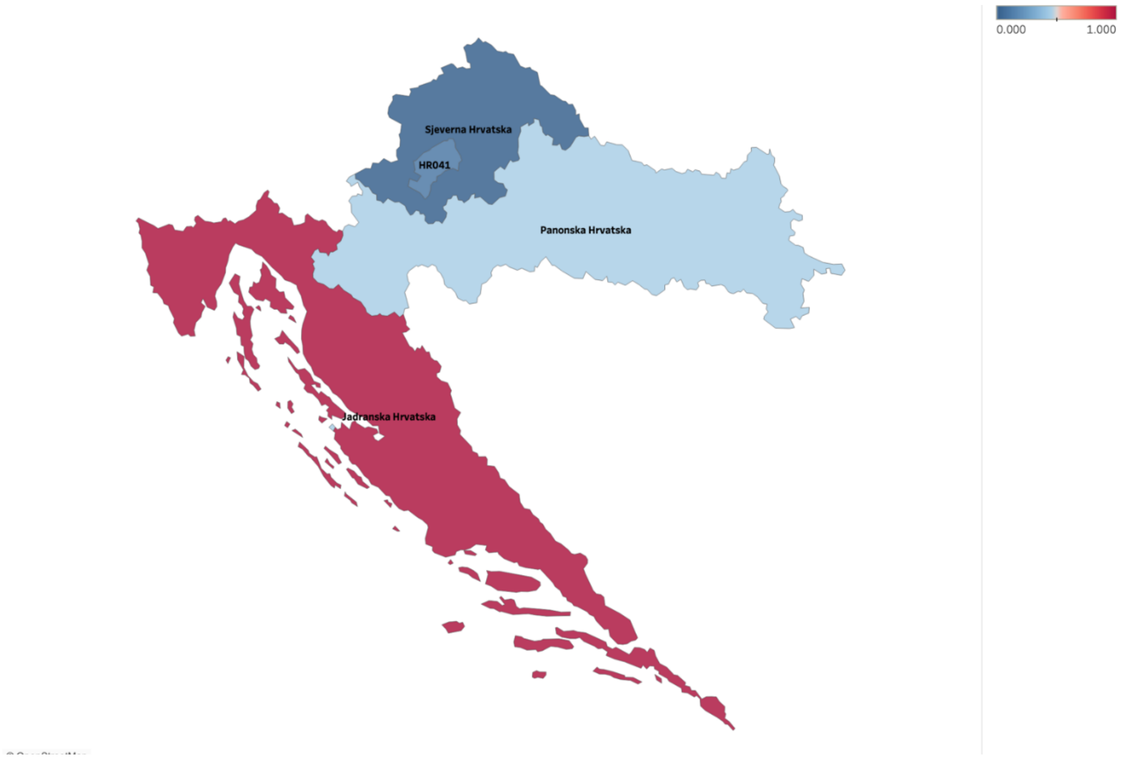


Fig. 28. Household Energy Consumption in Croatia, NUTS 2 level.

Household Energy Consumption in Croatia is presented in **Fig. 28**, **Panonska Hrvatska** reported a moderate energy consumption value, normalized at 0.443. This suggests that households in this region have a significant energy demand. It also shows a high normalized heating degree day value of 0.749, indicating a colder climate with substantial heating requirements, where needs are higher due to the colder climate. However, the consumption value is not proportional to its heating degree days value, indicating other factors might be influencing energy use. Secondly, **Jadranska Hrvatska** has the highest energy consumption among the regions, with the highest normalized value. Its PCE is relatively low at 0.072, hinting at potential variations in energy prices or household values and practices. Interestingly, this region has the lowest normalized HDD value, but the highest CDD, suggesting a warm climate with potentially significant cooling needs, exacerbated by aggressive coastal tourism and a lack of timely intervention to assure efficiency [66] Interestingly, the high energy consumption aligns with regional historical attempts to adopt solar energy following the oil crisis in the '70s, although the current utilization remains minimal [67].

Subsequently, **Zagreb**, despite its colder climate and heating requirements, appears to have lower energy consumption levels compared to other regions, with research arguing for some inherent problems in the energy sector in the capital, with issues such as an antiquated energy infrastructure, combined with poor management causing high losses and thus higher bills for citizens [68]. Notably, **Sjeverna Hrvatska** has the lowest energy consumption among the regions, but the highest normalised HDD value (1), suggesting a very cold temperature in line with its alpine climate [69], with the greatest heating needs as well as minimal cooling requirements [70].

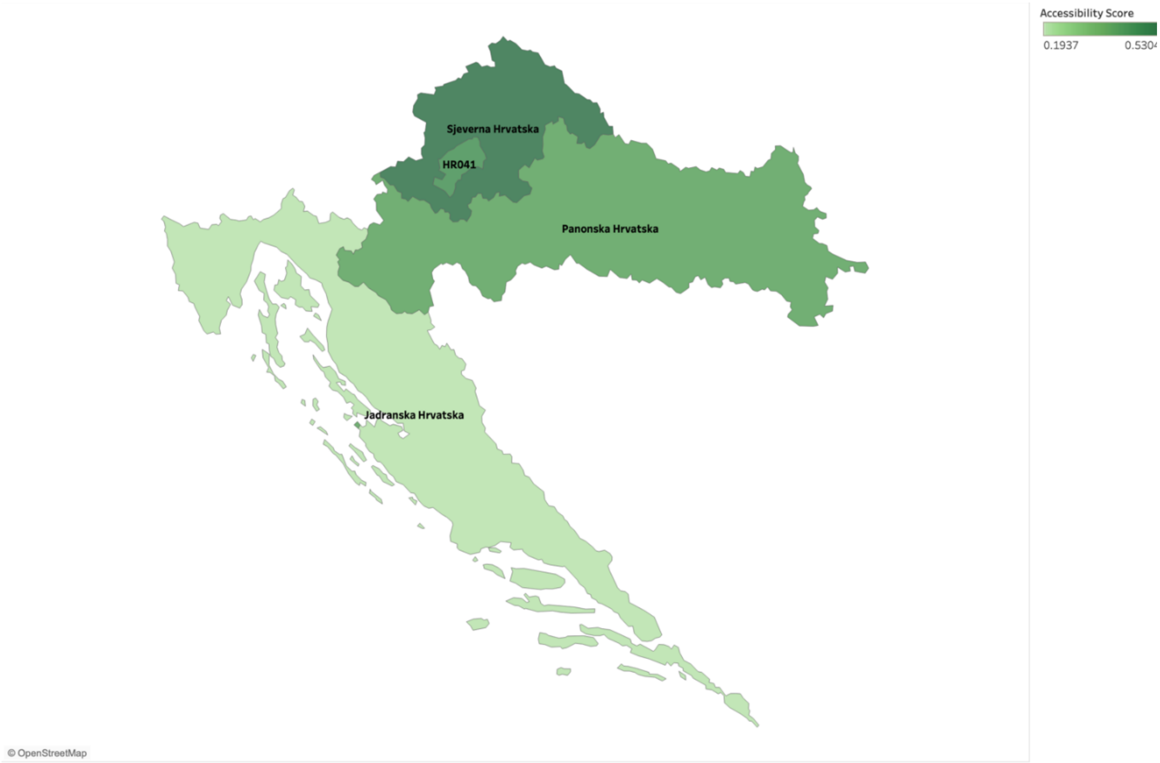


Fig. 29. Accessibility Scores in Croatia, NUTS 2 level.

In terms of accessibility, as shown in **Fig. 29**, **Panonska Hrvatska** has a moderate accessibility score.The combination of the three components suggests that while the region has decent rail connectivity, there's still a heavy reliance on private vehicles, possibly due to gaps in public transportation or the region's geographical layout. Second, despite having the highest average of vehicles per household, rail passenger intensity and multimodal accessibility are notably low in **Jadranska Hrvatska**, resulting in a lower accessibility score, likely due to the region's coastal geography, where road transportation might be more prevalent, and rail connectivity might not be as extensive. Third, **Zagreb** has an average score that includes the highest potential multimodal accessibility value in the country, reflecting its status as a transportation hub. Finally, **Sjeverna Hrvatska** has a commendable accessibility score but while the region has good multimodal accessibility, there's still a considerable reliance on private vehicles.

In regions like Panonska Hrvatska, a significant portion of the population is at risk of poverty (28.6%). In this context of this study, the economic vulnerability is contrasted by moderate accessibility levels, suggesting transportation availability but not necessarily affordability, as lower-income households in post-socialist states have been observed to have historically faced challenges, particularly in accessing affordable housing and transportation [71]. Other characteristics of post-socialist households relevant to understanding the disparities in Croatian regions are informality, very low tenure security, short-term occupancy, spatial exclusion, and eventually overcharging of the private rented sector [71]. While Jadranska Hrvatska shows a lower poverty risk (20.4%), its low accessibility score and high energy consumption suggest transportation inefficiencies, potentially exacerbating social justice, affordability and accessibility. This phenomenon, where socio-spatial mixing occurs alongside rising incomes and social inequalities, particularly in capital cities, is termed the "paradox of post-socialist segregation" [72]. Such dynamics might also be present in Grad Zagreb, which, despite its low poverty risk (13.3%) and efficient transportation infrastructure, shows low expenditure, possibly indicating economic constraints in spending. On this line, the importance of energy efficiency in housing is stressed, particularly in the context of thermal retrofitting [73]. In regions like Sjeverna Hrvatska, where transportation would seem more efficient because of a high accessibility value and where the energy consumption is the lowest, the focus might shift to improving housing conditions, by, for example, suggesting that retrofitting walls in households can be a cost-effective measure, potentially benefiting regions with high energy consumption and poor housing conditions [73].

Lastly, **Fig. 30** shows that the vulnerability of citizens in post-socialist countries is often linked to the legacies of the centrally planned economy [71]. Moreover, issues like poor thermal insulation of the housing stock and low energy prices contribute to this vulnerability [74]. Thus, the observed increasing trend of poverty in Croatia is particularly pronounced post-2008 [75], with a significant rise in the poverty rate urging policies to address immediate financial burdens but also long-term improvements in living conditions and energy efficiency.

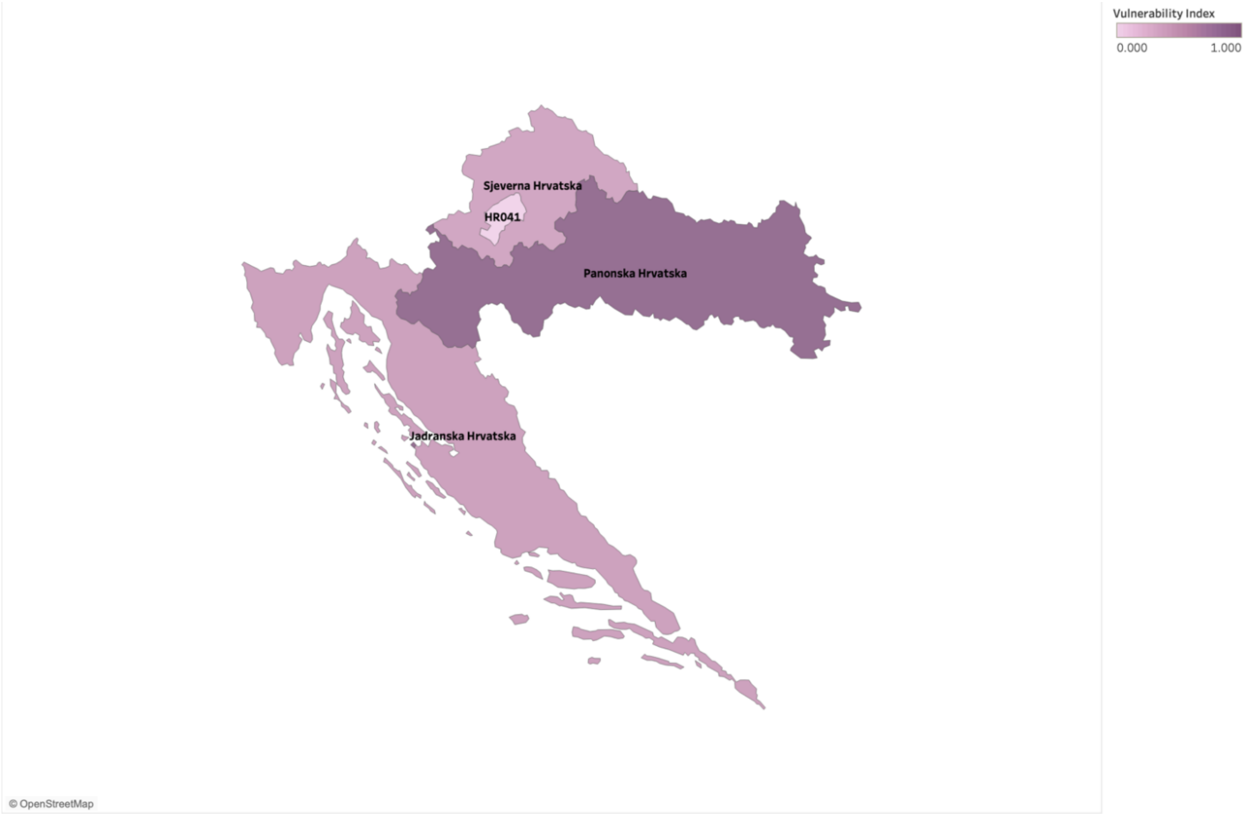


Fig. 30. Observed Risk of Poverty and Social Exclusion in Croatia, NUTS 2 level.

5.2.2 Italy

Fig. 31. Division of NUTS 3 Regions by Rural-Urban Typology in Italy.

In Italy, urban regions like Torino, Genova, and Milano show higher PCE values, indicating significant household expenditure on transport and energy, likely due to efficient transportation systems and a mix of public and private transport modes. Rural regions, however, display lower PCE values, reflecting limited transportation options and economic constraints. Intermediate regions exhibit characteristics of both urban and rural areas, with PCE values suggesting a balance between urban amenities and rural challenges, as illustrated in **Fig. 31**.

These findings highlight the stark contrast between urban and rural areas in both Croatia and Italy, with rural regions facing more significant challenges in terms of transportation accessibility, energy consumption, and economic indicators. The CEPTI effectively captures these disparities, providing valuable insights for policy development and strategic planning aimed at addressing energy and transport poverty.

Fig. 32. PCE on Energy and Transport in Italy, NUTS 3 level.

Fig. 32 shows PCE on Energy and Transport in Italy. Italy's PCE landscape is a reflection of its historical, economic, and geographical divides, starting from **Very Low, PCE Regions**[11] **were identified (PCE < 0.1)**, and include regions like Napoli and Caserta which likely have several socio-economic factors influencing their low PCE, similar to Agrigento. Moving on to **Low to Moderate PCE Regions**[12] **(0.1 ≤ PCE < 0.3)** these indicate a still low but more balanced expenditure on both energy and transport. The economic activities might be diverse, with a mix of agriculture, industry, and services. Infrastructure development and energy efficiency practices may be at an

[11] Barletta-Andria-Trani, Cosenza, Crotone, Vibo Valentia, Trapani, Agrigento, Caltanissetta, Enna, Siracusa, Caserta, Benevento, Napoli, Avellino, Salerno, Taranto, Brindisi, Lecce, Foggia, and several others.

[12] Biella, Verbano-Cusio-Ossola, Novara, Asti, Alessandria, Imperia, Savona, Pavia, Lodi, Rovigo, Gorizia, Ferrara, Massa-Carrara, Lucca, Pistoia, Livorno, Perugia, Terni, Pesaro e Urbino, Ancona, Macerata, Ascoli Piceno, Viterbo, Rieti, Latina, Frosinone, L'Aquila, Teramo, Pescara, Chieti, Isernia, Campobasso, Matera, Catanzaro, Messina, Ragusa, and others.

intermediate level. Then, **Moderate to High PCE Regions[13] (0.3 ≤ PCE < 0.6)** have a higher PCE, indicating a more significant expenditure on energy and transport services. Urbanization, industrial activities, and better infrastructure might be contributing factors. Regions like Torino, Genova, and Bologna have a higher urban population, leading to increased energy and transport demands. Finally, **Very High PCE Regions[14] (PCE ≥ 0.6)**, with Milano leading the list, signify the presence of major industrial hubs, advanced infrastructure, and a dense urban population possibly driving the high energy and transport expenditure. To support these results, many similarly valuable insights into these disparities and their implications are available in academic and policy-related literature.

[13] Torino, Vercelli, Cuneo, Valle d'Aosta/Vallée d'Aoste, Genova, La Spezia, Varese, Como, Lecco, Sondrio, Bergamo, Brescia, Cremona, Mantova, Monza e della Brianza, Verona, Vicenza, Belluno, Treviso, Venezia, Padova, Pordenone, Udine, Trieste, Piacenza, Parma, Reggio nell'Emilia, Modena, Bologna, Firenze, Prato, Pisa, Arezzo, Siena, Roma, Bari, and others.

[14] Milano, Bolzano, Trento.

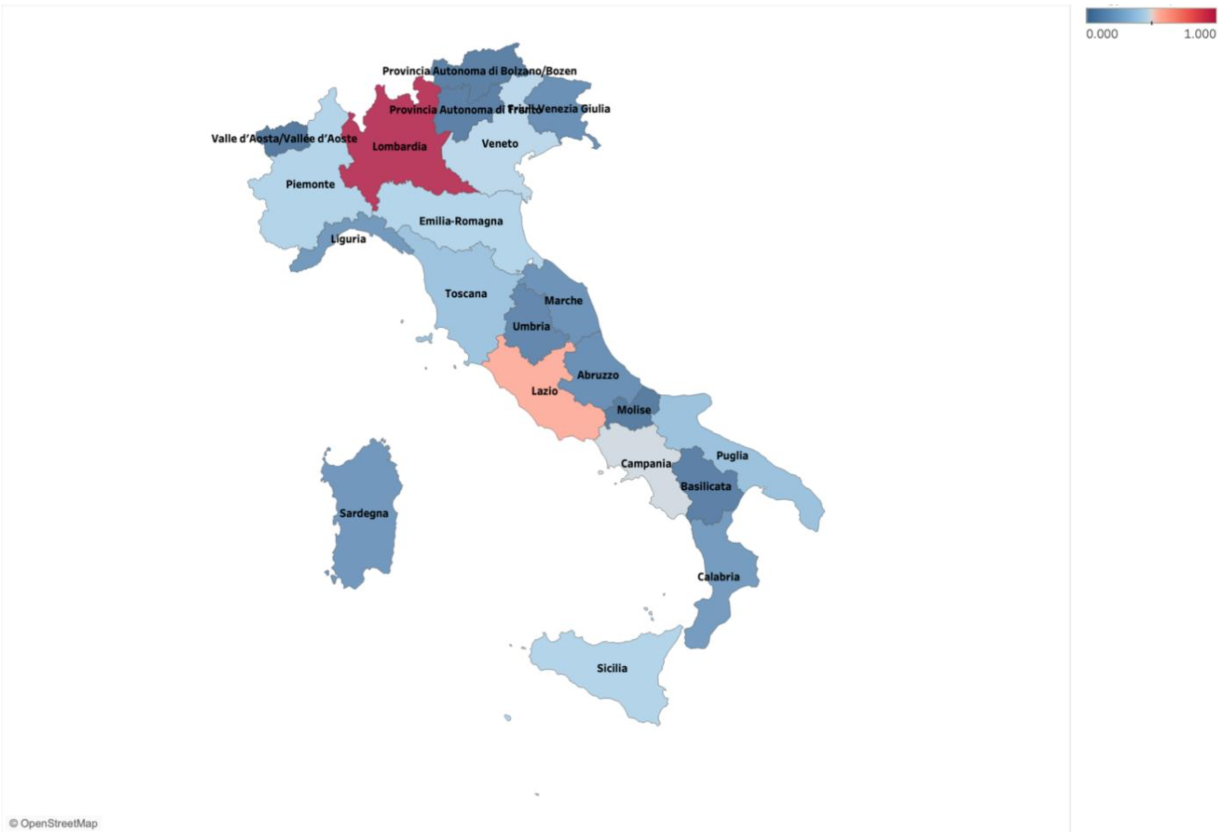


Fig. 33. Household Energy Consumption in Italy, NUTS 2 level.

Regions with High Cooling Demand and Low Heating Demand[15] have varied consumption levels, which can be seen in **Fig. 33**, with Sicilia and Lazio having higher values, while Calabria, Sardegna and Puglia have moderate consumption> These results are in line with evidence of energy consumptions in Italian regions between 2000 and 2013 [76]. At the same time, all of these regions have high normalized CDD values, indicating significant cooling needs due to warmer climates [77]. Their HDD values are relatively low, suggesting minimal heating requirements. In fact, these varying consumption levels might be influenced by regional infrastructure, energy efficiency practices, and household behaviours, overlapping with an observed lower energy efficiency level in the Southern region [76]. **Regions with Balanced Heating and Cooling Demand**[16] show Lombardia, confirmed by trends observed in literature sources [76], with the highest consumption, while the others have moderate levels that are influenced by both heating

[15] Calabria, Campania, Lazio, Puglia, Sicilia, Sardegna.

[16] Emilia-Romagna, Lombardia, Piemonte, Veneto.

and cooling demands [78]. In Lombardia's case, high consumption might also be attributed to urbanization, industrial activities, or other regional factors. Meanwhile, **Regions with High Heating Demand and Low Cooling Demand**[17] have relatively low consumption values, but they showcase high normalized HDD values [76]. On the other hand, their CDD values are minimal, suggesting low cooling needs. Despite their high heating demands, these regions have low energy consumption, possibly due to efficient heating systems, energy-saving practices, or in general more sustainable production practices, as indicated by the 100% regional share of renewable electricity production by Aosta, Trento and Bolzano [79]. Finally, **Regions with Moderate Heating and Cooling Demand**[18] have varied but on relatively low consumption levels. With moderate normalized HDD and CDD values, these utilization values are further confirmed in literature [76].

Fig. 34. Accessibility Scores in Italy, NUTS 2 level.

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[17] Provincia Autonoma di Bolzano, Provincia Autonoma di Trento, Valle d'Aosta/Vallée d'Aoste.

[18] Abruzzo, Basilicata, Friuli-Venezia Giulia, Liguria, Marche, Molise, Toscana, Umbria.

As shown in **Fig. 34**, the **Northern Regions**[19] of Italy generally have higher potential multimodal accessibility, with Lombardia, Piemonte, and Veneto leading in this aspect. These regions also display a significant rail passenger intensity, indicating a well-utilized rail system. The high accessibility score in Valle d'Aosta/Vallée d'Aoste is particularly notable, given its mountainous terrain. Continuing to **Central Regions**[20]**,** Lazio has a balanced transportation system. Both Lazio and Toscana have high rail passenger intensities, reflecting the importance of rail transport in these regions. The accessibility scores are relatively high, with Lazio leading, possibly due to its status as the national capital and transportation hub. Next, **Coastal Regions**[21] have moderate accessibility scores, whereas Liguria, with cities like Genoa, has a higher emphasis on rail transport. These central regions have a balanced mix of road and rail transportation, with a slight leaning towards private vehicles. Lastly, **Southern and Island Regions** [22] present varied accessibility scores. While Campania has a high score, which connects to Naples' urban influence of observed factors, regions like Sicilia have a lower score, although, the high value for potential multimodal accessibility in Sicilia seems to be an outlier and may need further verification in upcoming research.

[19] Lombardia, Piemonte, Veneto, Emilia-Romagna, Friuli-Venezia Giulia, Provincia Autonoma di Bolzano/Bozen, Provincia Autonoma di Trento, Valle d'Aosta/Vallée d'Aoste

[20] Lazio, Toscana, Umbria, Marche

[21] Abruzzo, Liguria, Marche

[22] Campania, Calabria, Puglia, Basilicata, Molise, Sardegna, Sicilia

Fig. 35. Observed Risk of Poverty and Social Exclusion in Italy, NUTS 2 level.

The broader context of Italy's regional disparities is historically rooted in its socio-economic structure; as the North-South divide is a well-documented phenomenon, with the northern regions generally being more affluent and the southern regions grappling with higher levels of poverty and social exclusion, this divide is even more exacerbated by urban-rural disparities, where urban areas tend to have lower vulnerability to factors like fuel price increases due to higher incomes and less reliance on cars, as opposed to rural or suburban populations [80], [81].

Fig. 35 presents the Observed Risk of Poverty and Social Exclusion in Italy. The northern regions, such as Lombardia, experience a contradictory scenario. With a moderate risk of poverty, these regions exhibit good accessibility scores, indicative of well-connected transportation networks. However, the high energy consumption in these areas suggests either a reliance on energy-intensive transportation modes or an inability for some to access it, potentially putting a financial strain on vulnerable populations, as high energy costs disproportionately affect those with limited resources [81].

In sharp contrast, the southern regions, exemplified by Campania, are stuck in high poverty risks, with rates soaring to 47.4%. These regions exhibit moderate accessibility values with high energy consumption and low expenditures accentuating a precarious situation: while transportation options may exist, they are not necessarily affordable or efficient for all, particularly for those in poverty [82]. The situation in Southern Italy, including regions like Sicily, is emblematic of the broader socio-economic issues prevalent in the EU's southern periphery, where poverty and social exclusion are intensely felt [80], [82]. Central regions like Lazio present a more complex picture. With a significant poverty risk of 24.1%, these regions have high accessibility scores, designating accessible transportation. Yet, similar to the north region cases, the high energy consumption here might point to energy inefficiencies or dependence on energy-intensive transport modes.

Moreover, Italy's struggle with hidden energy poverty adds another layer to this complex scenario. Hidden energy poverty, characterized by poor energy efficiency of buildings, low energy consumption, and climate sensitivity, is a significant issue, especially in regions with varying climate zones, and addressing this issue requires nuanced policy interventions that consider the heterogeneity of Italy's climate zones and socio-economic conditions [83]. In addition to economic and energy aspects, the ecological role of green infrastructures in Italian cities also determines the regional landscape and will gradually become either a chance for a just transition or a negative window of opportunity to further accentuate the divide. Nowadays, the relationship between urban green infrastructures and the delivery of ecosystem services in several Italian cities already demonstrates the variety of green infrastructure types and degrees of complexity that exist [84].

5.3 Next steps, recommendations, and final remarks

As we move forward within the RENOVERTY project, our focus shifts to a series of pragmatic and tangible steps that will enhance CEPTI's effectiveness and broaden its impact. Some major milestones ahead involve expanding CEPTI's reach to encompass more regions, thereby offering a richer, more diverse perspective on energy and transport poverty. In this regard, CEPTI will be exploited to provide valuable insights into the rest of the RENOVERTY pilot countries. On the other hand, the expansion of CEPTI is not just geographical. It also entails the thorough analysis of data as long as they keep being researched and reported, incorporating richer and more detailed sources to provide a clearer picture of the challenges and nuances specific to different areas, especially rural ones. Indeed, the refinement of our methodology is another critical step. A repetitive aim is to fine-tune CEPTI, drawing on the insights and feedback from its initial applications. This refinement process is crucial to ensure that our indicator not only captures the complex reality of energy and transport poverty, but does so with increased accuracy and sensitivity. CEPTI should not just become a tool for measurement, but a lens through which the subtleties and intricacies of this issue can be better understood. During this process, it is important to engage with those who can turn these insights into action. Through workshops, policy briefs, and seminars, it is possible to bring policymakers and stakeholders to participate in the dialogue, transforming data and analysis into practical, actionable policy recommendations. This step will be instrumental in ensuring that the knowledge gained from CEPTI is utilised beyond academic circles and makes a real impact on the communities most affected by energy and transport poverty. To make CEPTI as accessible and user-friendly as possible a tool could be designed to be intuitive and practical, enabling a wide range of users – from policymakers to researchers – to generate customized analyses that cater to their specific needs and contexts. Lastly, we see CEPTI as a living tool, one that evolves and adapts over time. Regular updates and revisions will ensure that it stays relevant, reflecting the ever-changing socio-economic landscapes and policy environments. This long-term commitment to monitoring and evaluation is key to maintaining CEPTI's role as a dynamic, responsive resource in the fight against energy and transport poverty.

6 Energy audits: Rural building stock characteristics

This section describes the outcomes of the RENOVERTY fieldwork, mainly related to the conduction of energy audits in vulnerable households in the project regions (Osona-Spain, Parma-Italy, Coimbra-Portugal[23], Bükk-Mak and Somló-Marcalmente-Bakonyalja-Hungary, Sveta Nedelja and Žumberak-Croatia, Tartu-Estonia, and Zasavje-Slovenia).

In accordance with the Energy Efficiency Directive (EU/2023/1791), an energy audit refers to a systematic procedure with the purpose of obtaining adequate knowledge of the energy consumption profile of a building or group of buildings, an industrial or commercial operation or installation or a private or public service, identifying and quantifying opportunities for cost-effective energy savings, as well as the potential for cost-effective use or production of renewable energy, and reporting the findings.

The methodology followed to conduct the energy audits in these specific contexts was to focus on identifying and assessing specific characteristics of dwellings in rural and peri-urban areas in CEE, SEE and Southern Europe, with a particular focus on dwellings used by vulnerable populations. The main goal of the energy audits was to gather solid evidence-based knowledge to better understand the complexity of the energy renovation scope and to contribute to the design of the renovation roadmaps following a tailor-made approach for each pilot area, also considering local geographic specificities of the targeted locations.

Due to the nature of the RENOVERTY project, the involvement of the Local Action Groups (LAGs)[24] was crucial to address local stakeholders, households, and citizens. LAGs were involved in identifying building typologies and suitable households to be used in the REERs, but also in the activities of carrying out the energy audits in the selected buildings. Moreover, LAGs have been acting as facilitators between local stakeholders and project partners, with a focus on the debates

[23] The results from the audits conducted in Portugal will be included in an updated version of this document.

[24] Local Action Groups (LAGs) are structures that aim to establish links between citizens, activities and rural areas. They set a local partnership to harness the differing and complementary resources of the public sector, the private sector and the civic and voluntary sectors, to unite local players in common activities and cross-sectoral actions and to envisage development through a multisectoral approach.

and topics arranged centrally by RENOVERTY and therefore supporting partners in the organisation of local events, but also in the dissemination of information within their local areas.

6.1 Energy audits conduction feasibility

One of the key steps to fully understand the specificities of energy poverty in rural areas is recognising the specificities of rural dwellings. Buildings are responsible for approximately 40% of EU energy consumption and 36% of energy-related greenhouse gas emissions, making buildings the single largest energy consumer in Europe. Heating, cooling and domestic hot water account for 80% of the energy that citizens consume [85]. At present, about 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is energy inefficient. Poor energy efficiency of rural dwellings is one of the key contributing factors to rural energy poverty, its depth and severity. As was discussed in the previous chapters, it is likely that many rural homes are older and poorly insulated, with outdated heating systems that are not efficient in keeping houses adequately warm or cool, when needed. Furthermore, rural heating systems are often dependent on individual heating sources, i.e., fuelwood stoves, various electrical heaters and similar, and do not always enable thermal comfort every room. That, coupled with the reality of rural areas aging and thus becoming more susceptible to feeling adverse impacts of inadequate indoor temperature, leads to the necessity of better understanding the characteristics of the rural building stock.

6.1.1 Description of the rural pilots for the conduction of the energy audits

To address the lack of understanding regarding the specificities of the rural building stock linked to energy poverty, a series of energy audits have been undertaken across the pilot areas in seven countries – Spain, Italy, Portugal, Hungary, Croatia, Estonia and Slovenia. More specifically, pilot areas are identified in rural and peri-urban areas with diverse cultural, economic, and social characteristics, with the aim to better identify and understand a wider variety of rural energy poverty manifestations. Pilot areas where energy audits have been conducted are described below.

1. **Osona-Spain:**

Osona and Lluçanès are two regions located in the interior of Catalonia. Both regions represent the most common organisational structure of rural areas in Spain, a country with a high diversity of climates and therefore household energy needs. In Spain, 89% of municipalities are rural (considering a maximum of 2,000 inhabitants). Osona has 42 municipalities and Lluçanès 11, with both regions being characterised by a climate marked by cold winters with thermal inversions and hot summers. For the carrying out of energy audits and in order to help identify and better understand rural energy poverty, the selection of the households has been carried out with the help of the social services and according to the following criteria: considering the two typologies of dwellings, single-family and multi-family and by selecting families who have applied for social support to pay energy bills.

2. **Parma-Italy:**

The province is typically divided into three zones from north to south: plains, hills and mountains. The northernmost, lowland part is bordered by the Po River. The main centres in the hill and mountain areas are located along the course of the main rivers, which descend from the Parma Apennines, flowing from south to north and flowing back into the Po. The climate is distinctly continental in the plains, with very hot summers and cold, wet and foggy winters. Climatic conditions improve in the Apennine foothills, where the annual temperature range decreases and summers are cooler. In the higher areas, the climate is typical of the mid-mountain zone, with intense humidity, cold winters and cool summers with frequent thermal inversions. Rainfall is moderate in the plains, more frequent and abundant in the Apennines, as are snowfalls, which are not lacking even in the plains and in the city of Parma itself, with an average of around 35/40 cm of snow every winter. Weather conditions lead, especially during winter, to the difficulty of maintaining house temperatures at adequate levels. This is due to both high energy and gas costs and inefficient buildings. Unfortunately, specific data from the pilot area are not currently available, but it is assumed that people affected by energy poverty are in line with the regional data, which stands at about 6% of households. One of the most rural areas in the province is in the Val di Taro, in which the audits were concentrated. To identify buildings, we have taken into consideration, with the support of the LAG, the year of construction, historical value, building size and whether the building was single-family or multi-family.

3. **Coimbra-Portugal**

The activities in Portugal will take place in two distinct locations in the District of Coimbra. The first is in the Tábua Municipality, a mountainous region in the centre of Portugal (60 km away from Coimbra). Climatic conditions are, therefore, typical of these regions with hot summers and very cold winters. The buildings are typically single-family houses, with poor energy performance. Although some buildings made of stone can still be found, the majority are made of brick (single wall). Most of the population still relies on wood burning (open fireplace) for their heating needs. The identification of households for the energy audits has been carried out with the help of the LAG (ADIBER) and the municipality.

The second is the small village of Arzila (around 650 inhabitants), part of the Coimbra municipality. It is located in the valley of the Mondego River, 30 km from the sea. Because of this, it has a fairly moderate climate, although rather humid. The village borders a marsh which is a natural reserve. The population used to rely on natural resources (fishing, agriculture) for their livelihood but now it is mainly a dormitory town with people working in nearby Coimbra. Buildings are all single-family houses, some semi-detached with poor energy performance. Most houses are over 30 years old and have not undergone renovation. Again, most of the population still relies on wood burning for their heating needs. The identification of households for the energy audits has been carried out with the help of the local LAG (CoimbraMaisFuturo), the local council and the local Ethnographic Group.

4. **Bükk and Somló-Marcalmente-Bakonyalja-Hungary:**

The Bükk region is located in Northern Hungary, where mining and forestry were dominant in the past, which also influenced the development of villages. In the Somló-Marcalmente-Bakonyalja area (located in Central Transdanubia) forestry is also important, but agriculture is dominant. Both of the Hungarian pilot areas (Bükk and Somló-Marcalment-Bakonyalja) include settlements where the majority of the dwellings are very poor from an energy performance point of view. In the Bükk area, air pollution is a particular problem in winter, when smog from inadequate fuel combustion settles in the river valleys. For the energy audits, house types that are typical of the areas were chosen. Some of these dwellings are traditional farmhouses, while others are representative of the socialist era. As a result of the renovations and alterations that have been carried out, the use of materials in the buildings is very varied and are therefore difficult to classify. Local building materials include stone, clay, brick and, in the beech region, slag concrete. The 44 residential buildings for the energy audit were selected with the help of local partners and LAGs.

5. **Sveta Nedelja and Žumberak -Croatia**

Sveta Nedelja and Žumberak are situated in central Croatia, not far from the country's capital Zagreb. Sveta Nedelja is one of the smaller cities, with a total of little more than 18,000 inhabitants, where almost half of its 14 settlements meet the criteria of rural areas. Sveta Nedelja is well developed with an increasing population and living standard. In contrast, the nearby Žumberak municipality has 610 inhabitants spread across more than 100 square kilometres, with a continuous decrease in population and some settlements having less than 5 inhabitants. Žumberak is also listed within the areas of special state protection, based on its economic development, structural challenges and demographics (Act on areas of special state protection, OG 86/08, 75/11, 148/13, 76/14, 147/14, 18/15, 106/18). These two areas have been selected to help identify and better understand rural energy poverty in central Croatia, focusing primarily on single-family houses as the most common type of rural dwelling in Croatia. With the help of LAG Sava and LAG Vallis Collapis who are well familiar with the local situation and trusted among the local community, 15 households residing in family houses have been selected for undertaking the energy audits.

6. **Tartu-Estonia**:

In Estonia, the focus lies with improving the energy efficiency and indoor climate of five typical designs of rural multi-residential apartment buildings. The renovation rate of the rural multi-residential apartment buildings is one of the lowest in the sector and the national refurbishment effort has not improved the situation. As many of these buildings have not seen refurbishment since their manufacturing in the 1960s and 1970s, the energy performance and indoor quality are not up to modern standards. Even worse, after the closing down of collective farming communities as an outcome of structural reforms at the end of the 20th century, indoor heating in many of these buildings was reorganized from central heating systems to local or individual heating solutions, something these buildings were not designed for. As an outcome of a lack of refurbishment efforts and do-it-yourself modifications in the heating systems, these buildings can offer only a substandard quality of life to their inhabitants, who otherwise have very few opportunities for choosing alternative housing. The situation of the buildings has not been studied in detail nor do we know the real scale of the problem. At the same time, these buildings are continuing to provide essential housing services for the rural centres that have not seen significant economic development during the last 30 years.

The selected pilot area in Estonia is a settlement called Kääpa (renamed in 2006, formerly Saare). This village has a population of about 250 people, most of whom live in multifamily houses built in the 1970s and 80s. Up to 2017, administratively reformed Kääpa was a centre of the Saare parish, and before 1991, the central hub of the Saare collective farm. The area is renowned through stories about the Estonian mythical hero Kalevipoeg (son of Kalev).

7. **Zasavje-Slovenia:**

The Zasavje region is the smallest in Slovenia, by surface area (264 km^2) and number of inhabitants. However, it is also the second most densely populated region in the country. It covers only three municipalities (Hrastnik, Trbovlje and Zagorje ob Savi) and has 42,824 inhabitants and 18,698 households. The average number of household members in Zasavje is 2.3 and the average age is 43.4 years (data for 2012). More than one-third of its gross value added comes from manufacturing and other industries, which makes it an industrial region. What is characteristic within the area is that heating is often based on wood fuels, while waste burning can occur too which both contribute to increased levels of indoor and outdoor air pollution. Larger single or multi-family houses where only 1 to 2 people live have problems with appropriate heating in winter due to high costs and energy inefficient buildings. The issue of energy poverty in Zasavje is not fully elaborated and well-defined due to the lack of data at the regional and local levels. Based on the available indirect indicators, it can be estimated that around 10% of households are facing energy poverty. The reasons for this lie in the socioeconomic status of the affected households, which are tied to low-income families living in old and energy inefficient building stocks. The average age of the dwellings in the region is over 45 years, and less than one-third of the dwellings built before 1970 have been renovated. RENOVERTY has thus worked with a set of local actors to identify the households and buildings that will take part in the pilot action including the

Municipality of Hrastnik, the Housing fund of Hrastnik, Centre for Social Work, Regional Development Agency Zasavje and ELARD local partners.

6.1.2 Definition and methodology of the conducted energy audits

As already mentioned, an energy audit is a systematic inspection and analysis of energy use and energy consumption of a building [22]. In simpler terms, an energy audit offers detailed information about the energy characteristics of the dwelling, its energy systems and energy sources and provides us with a list of measures identifying potential for improving the overall energy efficiency.

This type of information is crucial to fully understand energy poverty in rural areas, as well as to be able to address the identified contributing factors to its prevalence and severity and as a final result, to be able to successfully address them. Based on the results of energy audits, energy performance certificates (EPCs) are issued for each dwelling. EPCs are important instruments that help improve the energy performance of buildings, with a central role in the EPBD (2010/31/EU and 2018/844/EU together with the proposal for a recast COM/2021/802 final). Energy performance certificates provide information to consumers on buildings they plan to purchase or rent. *They include an energy performance rating and recommendations for cost-effective improvements. Certificates must be included in all advertisements in commercial media when a building is put up for sale or rent. They must also be shown to prospective tenants or buyers when a building is being constructed, sold, or rented. After a deal has been concluded, they are handed over to the buyer or new tenant. Energy Performance Certificates should also disclose cost-effective ways and, where appropriate, available financial instruments to improve the energy performance of the building to the owners or tenants of the buildings* [86].

While the overall approach to EPCs and energy audits is defined within the EPBD and other legislations related to it, member states' approaches to EPC schemes vary. Thus, for the purpose of this pilot study within the RENOVERTY project, a unified methodological approach was developed, allowing each participating pilot partner to use professional energy auditors according to their national methodology while ensuring that the data collected is comparable across the RENOVERTY pilots.

Guidelines were prepared outlining the minimum data required, which are adapted to identify the specificities of dwellings in rural and peri-urban areas of CEE, SEE and SE countries and subsequent activities of the project (i.e., simulations for the development of energy efficiency portfolios addressing energy poor households in pilot regions) (**Table 7**). The Data Inventory table developed within the crossCert project (publicly available [87]) was used as a starting point for creating these guidelines, considering also the diversity of the RENOVERTY pilot countries.

Table 7. Minimum data required from the energy audits.

Weather/ Climate characteristics	Climate/ Climate Zone Heating degree days (HDD) Cooling degree days (CDD) Heating season start/end date Cooling season start/end date
Building characteristics	Type of building/ usage: Year of Construction or Renovation: Building size: Total Floor area of the building [m^2]: Habitable area [m^2] Total area of external walls of the buildings [m^2] Conditioned area [m^2] Net conditioned volume [m^3] For each wall: Type [roof/wall/floor/inner partition], Total area [m^2], U-value [$W/(m^2 \cdot K)$], Orientation] Total Roof area of the building [m^2] Total Window area of the building [m^2] For each window: type (window, skylight, door), system (e.g., 3-mm clear glazing + wooden frame), U-value [$W/(m^2 \cdot K)$], total area [m^2]
Construction features (U-values)($W/m^2/K$)	U_{wall}: U_{floor}: U_{roof}: U_{window}: Type of construction (E.g. reinforced concrete, wood, etc.)
Building systems	HVAC system (e.g., DHW, heating-only, cooling-only, heating and cooling, heating and DHW, heating cooling and DHW, ventilation system) Type of system (e.g. standard boiler, condensing boiler, low-temperature boiler, heat pump, heat

	pump - variable flow-rate, electrical boiler, constant COP unit, air conditioning, air conditioning - variable flow rate) Nominal capacity [kW] COP / SCOP / EER/ SEER (if available): Ventilation and pumping (e.g., constant flow-rate ventilation, variable speed ventilation, constant flow-rate pump, variable speed pump) Energy consumption (kWh/year): Air flow (m^3h/m_2): Lighting equipment (estimated number of lighting appliances) Lighting equipment capacity (e.g., traditional or LED bulbs/ 60 or 40 W per bulb/ appliance) Installed power (W/m^2):
Other parameters	Occupancy (e.g., people/ m^2 or mean number of people using the building or building unit) Occupants' indicative working schedule (e.g., Weekdays 9:00–17:00) Occupancy schedule (e.g., working days, Saturdays and Sundays start/end hours)

The collected data was analysed per pilot and country. This analysis is presented in the following chapters.

6.2 Audit results

6.2.1 Osona-Spain

A total of 20 buildings were audited in Spain, including 19 multi-family buildings and 1 single-family house. On average, three or more household members live in most of the audited buildings and predominantly occupy the space from 5 pm to 9 am in the morning, and throughout the entire weekend (**Fig. 36**).

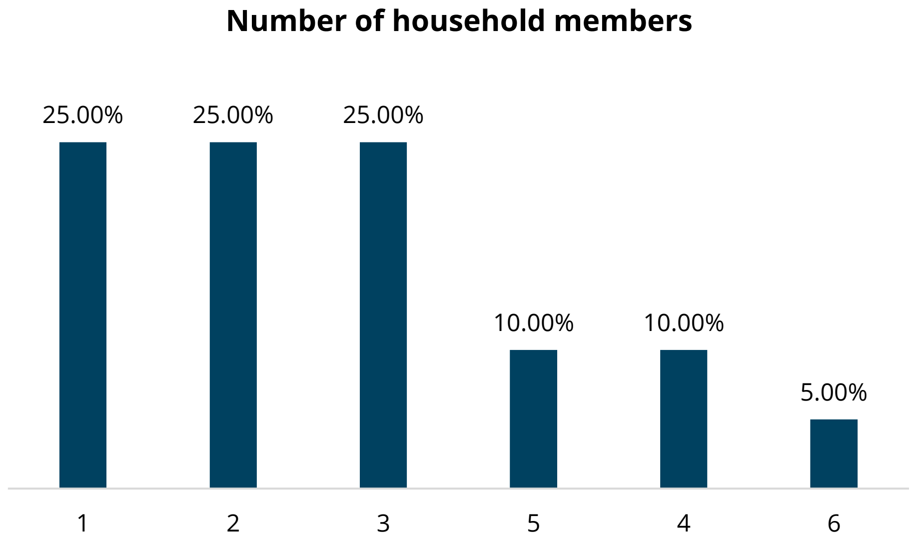

Fig. 36. Number of household members in pilot area Osona, Spain.

The year of construction of multi-family audited buildings is in the range of 1892 to 2010, and the average year of construction is 1960. Most of the audited multi-family buildings have a basement and 3 ground levels, with an average total floor area of 98.05 m^2, and an average habitable floor area of 82.38 m^2. The audited single-family house was constructed in 1790, but also reconstructed in 1967. It has 2 ground levels with a total floor area of 140 m^2 and a habitable area of 72.12 m^2.

Most dwellings have no building insulation, and the walls of the older houses are made of brick or stone with interior plaster, with the most common composition being mortar plaster, perforated brick, unventilated air chamber, perforated brick and plaster. Windows and doors are old and inefficient with single-glazing or double-glazed windows with wooden or metal frames, prone to air infiltration. Roofs are mainly double-pitched and above uninsulated attics, which further contributes to energy inefficiency due to significant heat losses and lack of heat retention in winter. Conversely, in the summer, the great radiation and lack of insulation means that there is also overheating in the house. Therefore, the lack of insulation makes it colder in the winter, but hotter in the summer as well.

The average U-values[25] of walls, floors, roofs, and windows of the Spanish pilot households are presented in **Table 8.**

Table 8. Average U-values of the Spanish pilot households as derived from the energy audits.

U-value (W/m²/K)	
U_{wall}	1.90
U_{floor}	1.76
U_{roof}	1.48
U_{window}	3.58

Heating systems among audited buildings differ, and the following heating systems are used:

- community oil boiler
- natural gas boiler
- oil boiler
- biomass boiler
- municipal biomass boiler system
- electric radiator
- butane cooker

Most heating systems used in audited buildings use generally inefficient heating sources and can pose health risks due to incomplete combustion, emissions of harmful particulate matter, poor indoor air quality, inadequate heat distribution, etc. In most buildings, LED bulbs (18 W) are installed in combination with incandescent bulbs (60W).

Overall, most of the audited houses in the Spanish pilot area Osona have an energy efficiency class **E** and **G** with an average primary energy of 223.49 kWh/(m²a). The distribution of energy efficiency classes for audited houses in the Spanish pilot area is shown in **Fig. 37.**

[25] U-value is a sum of the thermal resistances of the layers that make up an entire building element – for example, a roof, wall or floor. It also includes adjustments for any fixings or air gaps and provides a thorough estimation of the performance of the building in terms of thermal losses [88].

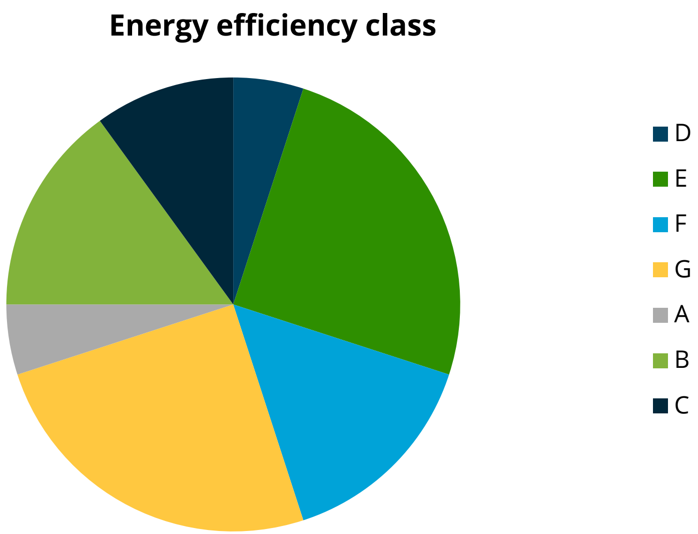

Fig. 37. Distribution of energy efficiency classes for audited buildings in pilot area Osona, Spain.

According to the data available from the Institute for Energy Diversification and Saving (IDAE), the National Statistical Institute (INE) and reports prepared and published by the Ministry of Transport, Mobility and the Urban Agenda, most family houses in Spain were built before 1980 and are ranked in energy class E and lower with almost no or only minimal thermal isolation. Such houses consume 70% of energy for heating, cooling and domestic hot water preparation. In terms of energy consumption, energy efficiency measures can significantly reduce the energy consumption in a building, in some cases up to 60% compared to current energy demands. As family houses are responsible for 30% of the total energy consumption at the national level, significant energy savings on the national level could be achieved with the implementation of the energy efficiency measures, therefore also contributing to the national goal of carbon emission reduction.

6.2.2 Parma-Italy

A total number of 8 buildings were audited in Italy, including 5 multi-family buildings (of which 2 bi-familiar) and 3 single-family houses. On average, two or more household members live in most of the audited buildings and the spaces are occupied throughout the day, regardless of the time considered, except in two cases: in the first case the space is occupied only during holidays; in the second case the building is not inhabited (**Fig. 38**).

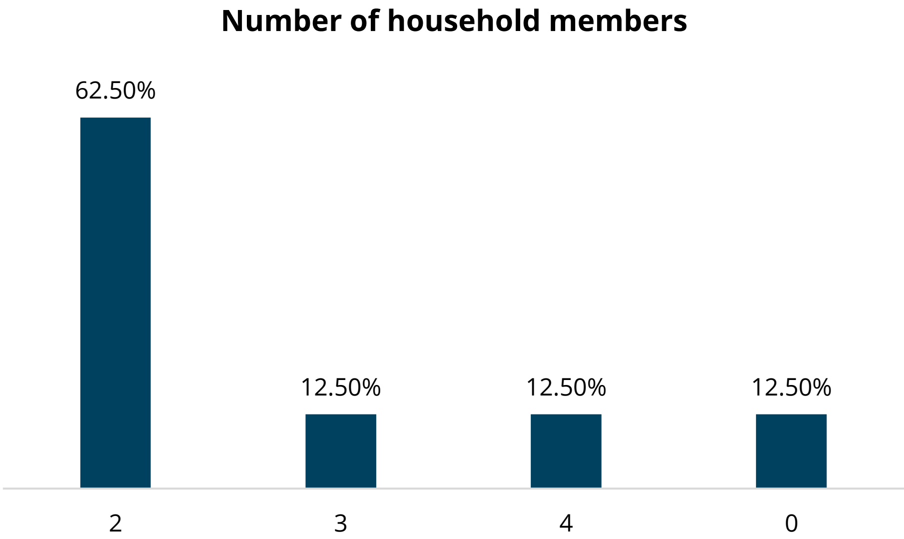

Fig. 38. Number of household members in pilot area Parma, Italy

The year of construction of the multi-family audited buildings is in the range of 1960 to 1975, and the average year of construction is 1966. The audited multi-family buildings have 1-4 ground levels with an average habitable floor area of 105.38 m^2. Audited single-family houses are constructed between 1900 and 1920, with the average year of construction being 1907. They have 1-2 ground levels with an average habitable floor area of 111.38 m^2.

Most of the buildings audited do not have building insulation, the buildings are predominantly made of brick. Other building materials used include stone brick, wood and pumice. Windows and doors are old and inefficient with single-glazing or double-glazed windows with wooden or metal frames, prone to air infiltration. The buildings all have brick attics without adequate insulation, thus contributing to energy inefficiency, heat loss or inadequate temperature maintenance.

The average U-values of walls, floors, roofs, and windows of the Italian pilot households are presented in **Table 9**.

Table 9. Average U-values of the Italian pilot as derived from the energy audits.

	U-value ($W/m^2/K$) of multi-family buildings	U-value ($W/m^2/K$) of single-family houses
U_{wall}	1.21	1.59
U_{floor}	1.27	1.26
U_{roof}	1.66	1.42

U_{window}	4.45	2.38

Heating systems among audited buildings differ, where oil and gas-fired boilers are mostly used in multi-family buildings, while LPG boilers and wood stoves are used in single-family houses. Most heating systems used in audited buildings are generally inefficient heating sources and can pose health risks due to incomplete combustion, emissions of harmful particulate matter, poor indoor air quality, inadequate heat distribution, etc. In most buildings, LED bulbs (18 W) are installed in combination with incandescent bulbs (40 or 60W).

Overall, most of the audited houses in the Italian pilot area Parma have an energy efficiency class G with an average primary energy of 411.94 kWh/(m^2a) with multi-family buildings consuming an average of 444.01 kWh/(m^2a) of primary energy and with an average of 358.49 kWh/(m^2a) consumed in single-family houses. The distribution of energy efficiency classes for audited houses in the Italian pilot area is shown in **Fig. 39**.

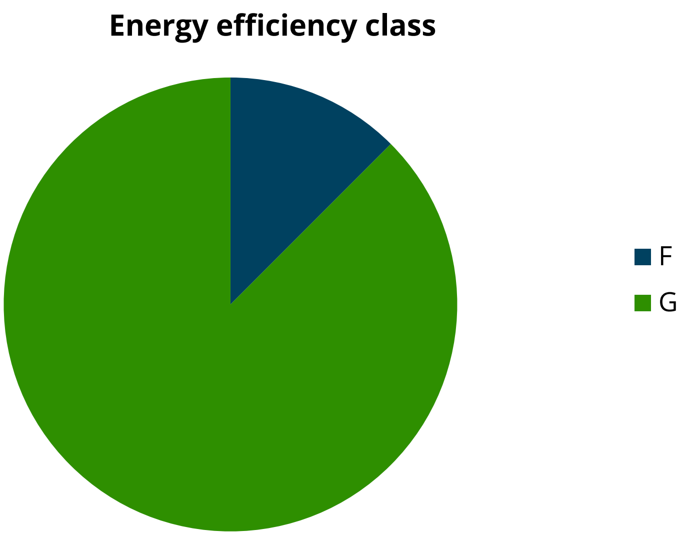

Fig. 39. Distribution of energy efficiency classes for audited buildings in pilot area Parma, Italy

According to the data contained in the 'Strategia per la Riqualificazione Energetica del Parco Immobiliare Nazionale', there are 12.42 million buildings for residential use. More than 65% of this building stock is over 45 years old and, of these, more than 25% record annual consumption from a minimum of 160 kWh/m^2 per year to more than 220 kWh/m^2. In line with this strategy, it is essential to focus efforts on improving the energy efficiency of residential buildings, especially those classified with a low energy class such as E or lower. These buildings make up a significant percentage of the Italian building stock and account for a large part of the country's total energy consumption. The implementation of targeted measures and interventions, such as thermal insulation, the installation of efficient heating and cooling systems and the adoption of low-emission technologies, could reduce the energy consumption of these buildings by up to 40%.

This reduction would not only contribute to a decrease in the environmental footprint of the residential sector but also to greater economic sustainability for owners and end users. The adoption of public policies focused on the energy efficiency of buildings can be a key catalyst to promote the energy upgrading of the national housing stock, while ensuring a more sustainable and responsible living environment for generations.

6.2.3 Coimbra-Portugal

The results from the audits conducted in Portugal will be included in an updated version of this document.

6.2.4 Bükk-Mak and Somló-Marcalmente-Bakonyalja-Hungary

A total of 8 single-family houses were audited in Hungary, 4 in the Bükk-Mak and 4 in the Somló-Marcalmente-Bakonyalja area. On average two to four household members live in most audited family houses and predominantly occupy the space from 4 pm to 6 am in the morning, and throughout the entire weekend (**Fig. 40**).

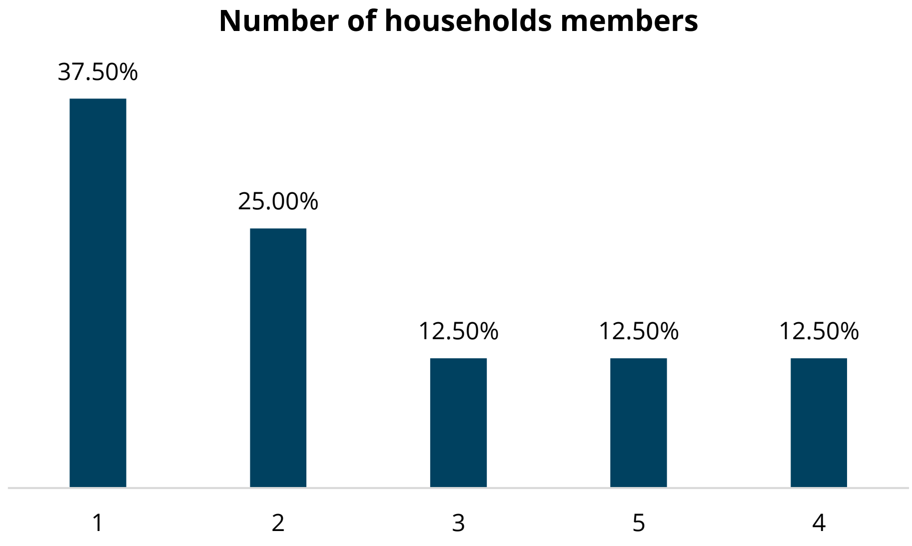

Fig. 40. Number of household members in pilot areas Bükk-Mak and Somló-Marcalmente-Bakonyalja, Hungary.

The year of construction of audited houses is in the range of 1868 to 1996, and the average year of construction is 1937. Most audited houses are ground floor buildings with basements in some cases, with an average total floor area of 145.76 m^2, and an average habitable floor area of 114.06 m^2.

Residential buildings in the two rural areas are in very poor condition in terms of energy performance. The wall structures are often of mixed construction (brick, concrete, adobe and stone) with poor thermal insulation. Retrofitted thermal insulation is rare and of inadequate thickness. The most common type of windows and doors is double-glazed wood. These have been replaced in several buildings by double-glazed plastic windows with better thermal insulation properties. For roofs, gable or hipped roofs are the most common - these are only insulated when the attic is built in. The average U-values of walls, floors, roofs, and windows of the Hungarian pilot households are presented in **Table 10**.

Table 10. Average U-values of the Hungarian pilot households as derived from the energy audits.

U-value (W/m²/K)	
U_{wall}	1.45
U_{floor}	1.74-2.84
U_{roof}	2.42
U_{window}	4.06

The audited houses have a central heating system with mixed fuel (wood and coal) or natural gas, wooden stoves, and gas-fired convectors with a nominal capacity of 24 to 30 kW. There are no cooling systems installed in the audited houses. The lighting equipment is traditional (40-60 W) in combination with compact fluorescent tubes (10-15 W) and LED bulbs (6-8 W).

Most of the audited houses in Hungary have an energy efficiency class **HH**[26] with an average primary energy of 367.80 kWh/(m²a). The distribution of energy efficiency classes for audited houses in Hungarian pilot areas is shown in (**Fig. 41**).

[26] Energy efficiency classification in Hungary: ***FF: Average condition***; ***GG: Approaching average condition***; ***HH: Poor condition***, II: ***Bad condition***.

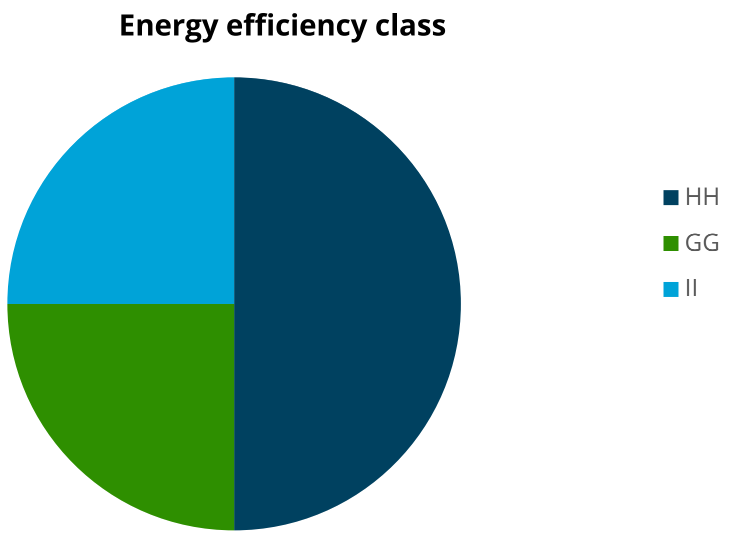

Fig. 41. Distribution of energy efficiency classed for audited buildings in pilot areas Bükk-Mak and Somló-Marcalmente-Bakonyalja, Hungary

The availability of building energy information on the building stock in Hungary is limited. There is no national database that would provide sufficient information on the actual state of the Hungarian building stock and thus provide an adequate basis for the development of targeted and effective strategic measures.

Energy consumption in the residential sector in 2018 was 244 PJ, representing 33% of the national final energy consumption. About half of the energy consumption of households in Hungary is related to natural gas and a quarter to renewables. It is worth noting that in the latter case, this is mostly biomass and firewood combustion. As a result of this (i.e. mostly fossil fuel combustion), about 13% of national Green House Gas emissions are attributable to residential energy consumption. Furthermore, more than 70% of energy consumption in residential dwellings is for heating purposes.

6.2.5 Sveta Nedelja and Žumberak-Croatia

A total of 15 single-family houses were audited in Croatia, 10 in the area of Sveta Nedelja, and 5 in the area of Žumberak. Most audited family houses generally consist of approximately two or more household members, with retirees being a prevalent demographic among these households **Fig. 42.**

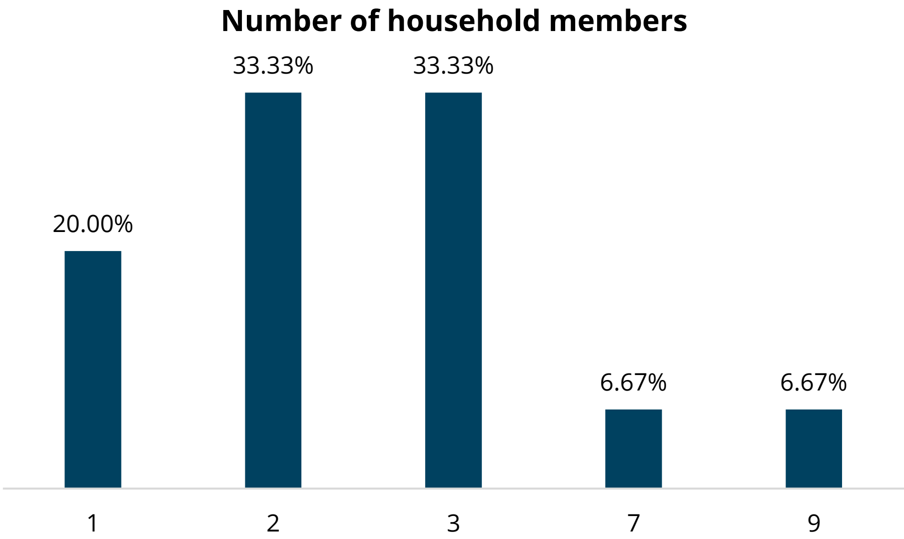

Fig. 42. Distribution of occupancy for audited houses in Croatia.

The year of construction of audited houses is in the range of 1920 to 1998, and the average year of construction is 1966. Most of the audited houses have 3 ground levels, namely the ground floor, the 1st floor and an unheated ventilated attic, with an average total floor area of 147.93 m^2, and an average habitable floor area of 124.43 m^2.

Most dwellings have no building insulation, and the walls of the houses are made of concrete or brick at most. Windows and doors are old and inefficient with single-glazing or double-glazed windows, prone to air infiltration. Roofs are mainly double-pitched and above uninsulated attics, which further contributes to energy inefficiency due to significant heat losses and lack of heat retention. The average U-values of walls, floors, roofs, and windows of the Croatian pilot households are presented in **Table 11**.

Table 11. Average U-values of the Croatian pilot households as derived from the energy audits.

U-value (W/m²/K)	
U_{wall}	1.51
U_{floor}	2.11
U_{roof}	2.39
U_{window}	2.63

Most of the audited houses have local wood heating systems with a nominal power of 5 kW in combination with an electrical boiler for domestic hot water, with a nominal power of 2 kW. These wood stoves are generally an inefficient heating source and can pose health risks due to incomplete combustion, emissions of harmful particulate matter, poor indoor air quality, inadequate heat distribution, etc. Only 3 out of 15 audited houses have a cooling system (1 air conditioning unit per household). In most houses, LED bulbs (18 W) are installed in combination with incandescent bulbs (60W).

Overall, most of the audited houses in the Croatian pilot areas of Sveta Nedelja and Žumberak have an energy efficiency class **D** with an average primary energy of 375.28 kWh/(m²a). The distribution of energy efficiency classes for audited houses in Croatian pilot areas is shown in **Fig. 43.**

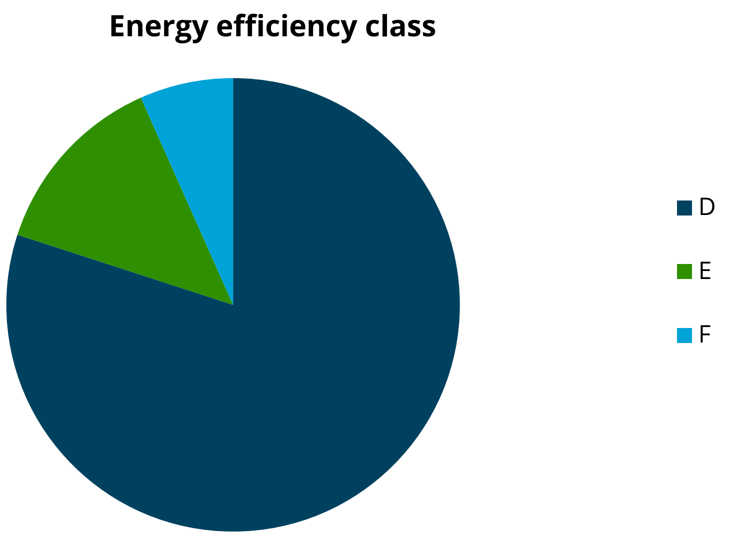

Fig. 43. Distribution of energy efficiency classed for audited buildings in pilot areas Sveta Nedelja and Žumberak, Croatia.

According to the data available from the Environmental Protection and Energy Efficiency Fund (EPEEF), most family houses in Croatia were built before 1987 and are ranked in energy class E and lower with almost no or only minimal thermal isolation. Such houses consume 70% of energy for heating, cooling and domestic hot water preparation. In terms of energy consumption, energy efficiency measures can significantly reduce the energy consumption in a building, in some cases up to 60% compared to current energy demands. As family houses make up 65% of the housing stock in Croatia and are responsible for 40% of the total energy consumption at the national level, significant energy savings on the national level could be achieved with the implementation of the energy efficiency measures, therefore also contributing to the national goal of carbon emission reduction.

6.2.6 Tartu-Estonia

A total of 5 multi-family buildings were audited in Estonia. On average, 34 people live in each audited multi-family building with approximately two members living in each apartment, as displayed in **Fig. 44.**

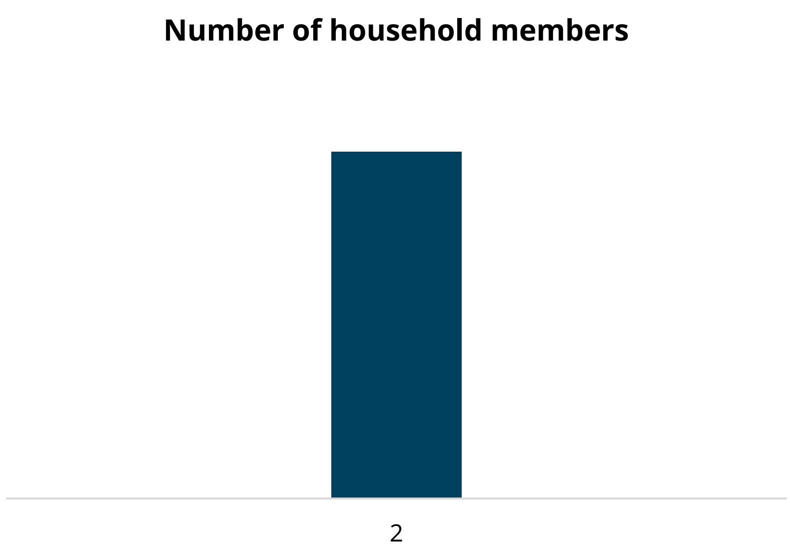

Fig. 44. Distribution of occupancy for audited houses in Croatia.

The year of construction of the multi-family audited buildings is in the range of 1980 to 1991, and the average year of construction is 1985. Most of the audited multi-family buildings have basements and 3 ground levels with an average total floor area of 1308.8 m^2, and an average habitable floor area of 949.18 m^2.

All audited dwellings are built with aerated concrete walls which have much lower insulation properties in terms of energy efficiency. Windows are double-glazed with PVC frames but prone to air infiltration which is visible from their high thermal transmittance. Roofs are low-pitched and insulated with 200mm aerated concrete slabs.

The average U-values of walls, floors, roofs, and windows of the audited buildings in the Estonian pilot area Tartu are presented in **Table 12.**

Table 12. Average U-values of the Estonian pilot households as derived from the energy audits.

U-value (W/m²/K)	
U_{wall}	0.9
U_{floor}	0.7
U_{roof}	0.8
U_{window}	2.5

Four out of five audited buildings are connected to the district heating system. District heating for multi-family buildings in rural areas has drawbacks including reliance on an external heat supplier, lack of individual temperature control, fluctuating heating costs, energy loss during transport and susceptibility to breakdowns. Due to the small size of the local district heating grid, providing heat for domestic hot water during the non-heating season is uneconomical for grid owners, thus the homeowners need to rely on more expensive electrical water heating.

District heating grids in small settlements are a remnant of soviet times when heat was also provided for social and agricultural infrastructure like social centers, schools, tractor workshops, wood kilns etc. This kind of infrastructure has since been discontinued or centralised, leaving still existing grids on the verge of profitability.

Apartments in one multi-family building have different individual heating systems, among which stand out air-to-air heat pumps, direct electric heating and masonry stoves. Most heating systems used in the audited buildings are generally inefficient heating sources and can pose health risks due to incomplete combustion, emissions of harmful particulate matter, poor indoor air quality, inadequate heat distribution, etc. In most buildings, LED bulbs are installed in combination with incandescent bulbs, with an average bulb wattage of 66.8W.

Overall, most of the audited houses in the Estonian pilot area Tartu have an energy efficiency class **G** with an average primary energy of 282.2 kWh/(m²a). The distribution of energy efficiency classes for audited houses in the Estonian pilot area is shown in **Fig. 45**.

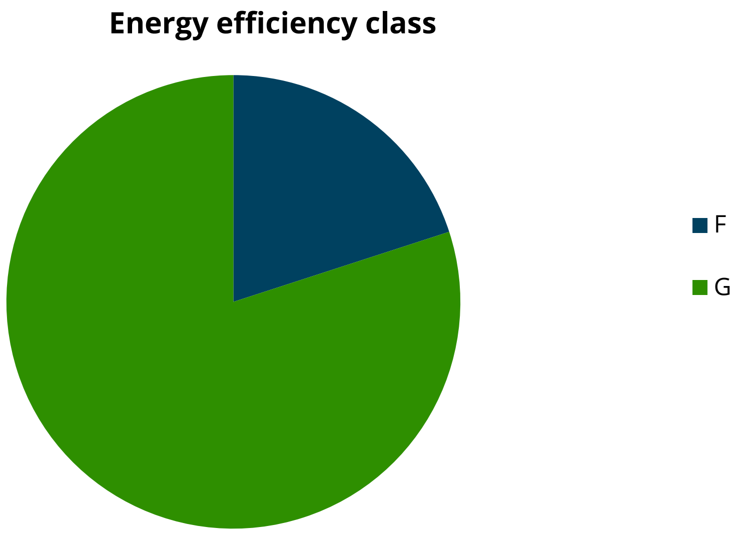

Fig. 45 Distribution of energy efficiency classed for audited buildings in pilot area Tartu, Estonia.

A total of 70% of the Estonian population is currently living in multifamily houses. Two-thirds of these houses were built between 1960 and 1990, mostly in a few developing large cities and industrial centers but also in rural areas. Most of the multifamily residential houses in rural Estonia were built in the 1970s and 1980s in settlements that were then considered “perspective central hubs” of large collective farms. These settlements had well-established infrastructure. Most of the residential buildings were erected according to a few standard designs from an architectural design office specialized in rural development. The houses are more comfortable than standard designs for cities. For example, they had larger kitchens and more roomier stairs.

These houses were mainly built of locally invented aerated silica calcite concrete and had a slightly better U-value of walls than reinforced concrete sandwich panels of high-rise city houses – 0.7-0.9 W/m²K versus 1.0-1.1 W/m²K.

After the demise of the Soviet Union, the corresponding socio-economic system and collective agriculture, those central hubs became redundant and most of their infrastructure collapsed. Recently these settlements have been gaining popularity as places of residence due to changes in the structure of employment, allowing people to live outside the city but not quite on the farm.

6.2.7 Zasavje-Slovenia

A total of 12 single-family, multiapartment and multi-family houses were audited in Zasavje, Slovenia. On average three household members live in most audited buildings and predominantly occupy the space from 5 pm to 9 am in the morning, and throughout the entire weekend (**Fig. 46**).

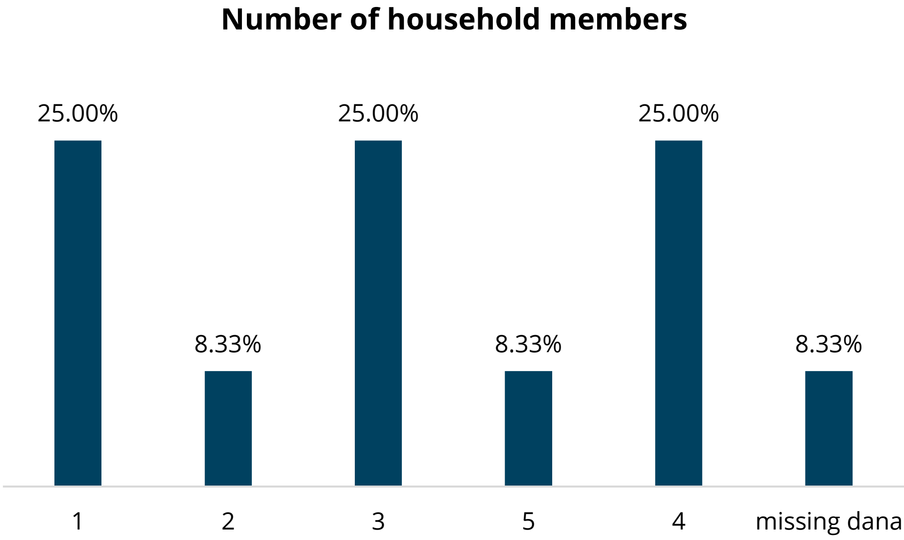

Fig. 46. Number of household members in pilot area Zasavje, Slovenia.

The year of construction of audited houses is in the range of 1905 to 1979, and the average year of construction is 1945. Most of the audited houses have 1 basement level and 3 ground levels, with an average total floor area of the apartment of 69.90 m^2.

Most dwellings have no building insulation, and the walls are made of brick or concrete. Windows and doors tend to be of newer making, which is most likely the cause of humidity due to lack of airing systems and poor airing practices. All windows have 3mm clear glazing. Roofs are mainly double pitched and above uninsulated attics, which further contributes to energy inefficiency due to significant heat losses and lack of heat retention. The average U-values of walls, floors, roofs, and windows of the Slovenian pilot households are presented in **Table 12.**

Table 12 Average U-values of the Slovenian pilot households as derived from the energy audits.

	U-value (W/m²/K) of single-family houses	U-value (W/m²/K) of multiapartment houses	U-value (W/m²/K) of multi-family houses
U_{wall}	0.75	1.02	1.40
U_{floor}	/	1.42	/
U_{roof}	1.65	0.59	0.59
U_{window}	1.32	1.32	1.28

Out of the 11 audited housing, four rely on wood fuels (wood stove, wood oven, etc.) sometimes combined with electric heating (e.g. wood fireplace and electric radiator), three households are connected to a district heating system (natural gas), two have a central heating system (natural gas boiler - 42 Kw), one relies on electric heating (4Kw) and one uses a fuel oil boiler (40kW). Almost all audited househokds use LED bulbs with a capacity of 2-4W, while only one uses classical bulbs (25-60W).

Most of the audited houses in Slovenia have an energy efficiency class **G** (according to the required energy for heating) with an average primary energy of 341 kWh/(m²a). The distribution of energy efficiency classes for audited houses in Slovenian pilot areas is shown in (**Fig. 47**).

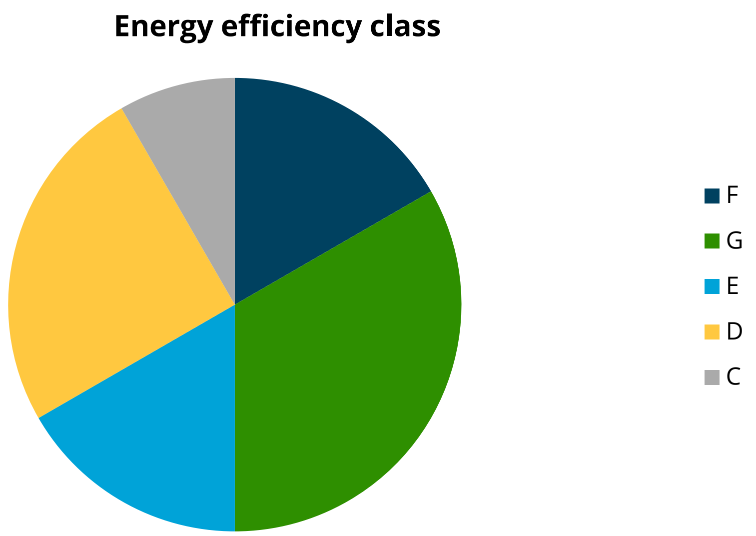

Fig. 47. Distribution of energy efficiency classed for audited buildings in pilot area Zasavje, Slovenia.

According to the Statistical Office of the Republic of Slovenia, more than half of all occupied housing in Slovenia (54%) are single-family houses, while 63% of the population lives in them, and almost 30 % live in multi-apartment buildings. Taking a closer look at the Zasavje region, we can see that multi-apartment buildings account for 50% of all occupied housing, while 44% are single-family houses.

Most of the residential building stock in Slovenia was built before 1991. More specifically, 75% of single-family houses in Slovenia were built before 1991, with the biggest building boom occurring in the 1970s and 1980s. Similarly, 84% of multiple apartment buildings were built before 1991, most of them between 1961 and 1991.

According to the national long-term strategy for energy renovation of buildings until 2050 more than 40% of single-family houses, or around 100,000 households are classified in energy classes F and G. These buildings were built mostly before 1980. These households are likely to be the most prone to high energy consumption for heating and related high costs for heating. The share of such multi-apartment buildings is almost 8% or approximately 24,000 households.[27]

Homes in Slovenia are heated mainly by using a central heating system (76.6 %). In the Zasavje region, 58% of residential housing use central heating, while 25% are connected to a district heating system. In terms of energy sources, heating in Slovenia heavily relies on wood fuels, where 44% of household heating comes from wood fuels.

An important characteristic of the Slovenian housing market is the high share of private ownership. According to the Statistical Office of the Republic of Slovenia, 92.1 % of residential housing is privately owned by individuals. In the Zasavje region, 71% of residential housing is privately owned. Almost 79% of all occupied housing in Slovenia is occupied by the owners of those dwellings or their family members. Housing offered for rent account for just 9% of all occupied housing.

6.3 Findings of pilot studies

Overall, a total of 68 residential buildings have been audited from September 2023 to February 2024. The audited buildings in the selected pilot areas were constructed between 1868 and 2010, with an average year of construction of 1954. The average year of construction per pilot country is given in **Fig. 48**.

[27] https://www.energetika-portal.si/fileadmin/dokumenti/publikacije/dseps/dseps_2050_final.pdf

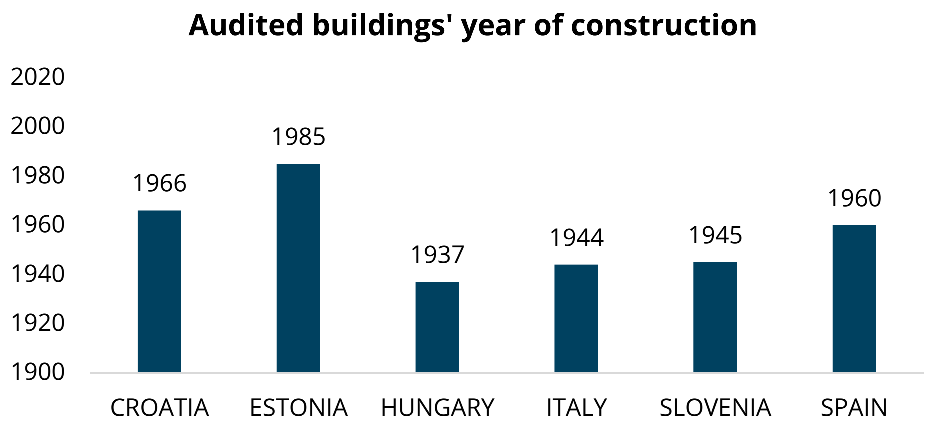

Fig. 48 Year of construction of audited buildings in the RENOVERTY pilot areas.

The audited buildings are mostly constructed using concrete and brick with non or minimal insulation, resulting in poor thermal performance. These buildings generally have low energy efficiency due to heat losses through walls, roofs and windows and therefore tend to have high energy consumption compared to modern standards. Most heating systems are outdated and fuelled by natural gas, wood, electricity or oil and are generally inefficient heating sources that can pose health risks due to incomplete combustion, emissions of harmful particulate matter, poor indoor air quality, inadequate heat distribution, etc.

Their energy inefficiency is evident from their annual primary energy consumption and thermal transmittance (U-values). **Fig. 49** and **Fig. 50** provide more detailed information:

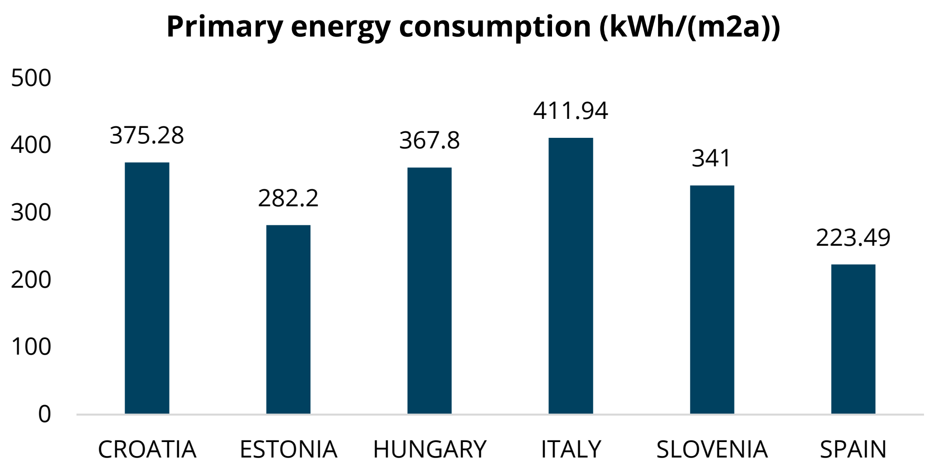

Fig. 49. Primary energy consumption in audited buildings in the RENOVERTY pilot areas.

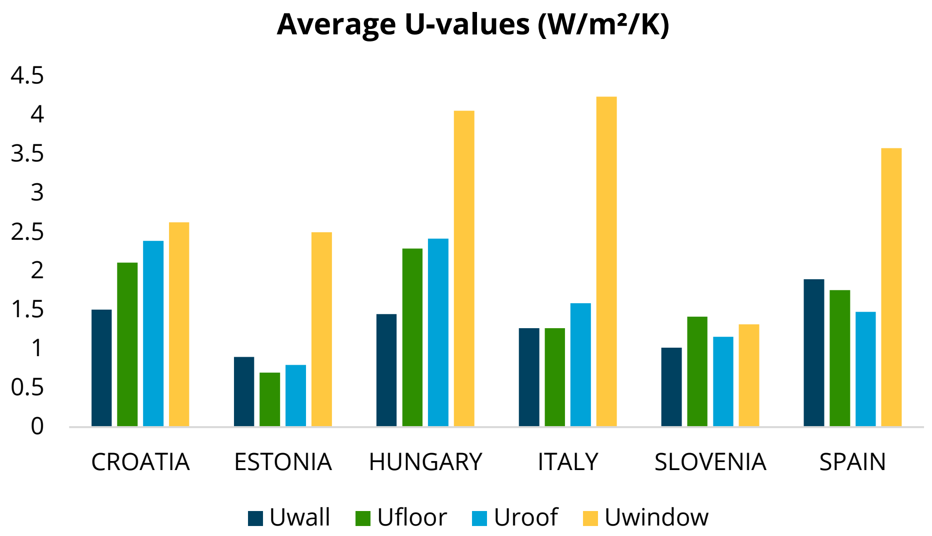

Fig. 50. Thermal transmittance (U-values) of audited buildings in the RENOVERTY pilot areas.

Retrofitting older buildings to improve energy efficiency can be challenging and costly, but it is also essential for addressing energy poverty among citizens living in such structures. As visible from energy audit results, most audited buildings lack proper insulation, have outdated heating systems, and inefficient windows, resulting in higher energy bills and discomfort for occupants.

To address energy poverty, the implementation of energy audits has played a crucial role in guiding energy renovation efforts for energy-poor households by assessing energy performance, identifying opportunities for improvement, prioritizing energy renovation measures and ensuring regulatory compliance. RENOVERTY pilot project partners will further use the energy audit results to work on their country-specific REERs, which will serve as comprehensive plans outlining the steps and strategies needed to improve the energy efficiency of existing buildings. By providing a structured framework for action, these roadmaps will help accelerate the transition to a more sustainable environment while addressing energy poverty effectively.

7 Conclusions

This report is aimed at framing energy poverty in the rural areas of the EU, with an extra focus on CEE, SEE and SE. To achieve this, a four-step methodology was utilised. The first step concerns the review of more than 60 literature sources, aiming to conceptualise energy poverty and energy efficiency in rural areas. From this analysis, key insights about rural energy poverty are identified, like the unfavourable demographic structure, limited education and labour capabilities, as well as the lack of infrastructure and services in comparison with urban areas. This analysis indicated significant regional differences across Europe, with rural areas in CEE and SEE indicated as poorer and more excluded than their urban counterparts. Furthermore, we identified how the key characteristics of rural areas, such as the nature of building stock and the limited choice of energy sources, also increase the exposure of the rural population to energy poverty. In addition, we analysed how the higher energy costs of rural households, as well as the consumer behaviour of the local populace also contribute to the higher rates of energy poverty.

As a next step, 25 energy efficiency policies targeted in rural contexts across Europe were gathered and analysed in order to gain preliminary insights into the energy efficiency and energy poverty policy landscape in such contexts. Overall, it was observed that policies aiming at the specific characteristics of rural areas are lacking, while the ones identified are inadequately mapping rural energy poverty and engaging vulnerable groups, highlighting the need to shift the energy policy focus onto the regional and local levels to effectively address their needs and effectively monitor and map rural energy poverty.

The last step of the desk research analysis concerns the identification and analysis of different categories of barriers to implementing energy efficiency policies to alleviate energy poverty in rural areas. This process indicated four key categories of barriers, namely **financial**, **awareness and access**, **geographical**, and **regulatory/political barriers**, indicating financial ones as the most prominent ones.

The literature review was coupled with a European-wide experts' survey that aimed to assess stakeholder needs and viewpoints about energy poverty and energy efficiency in vulnerable rural and peri-urban areas. The survey indicated the importance of transportation needs of rural households, as among the most important challenges faced by rural households are high transportation costs and poor public transport. The findings of the literature review were also confirmed, as the nature of the building stock is indicated as one of the most important drivers of energy poverty, while the lack of sufficient investments that could address rural energy poverty issues is also highlighted.

In addition, the survey validates the different categories of barriers and provides useful insights about them. More specifically, stakeholders consider ***financial barriers*** as the most important category of barriers, followed by ***awareness and access barriers***, ***regulatory barriers*** and

geographic barriers. Moreover, it was found that the most important financial barriers are ***lack of capital*** and ***high upfront costs***, while the most important ***awareness/access barriers*** are ***lack of technical information*** and the ***scepticism*** of rural households. With regards to ***geographic barriers*** the most important are the ***lack of local energy efficiency workers*** and ***expertise***, while for ***regulatory barriers*** are the existent ***unsupportive and inconsistent policy settings***.

Furthermore, the survey investigated **the importance of different levels of governance** in terms of energy efficiency implementation to address energy poverty, by providing recommendations on actions that governmental bodies at all levels (i.e., local, regional, national, and EU) could implement to address energy efficiency and energy poverty in rural contexts. An overarching finding from this analysis is the strong need for collaboration across the different levels of governance to achieve customised solutions considering the specific needs of the local communities and establish proactive engagement to assist in the empowerment of rural areas. Furthermore, it is suggested that EU level institutions should focus on improving the existing legislative framework for member states in order to enhance support of rural areas, national governments should focus on proposing strategies that consider the unique challenges faced by rural communities, regional level governmental bodies should advocate for the creation and implementation of plans that leverage the specificities of rural areas and lastly local governments should focus on the allocation of support provided by the strategies that are designed by the national governments.

The knowledge gained by the survey and the findings contributed to the development of CEPTI, an innovative tool designed to identify potential areas of concern and challenges of energy poverty in European rural areas. Preliminary findings of the application of the tool offered interesting insights into the cases of Italy and Croatia. As RENOVERTY continues its activities, CEPTI will also be applied to other pilot countries and will further assist in the development of subsequent actions. By doing so, CEPTI seeks to assist policymakers and stakeholders beyond academic circles in the formulation of effective policies to address rural energy poverty.

Finally, our study dives into assessing and identifying the special characteristics of dwelling in rural and peri-urban areas in CEE, SEE, and SE, while also specifically focusing on dwellings inhabited by the vulnerable population. This has been achieved by the conduction of energy audits in more than **65** households in the pilot regions of the project. The technical analysis of the data provided through the energy audits provides evidence-based knowledge of the specificities of rural households and helps define the baseline situation for the areas under study to assist subsequent activities of RENOVERTY, including the development of energy efficiency portfolios and the codesign of REERs.

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