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Rural Energy Efficiency Roadmap (REER) for the energy renovation of family houses of households experiencing energy poverty in Croatia: A framework for stakeholders

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Legal notice

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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.

CONTENT

List of abbreviations

EU	European Union
CEC	Citizens' Energy Community
COP	Coefficient of Performance
DHW	Domestic Hot Water
DREEM	Dynamic High-Resolution Demand Management Model (DSM) *Dynamic high-Resolution dE-mand-sidE Management*
EBRD	European Bank for Reconstruction and Development
EEM	Energy Efficiency Measure
EER	Energy Efficiency Ratio
EIB	European Investment Bank
ELENA	*European Local Energy Assistance*
EPBD	The Energy Performance of Buildings Directive
EPC	The Energy Performance Contract (EPP) *Energy Perfomance Contracting)*
ERDF	European Regional Development Fund
ESCO	The Energy Service Model *Energy Service Company)*
ESIF	European Structural and Investment Funds
EU	European Union
FZOEU	Environmental Protection and Energy Efficiency Fund
HBOR	Croatian Bank for Reconstruction and Development
HKBO	Croatian Credit Bank for Reconstruction
HVAC	Heating, Cooling and Air Conditioning
IPA	Instrument for Pre-Accession Assistance
JASPERS	Joint assistance to support projects in Europe's regions
LAG	Local Action Group
LCSE	Levelised Cost of Saved Energy
MPGI	Ministry of Physical Planning, Construction and State Property
NCFF	Natural Capital Financing Facility

NDICI	Neighbourhood, Development and International Cooperation Instrument
NPOO	National Recovery and Resilience Plan
NPV	Net Present Value
OG	The People's Newspaper
OSS	One Stop Shop
PP	Payback Period
PPP	Public-Private Partnership
QH,nd	Annual energy required for heating
REC	Renewable Energy Community
SEER	Seasonal Energy Efficiency Ration
SCOP	Seasonal Coefficient of Performance
SPP	Simple Payback Period

SUMMARY

The Northwest Croatia Regional Energy and Climate Agency participates in the implementation of the EU-funded RENOVERTY project[1]. The project encourages improvements in the energy efficiency of buildings inhabited by those experiencing energy poverty through the development of roadmaps for energy renovation of family houses in rural areas, the guidelines of which have been adapted to the local characteristics of the pilot areas of Sveta Nedelja and Žumberak.

The main target groups of the Rural Energy Efficiency Roadmaps (hereinafter: REERs) are homeowners who want to implement energy renovation, as well as organisations that help guide households such as energy agencies, civil society organisations, local action groups (LAGs), decision-makers and implementers, and other organisations involved in energy renovation policies and processes.

Through the REERs, all involved stakeholders are introduced to the process of planning an energy renovation, as well as possible challenges and obstacles in the planning and implementation phase. An overview of key stakeholders that should be involved in the planning process and the implementation of energy renovation projects is given. The main focus of the REERs is placed on overcoming legal, financial and administrative obstacles, where LAGs operating in pilot areas play an extremely important role.

[1] Official website of the RENOVERTY project available on: https://ieecp.org/projects/renoverty/

1 Introduction

Energy efficiency in buildings is one of the strategic priorities of the European Union (EU). The EU seeks to achieve reductions in CO_2 emissions and increases in energy efficiency through legislation, cross-sectoral cooperation, engagement with international, national, and regional stakeholders, EU projects, and encouraging research in the energy sector.[2]

In Croatia, family houses constitute 65% of the housing stock and are responsible for 40% of the nation's total energy consumption. Most family houses were constructed before 1987 and lack sufficient thermal insulation, falling into energy class E or worse. These houses consume up to 70% of their energy for heating, cooling, and domestic hot water. Implementing energy efficiency measures can significantly reduce this consumption, in some cases by up to 60%.[3].

To better understand the specific needs of family houses affected by energy poverty in rural and peri-urban areas of Croatia, 15 energy audits were conducted in the pilot areas of Sveta Nedelja and Žumberak (10 in Sveta Nedelja and 5 in Žumberak). The homeowners received energy certificates, which remain their permanent property.[4] The results of energy audits have shown that most of the inspected buildings do not have adequate thermal insulation, have outdated heating systems and inefficient joinery, which results in higher energy bills and lower quality of living, and the occurrence of dampness and mould, which often occurs in such conditions, can also have a negative impact on health.

'Energy poverty', for the purposes of this document, refers to *a household does not have access to basic energy services, where such services ensure basic levels and a decent standard of living and health, including adequate heating, hot water, cooling, lighting and energy to power household appliances, in the relevant national context, existing national social policies and other relevant national policies, which is caused by a combination of factors, including at least affordability, insufficient disposable income, high energy expenditure and poor energy efficiency of homes*, in accordance with Article 2, paragraph 52 of the Act. Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast)[5].

[2] https://mpgi.gov.hr/o-ministarstvu-15/djelokrug/energetska-ucinkovitost-u-zgradarstvu/8303
[3] https://www.fzoeu.hr/energetska-obnova-obiteljskih-kuca-7679-7679
[4] Since the possession of an energy certificate is a prerequisite for applying to existing tenders for the co-financing of energy renovation projects and renewable energy sources, all Energy Audit Reports and issued certificates are also aligned with the Conditions and Criteria for Co-financing the Energy Renovation of Family Houses of the Environmental Protection and Energy Efficiency Fund (FZOEU) published at the end of December 2023 https://www.fzoeu.hr/hr/objavljeni-uvjeti-za-sufinanciranje-energetske-obnove-obiteljskih-kuca-u-2024-godini-9647/9647
[5] https://eur-lex.europa.eu/legal-content/HR/TXT/HTML/?uri=CELEX:32023L1791

Furthermore, 'vulnerable households' are *households experiencing energy poverty or households, including those with lower middle incomes, which are particularly exposed to high energy costs and do not have the means to renovate the building in which they live*, as defined in Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the energy performance of buildings[Errore. Il segnalibro non è definito.]. The same directive further states: *Inefficient buildings are often associated with energy poverty and social problems. Vulnerable households are particularly exposed to the increase in energy prices, as they spend most of their budget on energy products. Reducing excessive energy bills Building renovation can lift people out of energy poverty and prevent energy poverty. At the same time, building renovation is not free and it is crucial to ensure that the social impact of building renovation costs, especially on vulnerable households, is kept under control.*

In a conversation with the owners of family houses during the field visit, feedback was collected on the wishes for energy renovation of their houses, as well as on the obstacles they face.

The most common **expectations and advantages in the case of energy renovation** among owners of certified family houses:

1. Reducing Energy Costs: Homeowners expect energy renovation to lower their monthly energy bills via measures such as thermal insulation of building envelopes, and replacement of windows or heating systems, which can significantly reduce energy consumption.
2. Improved Living Quality: Energy-efficient homes provide better living conditions, including more comfortable indoor temperatures, improved air quality, and reduced dampness and mould.
3. Long-term Sustainability: Some homeowners recognise energy renovation as a safeguard against rising energy prices and the impacts of climate change.
4. Increased Property Value: Enhancing energy efficiency, lowering heating and cooling costs, and creating healthier living spaces contribute to higher property values.

The **most common obstacles** to the energy renovation of family houses include:

1. Financial Costs: High upfront costs remain the primary obstacle, as homeowners often lack the financial means to fund renovations. In rural areas, the costs of implementing energy efficiency measures or renewable energy solutions are often higher due to limited access and fewer available contractors.
2. Access to Information and Support: Homeowners experiencing energy poverty often lack information about renovation opportunities, subsidies, or incentives, even when available. The absence of advisory support further complicates the process.

3. Administrative Challenges: Application processes for existing programmes are often unclear and inaccessible to people experiencing energy poverty. The collection and submission of necessary permits and documentation can discourage homeowners from pursuing renovations.
4. Technical and Legal Constraints: Older houses may require significant structural improvements before energy renovations can proceed, increasing project complexity and cost. Additionally, proof of building legality is often required for national funding programmes, posing another barrier to securing financial support.

It can be concluded that implementing energy efficiency measures in rural areas is closely linked to broader financial, social, and geographical challenges.

Energy renovation, while challenging and costly, is crucial in addressing energy poverty. Energy audit results indicate that most single-family homes lack adequate thermal insulation, have outdated heating systems, and feature inefficient windows and doors, leading to higher energy bills, discomfort, and potential health risks for occupants.

When planning energy renovation measures, households experiencing energy poverty often encounter numerous barriers. They typically lack the financial resources and awareness of co-financing mechanisms, face difficulties accessing contractors, and lack the necessary information to make informed decisions. Geographic isolation further increases service costs and logistical challenges. Additionally, these households may struggle to identify and prioritise the measures needed, balancing necessity with cost-effectiveness.

The aim of these REERs is therefore to provide support to the local communities in achieving easier, faster and better implementation of energy renovation measures with the aim of combating energy poverty. The implementation of energy efficiency measures in single-family homes in rural areas is key to reducing energy poverty and raising the quality of life. The owners of the audited family houses recognise the benefits of energy renovation such as reducing energy costs, improving living conditions and long-term sustainability. Given that they face obstacles such as high financial costs, lack of information and support, administrative challenges, and technical and legal constraints, it is crucial to develop models of targeted expert and technical support and clearly targeted programmes and strategies that will enable the effective implementation of energy efficiency measures and the application of renewable energy sources in single-family homes in rural and peri-urban areas.

2 Technical aspects of energy renovation of buildings of energy-poor households

2.1 Energy audit and energy certification

Energy certification is a set of actions and procedures that are carried out for the purpose of issuing an energy certificate and includes an energy audit of a building, the necessary calculations for reference climate data to express the specific annual heat energy required for heating, the specific annual heat energy required for cooling, the specific annual energy supplied, the specific annual primary energy, the specific annual CO_2 emissions, the determination of the energy class of the building and the construction of the building.

Simply put, an energy audit evaluates the actual energy consumption of a family house and identifies measures to reduce this consumption while simultaneously improving living conditions.

An energy certificate is a document that details the building's energy performance. It is prepared by an energy certifier, a qualified professional authorised to conduct energy certification.[6]

Residential and non-residential buildings, including family houses, are classified into eight energy classes on a scale from **A+** (most energy efficient) to **G** (least energy efficient). An example of the energy class scale is shown in **Errore. L'origine riferimento non è stata trovata.**.

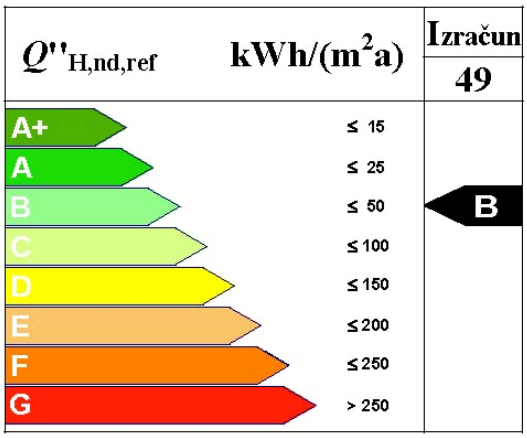

Figure 1 Overview of energy classes of buildings in the Republic of Croatia

(Source: Ordinance on Energy Audit of Buildings and Energy Certification OG 88/17, 90/20, 01/21, 45/21[7])

The energy audit provides detailed information on the energy performance of the building, its energy systems and energy sources, and provides a list of measures that identify the potential

[6] https://mpgi.gov.hr/o-ministarstvu/djelokrug/energetsko-certificiranje-zgrada-8304/8304

[7] https://www.zakon.hr/cms.htm?id=45406

for improving overall energy efficiency. Such information is crucial for a complete understanding of energy poverty in rural areas, as well as for solving the identified factors that contribute to its prevalence, and as a final result enable a more successful solution to this problem. Energy performance certificates are an important tool for improving the energy performance of buildings, they are a central component of the Energy Performance of Buildings Directive (Directive (EU) 2024/1275[8]).

The energy audit, i.e. the cost and organisation of its implementation, can be one of the obstacles to the energy renovation of a family house when it comes to applying to the Public Call for Energy Renovation of Family Houses[9] published by the Environmental Protection and Energy Efficiency Fund (FZOEU) because it is part of the mandatory documentation that the application must contain, and is not subject to co-financing. The organisation and cost of conducting an energy audit are especially a significant barrier when it comes to vulnerable, i.e. households experiencing energy poverty that are often not familiar with the process and obligation to conduct an energy audit, nor do they have the necessary financial resources. The cost of conducting an energy audit depends on the type and size of the building, as well as on the systems within the building and their complexity, and its price for a family house of average size in the Republic of Croatia is in the range of €200-350. For comparison, the minimum wage in Croatia in 2024 is €840 gross, which for a single household in Sveta Nedelja and Žumberak is €770 net. In the case of permanently unemployed people and people who meet other social criteria, the guaranteed minimum allowance for single people in Croatia in 2024 was 150€ per month[10]. From the above, it is evident that households that do not have employed members, or whose members are employed on the minimum wage, and the cost of the energy audit itself represents a significant or unattainable expense.

While a comprehensive approach to energy audits and energy performance certificates is defined under the EPBD and other related directives or laws, there are different approaches to energy audits in the Member States. For this reason, a unique methodological approach has been developed for the purpose of conducting energy audits within the RENOVERTY project, thus enabling each pilot partner to conduct energy audits in accordance with their national methodology, and at the same time ensuring the comparability of the collected data within the RENOVERTY pilot. Guidelines for the implementation of energy audits have been prepared, defining the minimum data required, adapted to the specificities of residential buildings in rural and peri-urban areas of Central and Eastern Europe, South-Eastern Europe and Southern Europe, as well as to the subsequent activities of the project (i.e. simulations for the development of a portfolio of energy efficiency measures targeting energy-poor households in pilot regions)

[8] https://eur-lex.europa.eu/legal-content/HR/TXT/PDF/?uri=OJ:L_202401275

[9] https://www.fzoeu.hr/docs/225/Javni%20poziv%20za%20energetsku%20obnovu%20obiteljskih%20kuća%20EnU-1_24.pdf

[10] https://gov.hr/hr/zajamcena-minimalna-naknada/714?lang=hr

(Table 1). As a starting point for the development of these REERs, a data inventory table developed within the EU project crossCert was used[11] also taking into account the diversity of RENOVERTY pilot countries.

Table 1 Minimum information required for the implementation of energy audits

Climate data	Climate zone (continental or coastal Croatia) Heating degree days Cooling degree days Date of start/end of the heating season Date of start/end of the cooling season
Building characteristics	Type of building: Year of construction or reconstruction/renovation: Building size: Total floor of the building [m^2]: Habitable area of the building/Ak [m^2] Total area of external walls of the building [m2] Conditioned area of the building [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·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., single/double glazed + wooden frame/pvc frame), U-value [W/(m^2K)· total area [m^2]
Construction features – U (W/m²K)	Uwall: Ufloor: Uroof: Uwindow: Type of construction (e.g. brick, concrete, wood…))
Thermotechnical systems of the building	HVAC system (e.g., DHW, cooling, heating and cooling, heating and DHW, heating, cooling and DHW, ventilation) Type of system (e.g. standard water heater, condensing water heater, low-temperature water heater, heat pump, variable pump heat pump, electric water heater, ventilation…) Nominal capacity [kW] Coefficient of Performance (COP) / Seasonal Coefficient of Performance (SCOP) / Energy Efficiency Ratio (EER) / Seasonal Energy Efficiency Ratio (SEER) (if known): Ventilation (e.g., mechanical ventilation, heat recovery systems…) Energy consumption (kWh/year): Air flow (m3h/m2): Lighting equipment (number of installed lighting fixtures) Lightning equipment capacity (e.g. traditional or LED lighting/ 60 or 40 W per luminaire) Total installed power (W/m2):

[11] https://www.crosscert.eu/fileadmin/user_upload/D2-4_EPC_cross-testing_procedure_v2-9.pdf

Other features	Number of households
	Period of use of the heating and cooling system during the day (e.g. 0-24, 17:00 – 07:00…)
	Period of use of the building (e.g. every day, weekend)

2.2 Energy renovation planning

To ensure a successful and timely energy renovation, it is crucial that local, regional and national authorities have an overview of and the ability to understand the local specificities of more vulnerable areas. In addition, decision-makers need to be empowered with the information and tools needed to identify energy-poor households in their area and to implement measures to reduce energy poverty.

The analyses and recommendations developed within the RENOVERTY project aim to provide support and the necessary information to decision-makers, other key stakeholders as well as end users in recognising the specificities of rural areas when it comes to the implementation of energy renovation measures and to support policymakers in effective planning and implementation of energy efficiency policies to address energy poverty in rural areas. Below are the key identified steps that can contribute to the success and wider and faster implementation of energy renovation of family houses in rural areas, with a primary emphasis on those in which energy-poor households permanently live.

Key steps in the energy renovation of family houses of households experiencing energy poverty in rural areas of the Republic of Croatia:

1. STEP 1: ENERGY AUDIT AND ENERGY CERTIFICATE

Analysis of the current situation

It is necessary to hire experts who will make a field tour of the building and look at its current real energy and construction condition. In order to obtain initial data on the energy performance of a building, it is necessary to conduct an energy audit of the building, which will result in the preparation of an energy performance certificate and an energy audit report for the building. Information on the existing condition of the building and suggestions for improvement related to healthy indoor climatic conditions, the condition of the building structure, the possibilities of increasing the earthquake resistance of the building, and increasing safety in the event of fire can be obtained by analysing the existing condition of the building in accordance with the Ministry of Physical Planning, Construction and State Property (MPGI) Guidelines:

Guidelines for the preparation of an analysis of the existing condition of the building with a proposal of measures and an assessment of the investment in the part - healthy indoor climatic conditions, mechanical resistance and stability, fire safety

It is advisable to analyse the actual consumption of energy and water through the data from the energy and water bills in the past three years.

Building documentation and property relations

Through activities within the analysis of the situation and planning, it is necessary to look at the status of the existing documentation of the building, look into archives and files or, if available, in digital databases, including evidence of legality (building permit, use permit, decision on as-built condition, etc.) and the status of property and legal relations.

It is necessary to study the history of the existing building that is the subject of renovation, to get a clear picture of the existing condition and history of the building at the very beginning.

2. STEP 2: PREPARATION AND CREATION OF PROJECT DOCUMENTATION

Project assignment and project-technical documentation

Following the analysis of the existing condition of the building and the conclusions derived from it, it is recommended to prepare a project assignment for the preparation of the project and technical documentation for the energy and/or comprehensive renovation of the building.

Depending on the scope of the energy renovation, it is possible to contract and perform energy renovation in certain cases, using the energy certificate to obtain co-financing and carry out the work. For larger buildings, or in cases of consolidating procurement or joint planning of energy renovations for multiple family houses in a specific area, as further suggested in this document, it is recommended to prepare a main project. This ensures better planning of the works and helps avoid omissions or additional costs during the construction phase.

For the preparation of the project assignment, it is necessary to contract an expert based on the scope of the works (construction, electrical, and/or mechanical profession). The project assignment should be created according to the recommendations from the conducted reviews and analysis. It should list all the measures, planned works, systems, and technologies to be implemented during the energy/comprehensive renovation.

The project assignment is part of the procurement documentation for preparing the project and technical documentation, based on which the selected designer will prepare the required documentation. The project assignment document provides a detailed overview of the input data, design guidelines, and the scope of the project and technical documentation.

After analysing and reviewing several alternative solutions, a renovation concept must be developed. The designer will present this concept as a description and graphic representation, proposing it to the investor. Once agreed upon with the investor, the most suitable solution is selected and further developed through the main project.

The renovation concept should contain solutions and proposals for measures to be applied to the building and its plot. When choosing a concept, it is important to ensure that, in addition to energy efficiency, it also addresses safety concerns, such as improving the mechanical resistance and stability of the building, increasing earthquake resistance, fire safety, ensuring healthy indoor climate conditions, accessibility for people with disabilities, and selecting an ecologically and economically optimal renovation concept that plays a key role in the building's future performance - both in terms of costs and its impact on the surrounding environment.

A final description and graphic representation of the project are also necessary for obtaining special conditions and conditions for the connection of public bodies. **For family houses that have the status of cultural heritage or are located within protected cultural and historical complexes**, it is advisable to send the proposal to the competent conservation department with a request for an expert opinion before obtaining special conditions. This will speed up the process and help find the best solution in compliance with conservation requirements. For protected buildings, it is essential to hire a designer authorised by the Ministry of Culture to work on such properties. The project and technical documentation for these buildings must be approved by the relevant conservation department.

The use of solar energy and other renewable energy sources located near the building is especially encouraged. Solar energy, optimal sunlight exposure, and seasonal characteristics are crucial for maximising heat gains during the building's heating period and meeting the hygienic conditions within the building.

Increasing energy efficiency—primarily by reducing the energy required for heating, cooling, lighting, and operating technical systems—is key to the energy renovation of the building. Connecting buildings to efficient centralised systems, utilising renewable energy sources, and producing energy from renewable sources on-site are all essential components of the energy renovation concept.

Recommended energy and comprehensive renovation measures include:

- renovation of the building envelope:
    - thermal protection - façade, roofs, windows, doors, floors, ceilings (towards heated spaces), thermal bridges, etc.
- mandatory checks and, if necessary, waterproofing of foundations and roofs, remediation of capillary moisture rise, and drainage around the foundation structure (especially in basements)
- installation of new or replacement of existing technical systems (heating, cooling, ventilation, air conditioning and DHW)
- use of RES in heating and/or DHW systems (pellet/woodchip boiler, heat pumps, solar collectors)

- installation of solar power plants with the installation of electricity storage
- replacing interior lighting with more efficient ones
- introduction of building automation and management systems

Additional measures that are recommended to be carried out in accordance with the analysis of the current situation and recommendations (comprehensive renovation):

- fire safety improvement measures
- measures to ensure healthy indoor climate conditions
- improvement of the building's mechanical resistance and stability, particularly increasing earthquake resistance.

If the main project is being prepared (which is usually NOT necessary for family houses), the energy/comprehensive renovation includes (depending on the designed measures and the scope of the project):

- an architectural project that includes an architectural snapshot of the existing state of the building with photo documentation
- *an overview of all applied fire protection measures* in Map 1 of the main project, made by an authorised person for the preparation of a fire protection study according to a special regulation, with the conclusion that the basic requirement of fire safety has been met in all parts of the main project
- project of rational use of energy and thermal protection of the building (according to the competence of the profession)
- construction design (proof of mechanical resistance and stability for measures applied in the main design with possibly necessary repairs/reinforcements of the structure, chimney repair project, design of hydraulic installations, project of increasing the earthquake resistance of the building and others according to the competence of the profession)
- electrical design (installation of high and low current, lighting, solar power plant, lightning protection system, fire alarm, automation and building management and other according to the competence of the profession)
- mechanical design (heating, cooling, ventilation and domestic hot water systems, building automation and management, chimney repair project and others according to the competence of the profession)
- project of landscaping of the building plot
- other projects in accordance with the applicable regulations and competencies of the profession

The main design is made in accordance with the Construction Act and **the Ordinance on the Mandatory Content and Furnishing of Construction Projects** ("Official Gazette" No. 118/19, 65/20) and other related regulations. It should be well-prepared with implementation details to avoid unforeseen works that could create additional costs during execution.

It is essential to **prepare a unified cost estimate for the equipment and works required for the energy/comprehensive renovation**, which should cover all work groups based on the selected renovation concept, planned measures, and design. The cost estimate must align fully with the main design and include detailed descriptions of all items, general conditions, work groups, recapitulation, and detailed drawings for locksmith and carpentry work.

3. STEP 3: SECURING FUNDING

Consolidation of investments using the model of energy communities

In rural areas, the association of family house owners in a particular region can have a significant positive impact on the energy renovation process. By joining an energy community, households can optimise and reduce investment costs by consolidating procurement, both for the preparation of project documentation and for executing the works.

In rural areas, where there is often a large number of smaller family homes that are difficult to access and spread across a wide geographical area, designers and contractors are more likely to offer their services if procurement is consolidated. This approach also contributes to the development and transformation of the entire local community, influencing its social and economic growth. Furthermore, the energy community can engage in other activities related to energy, such as energy sharing and other forms of active participation in the energy transition.

It is recommended that owners of family homes who are part of the energy renovation community hire a project manager engineer to professionally oversee the entire process.

Application for calls for project proposals

It is essential to consistently monitor, inform, and simultaneously prepare documentation for applying to project proposal calls. To make the proposals as competitive as possible in tenders, it is highly recommended to prepare the investment in a way that maximises the projected savings and the measures applied in the renovation. This will help collect as many points as possible during the tender process, especially considering the high level of interest and the large number of applications.

If the application is successful, financing will be contracted with the competent implementing body.

4. STEP 4: EXECUTION OF WORKS AND USE OF THE BUILDING AFTER RENOVATION

Execution of works

After selecting the contractor, the construction site should be reported (only if there is an obligation to apply), and then the execution of works begins. The investor is obliged to report the start of energy renovation works. In accordance with the scope of the work, the execution can be quite a complex process in which good coordination between the participants in the construction is essential, while the following are involved in this process:

- Investor's Representative
- Project Manager
- Designer in the role of design supervision
- A contractor with all of their co-workers
- Professional supervision in the necessary professions
- Other specialist experts (occupational safety coordinator, conservation supervision and others, if applicable).

It is important to carry out the work in accordance with the project assignment and project documentation, with quality, efficiency and within the agreed deadline, while taking into account that the usual activities in the building can take place as smoothly as possible during the execution of works. If the main design is not developed, the work must be carried out according to the recommendations from EPC.

During energy renovation, the greatest attention should be **paid to details**. Not following the correct installation methods, using the wrong construction materials, or skipping certain steps can lead to problems and prevent achieving energy efficiency. This can result in issues such as poor window installation, façade detachment, thermal bridges, increased air leaks, or condensation on interior walls. It is very important that **professional supervision** is present during the execution of works to control the quality of the works performed and to be able to give a positive final report after the execution of all works with a written statement of the contractor on the performed works and the conditions of maintenance of the building.

Experience from practice shows that the **preparatory phase is very important**, i.e. a quality and detailed inspection of the building in the main design phase so that there are no additional costs during the execution of works.

It is best to entrust the preparation of the project, technical documentation and the execution of works to designers and contractors with experience and references in the energy renovation of existing buildings. It is advisable to compile quality procurement documentation, set criteria and score bidder references, and create extensive and clear contracts for all participants in the construction that are contracted, with defined responsibilities, deadlines, intermediate

deadlines, payment methods, penalties for being late in the interim deadlines and deadline for completion of works, quality assurance of works and guarantees of the quality of works after the completion of works, and more.

Use of the building after renovation

After the completion of the renovation, the investor or user must get acquainted with the way the building is used, undergo certain education and learn how to use the renovated building in the best and most efficient way, i.e. all technical systems that have been installed or modernised. This is necessary in order to actually achieve the projected savings, but also to realize the full potential of renovation in the context of indoor climatic conditions and the comfort of living in the renovated building. Designers and contractors are obliged to provide support in this regard to the investor or user and to present him with instructions for the use of the building and technical systems, i.e. to educate him about it.

The investor or user is also expected to monitor the actual consumption of energy and water, notice any anomalies and act promptly if they occur.

3 Financing mechanisms for energy renovation

The implementation of the identified measures will require the mobilisation of significant financial resources. The overview of potential sources of financing for the implementation of the measures of these REERs generally covers three categories of financial instruments:

- Financial instruments and models available today in the Republic of Croatia;
- Financial instruments and models that are available to the EU today, but have not yet been used in Croatia;
- Innovative financial models that are being developed for the purpose of implementing individual measures.

3.1 Environmental Protection and Energy Efficiency Fund (FZOEU)

The Environmental Protection and Energy Efficiency Fund (FZOEU), established by the Act on the Environmental Protection and Energy Efficiency Fund (Official Gazette 107/03, 144/12) and since its inception, on 1 January 2004, has been encouraging projects in the field of environmental protection, energy efficiency and renewable energy sources through numerous co-financing programmes. Funds for financing the activities of the Fund are provided from the Fund's earmarked revenues from:

- Compensation of environmental polluters;
- Compensation of environmental users;
- Compensation for burdening the environment with waste;
- Special environmental charges on motor-driven vehicles.

The funds of the Fund are allocated based on adopted national programmes, i.e. a public tender or call, for financial instruments that include interest-free loans, subsidies, financial assistance and donations, and the beneficiaries can be local and regional self-government units, companies and other legal entities, craftsmen and natural persons. With the accession of the Republic of Croatia to the European Union, the Fund's funds serve as complementary sources of ESIF financing.

3.2 Recovery and Resilience Facility

The Recovery and Resilience Facility is the backbone of the temporary recovery instrument NextGenerationEU, which allows the European Commission to raise funds to repair the

immediate economic and social damage caused by the coronavirus pandemic. The Reform and Related Investment Facility makes available to Member States an amount of €672.5 billion, consisting of €312.5 billion in grants and €360 billion in soft loans.

In order to use part of the funds provided by the Recovery and Resilience Facility, Member States had to prepare a National Recovery and Resilience Plan (NPOO).[12] Taking into account the main objectives of the Mechanism, the focus of the Croatian NPOO is on reforms and investments, especially those related to the green and digital transition and transformation, which are the backbone of the NRRP. Croatia has provided financial resources for its NPOO under the Mechanism in the amount of almost HRK 75 billion (€ 9.9 billion), of which HRK 47.5 billion (€6.3 billion) are grants, and about HRK 27 billion (€3.6 billion) are favourable loans.

The funds allocated under the NPOO will be allocated through public calls and the national programmes mentioned earlier. The measures planned in this document, in the part of the financing proposal, are processed in such a way that, where possible, the availability of funds from the NPOO and related national programmes is used.

3.3 European Structural and Investment Funds (ESIF)

More than half of EU funding is channelled through the five Structural and Investment Funds, of which the European Regional Development Fund (ERDF) and the Cohesion Fund are the most important sources of funding for national infrastructure projects. The funds of these funds in Croatia will be used to the greatest extent to finance investments envisaged by the Competitiveness and Cohesion Programme 2021-2027.

The level of co-financing from the ESIF can be up to 100% of the total eligible costs, where it is important to emphasise that this rate significantly depends on the development index of the city or municipality within which the investment is realised and its financial profitability. The rules of financing through EU funds dictate that projects that are commercially viable, i.e. achieve a quick return on the initial investment, are not eligible for financing with EU funds. On the other hand, projects that have unfavourable financial indicators, but create a positive social and environmental impact on the wider community, are considered eligible for financing with EU grants.

In the new seven-year financial perspective 2021-2027, Croatia has €9 billion available from the ERDF and the Cohesion Fund, while the total amount of available ESIF funds is slightly more than €14 billion, which is a significant increase compared to the 2014-2020 Multiannual Financial Framework.

[12] National Recovery and Resilience Plan, https://planoporavka.gov.hr/UserDocsImages/dokumenti/Plan%20oporavka%20i%20otpornosti%2C%20srpanj%202021..pdf?vel=13435491

The Decision of the Government of the Republic of Croatia on operational programmes related to cohesion policy for the financial period of the European Union 2021 – 2027 in the Republic of Croatia and the bodies in charge of their preparation[13] determined the implementation of three operational programmes related to cohesion policy, instead of the previous two.

For the financial period 2021-2027, the following operational programmes related to cohesion policy have been established:

1. Operational Programme Competitiveness and Cohesion 2021-2027,
2. Operational Programme Effective Human Resources 2021-2027,
3. Integrated Territorial Programme 2021-2027

3.4 Croatian Bank for Reconstruction and Development

The Croatian Bank for Reconstruction and Development (HBOR) was established on 12 June 1992 with the adoption of the Act on the Croatian Credit Bank for Reconstruction (HKBO) (Official Gazette 33/92) with the main objective of lending to the reconstruction and development of the Croatian economy. The founder and 100% owner of HBOR is the Republic of Croatia, which guarantees all incurred liabilities. The share capital is determined by the HBOR Act (OG 138/06, 25/13) in the amount of HRK 7 billion, the dynamics of payment from the State Budget determined by the Government of the Republic of Croatia.

HBOR's special lines called ESIF loans for public lighting are available to local self-government units and, in some cases, to other public and social institutions[14]. It is possible to obtain a loan in the amount of HRK 500,000 to HRK 50,000,000, with a repayment period of up to 10 years (including a grace period of up to 6 months). The interest rate is 0.1% to 0.5% per annum, depending on the level of development of the area in which it is implemented.

HBOR also offers investment loans[15] that offer favourable conditions with additional interest rate reduction options:

- Investment in natural capital[16] (green infrastructure projects, green entrepreneurship, payment of eco-system services and compensatory measures for environmental damage) – NCFF (up to 1 percentage point), and for projects in accordance with the conditions of the NPOO:

[13] Decision on Operational Programmes related to Cohesion Policy for the financial period of the European Union 2021-2027 in the Republic of Croatia and the bodies in charge of their preparation, https://strukturnifondovi.hr/wp-content/uploads/2021/12/2021602.pdf
[14] ESIF Loans for Public Lighting, https://www.hbor.hr/kreditni_program/esif-krediti-za-javnu-rasvjetu/
[15] Public sector investments, https://www.hbor.hr/investicije-javnog-sektora/
[16] Natural capital financing, https://www.hbor.hr/tema/financiranje-prirodnog-kapitala-ncff/

- Investments in the green and/or digital transition: interest rate reduction by up to 75%, maximum 3 percentage points;
- Investments in research and development and/or less developed areas and/or investments with the aim of recovering from the consequences of earthquakes: reduction of the interest rate by up to 65%, maximum 3 percentage points;
- Other investments in strengthening the sustainability and quality of public infrastructure: reduction of the interest rate by up to 50%, maximum 3 percentage points.

3.5 European Investment Bank (EIB)

The European Investment Bank (EIB), established by the Treaties of Rome in 1958, is a financial institution owned by EU member states specialising in the long-term financing of projects that support the EU's development policy.

The EIB aims to finance projects that contribute to economic progress and the reduction of regional disparities. EIB services for public and private sector beneficiaries are divided into 4 main groups:

- the granting of individual, indirect or collective loans;
- issuing guarantees on loans;
- providing technical assistance through specialised instruments: ELENA, JASPERS;
- financing of projects through funds and special instruments.

Individual loans are granted for infrastructure projects in the fields of transport, energy, environmental protection, industry, services, health and education, financed directly through the EIB, with an investment value of more than €25 million. The loan amounts are not limited, the payback period ranges from 5 to 12 years for industrial projects, and 15 to 25 years for investments in infrastructure and energy, with the EIB financing up to 50% of the investment as a standard. Interest rates can be fixed or variable, with the possibility of a grace period for the repayment of the principal with obligatory loan insurance with a bank guarantee or some other first-class collateral.

Indirect loans are mainly granted to small and medium-sized enterprises and local government units with the intermediation of the partner bank in the country of the investor itself. The loan amount ranges from 40,000 to €25 million, and 100% of the investment value is financed for projects in industry and service activities, technology modernisation, energy savings, environmental protection and infrastructure improvement. In cases where investors cannot meet the requirement of a minimum investment amount of €25 million, there is a possibility of grouping a larger number of individual projects and granting group loans.

When applying for a project loan from the EIB, there is no standard documentation or questionnaire to fill in. However, for each project, it is necessary to prepare a feasibility study, obtain the necessary legal permits, provide detailed technical specifications of the project, relevant information about the investor, create a cost plan and financial analysis, and make an environmental impact study. It is possible to combine EIB loans with ESI Funds.

3.6 European Bank for Reconstruction and Development (EBRD)

The European Bank for Reconstruction and Development (EBRD) was established in 1991 as an international financial institution to assist transition countries to a market economy and democratic order. The bank is headquartered in London and is owned by 61 countries and 2 international institutions: the EU and the EIB. The investment is carried out in 29 countries in Europe and Asia, including Croatia. The beneficiaries of the funds primarily come from the private sector and are not able to find suitable sources of financing on the market. The EBRD also works closely with regional banks to finance public sector projects.

The conditions for financing the project by the EBRD Bank are as follows:

- the project must take place in an EBRD member country;
- the project should have a significant market perspective;
- the financial contribution of the investor must be significantly higher than that of the EBRD;
- the project should contribute to the local economy and the development of the private sector;
- The project should meet strict financial and environmental criteria.

The EBRD normally finances projects in the fields of agriculture, energy efficiency and supply, industrial production, local community infrastructure, tourism, telecommunications and transport. The EBRD is financed through loans and securities in the amount of €5 to €230 million. Less valuable projects can be financed indirectly through private banks or special development programmes. The loan repayment period ranges from one to 15 years. The EBRD adjusts the financing conditions depending on the state of the region and the sector in which the project takes place. The EBRD's contribution to the project is up to 35%, but it can be higher.

3.7 Programmes and special instruments of support in the European Union

3.7.1 Horizon Europe

Horizon Europe is the EU's framework programme for research and innovation in the period from 2021 to 2027 and represents one of the key EU instruments for strengthening the European Research Area, strengthening European competitiveness, guiding and accelerating the digital and green transitions, European recovery, and preparedness and resilience. This largest public research and innovation programme in the world, with a budget of more than €95 billion for the period 2021-2027, focuses on a number of different activities such as research and innovation activities, coordination and support activities, training and mobility activities, and co-financing rates range from 30 to 100%, depending on the type of activity.

The structure of the Programme consists of three pillars:

1. Excellent Science,
2. Global challenges and European industrial competitiveness,
3. Innovative Europe.

In addition to the three pillars of the programme, the horizontal part of the programme structure supports the overall objectives of the European Research Area, with an emphasis on creating and implementing the most favourable environment for research and innovation, in which all Member States and their regions have the same opportunities for development and access to funding. Missions are a new instrument in the Programme that is focused, measurable, time-bound and with a clear budgetary framework to address societal challenges and is of common relevance for the whole Union.

3.7.2 European territorial cooperation programmes

European territorial cooperation programmes were launched with the aim of developing partnerships in sectors of strategic importance to advance the process of territorial, economic and social integration and achieve cohesion, stability and competitiveness at the regional level. The programmes are financed by the European Regional Development Fund (ERDF), the Neighbourhood, Development and International Cooperation Instrument (NDICI) and the Instrument for Pre-Accession Assistance (IPA), depending on whether the applicant comes from a Member State of the European Union or not.

In the period 2021-2027, cross-border cooperation programmes have four components:

1. Cross-border cooperation (Interreg A);
2. Transnational cooperation (Interreg B);

3. Interregional cooperation (Interreg C);
4. Outermost Regions Cooperation (Interreg D).

During the 2021-2027 programming period, around €10 billion will be allocated to cross-border cooperation programmes[17], for almost 100 different Interreg programmes that will contribute to the achievement of the objectives of the European Cohesion Policy:

- A more competitive and smarter Europe (PO1)
- Greener, low-carbon transition towards a net-zero carbon-free economy and a resilient Europe (PO2)
- A better-connected Europe (PO3)
- A more social and inclusive Europe (PO4)
- A Europe closer to its citizens (PO5)

As a rule, a project consortium must include several partners from different countries of the programme area in order to apply for Interreg programmes, whereby the project coordinator can only come from an EU Member State[18]. Co-financing of project activities can be up to 80% of eligible costs.

3.7.3 European Local Energy Assistance (ELENA)

ELENA is a technical assistance service launched in cooperation between the European Commission and the European Investment Bank at the end of 2009. Technical assistance shall be provided to cities and regions in developing energy efficiency projects and attracting additional investments, covering all types of technical assistance needed to prepare, implement and finance the investment programme. The key criterion in the selection of projects is their impact on the overall reduction of CO_2 emissions, and eligible projects include the construction of energy-efficient heating and cooling systems, investments in cleaner public transport, sustainable construction, etc.

ELENA funds typically support investment programmes above €30 million with a three-year implementation period for energy efficiency (including residential projects) and a four-year period for urban transport and mobility.

The ratio of the amount of technical assistance to capital investment must be at least between 1:10 and 1:20, depending on the type of sector to which technical assistance is granted, while the share of non-refundable co-financing is 90%.

[17] https://ec.europa.eu/regional_policy/en/policy/cooperation/european-territorial/
[18] https://interreg.eu/call-for-project/

3.7.4 Grants from the members of the European Economic Area and Norway

The Programme of Grants of the Members of the European Economic Area and Norway (*Eng. The European Economic Area (EEA) and Norway Grants* represent the contribution of 3 countries – Iceland, Liechtenstein and Norway – to the reduction of economic and social inequalities and the strengthening of bilateral relations with 15 countries in Central and Southern Europe, including Croatia.

The EEA countries jointly finance the grant in proportion to their economic strength, and the total allocation intended for the Republic of Croatia is €103.4 million for the period 2014-2021. An operational programme for the use of these funds is currently being drafted, and the funding priorities reflect the main challenges facing Europe:

- innovation, research, education and competitiveness;
- social inclusion, youth employment and poverty reduction;
- environment, energy, climate change and greenhouse gas reduction;
- culture, civil society development, good governance and fundamental human rights;
- Justice and Home Affairs.

In the previous period, this fund financed projects related to energy efficiency in residential buildings in the Czech Republic, Bulgaria, Hungary, Poland, Romania, Slovakia and Slovenia.

3.7.5 European Social Fund for Climate Action

With the aim of providing a fight against energy poverty and empowering and protecting small businesses in transition, the European Commission has proposed the creation of a Social Climate Fund with an estimated budget of €16.4 billion by 2027, which could potentially reach €72 billion by 2032.

The creation of the Fund is part of the "Fit for 55" legislative package, which aims to achieve the objectives of the European Green Deal. On 22 June 2022, the European Parliament adopted its position in favour of the Social Climate Fund, opening up opportunities for negotiations with EU governments.

The Social Climate Fund should finance concrete measures to address energy and mobile poverty, both in the short and long term, including[19]:

[19] https://www.europarl.europa.eu/news/hr/headlines/economy/20220519STO30401/socijalni-fond-za-klimu-ideje-parlamenta-za-pravednu-energetsku-tranziciju

- Reducing taxes and energy charges or providing other forms of direct income support to address the rising prices of road transport and heating fuel. This will be phased out by the end of 2032.
- Incentives for the renovation of buildings and the transition to renewable energy sources in buildings.
- Incentives for switching from private to public transport, car sharing and cycling.
- Support for the development of the market for used electric vehicles.

3.8 ESCO model

ESCO is an abbreviation for Energy Service Company and is the generic name of a concept in the energy services market. The ESCO model encompasses the development, implementation and financing of projects with the aim of improving energy efficiency and reducing operating and maintenance costs. The goal of each project is to reduce energy and maintenance costs by installing new, more efficient equipment and optimising energy systems, which ensures the repayment of the investment through the achieved savings over a period of several years, depending on the client and the project.

The risk of achieving savings is usually assumed by the energy service provider, i.e. the ESCO company, by providing guarantees, and in addition to innovative projects to improve energy efficiency and reduce energy consumption, financial solutions for their realisation are often offered. The client repays the investment through the savings achieved by applying energy efficiency measures. Depending on the type of contract, the ESCO company can provide a guarantee that the savings generated by the project will be sufficient to cover the costs of financing the project for the duration of the project. After repaying the investment, the ESCO company exits the project and hands over all the benefits to the client. All projects are specially tailored to the client, and it is possible to expand the project by including new energy efficiency measures with an appropriate division of the investment. In this way, the client can modernise the equipment without the risk of investment, since the risk of achieving savings can be assumed by the ESCO company. In addition, after the repayment of the investment, the client achieves positive cash flows in the repayment period and long-term savings.

An additional advantage of the ESCO model is the fact that during all phases of the project, the service user cooperates with only one company on a one-stop-shop basis, and not with several different entities, which greatly reduces the costs of energy efficiency projects and the risk of investing in them. Also, the ESCO project includes all energy systems at a specific location, which enables an optimal selection of measures with a favourable ratio of investments and savings. Users of the energy service and the ESCO model can be private and public companies, institutions and local and regional self-government units.

3.9 Public-Private Partnership

A public-private partnership (PPP) is a joint, cooperative action between the public sector and the private sector in the production of public products or the provision of public services. The public sector appears as a producer and provider of cooperation – as a partner who contractually defines the types and scope of jobs or services that it intends to transfer to the private sector and who offers the performance of public tasks to the private sector. The private sector appears as a partner that seeks such cooperation if it can achieve a business interest (profit) and that is obliged to perform the contractually obtained and defined jobs in a quality manner. The goal of a public-private partnership is to produce public products or services more economically, effectively and efficiently than the traditional way of providing public services. PPP occurs in different areas of public administration, in different forms, with different durations and intensity, and most often in cases where the public administration is not able to directly perform public tasks on its own for two reasons:

- due to insufficient expertise of public administration employees, when it comes to specifically professional jobs (e.g. medicine, oil, etc.);
- due to the high costs of performing public works at their own expense (e.g. purchase of construction machinery).

The characteristics of PPP projects are:

- long-term contractual cooperation (maximum 40 years) between the public and private sectors;
- material redistribution of the business risk of construction, availability and demand (two of these three risks must be on the private partner).

The advantage of financing projects through public-private partnerships is the fact that such an investment is not seen as an increase in public debt. A key condition is found in the classification of assets considered in the partnership agreement. Property from a contract is not considered property of the city only if there is solid evidence that the private partner bears most of the risk associated with the partnership. In the conditions of over-indebtedness of local and regional self-government units and the lack of public (grants) funds, public-private partnership is a model that can initiate a significantly larger volume of projects in the energy renovation sector.

3.10 Energy Communities

Citizens' Energy Communities are a relatively new concept of citizen energy that has received its formal recognition through the Clean Energy for All Europeans 2019 package of directives, as one of the key elements for achieving the EU's energy transition goals by 2050.

The goals are set by the EU Solar Energy Strategy (SWD(2022) 148 final), which envisages the establishment of at least one RES-based energy community in each local self-government unit with more than 10,000 inhabitants by 2025 in each EU member state.

There are two basic types of energy communities in Croatian legislation: citizen energy communities (CEC), which are defined by the Electricity Market Act (OG 111/2021, 83/2023) and renewable energy communities (REC) and their subset, consumers of own renewable energy acting jointly, defined by the Act on Renewable Energy Sources and High-Efficiency Cogeneration (OG 138/21, 83/2023).

Energy communities can make a significant contribution to the fight against energy poverty through access to cheaper, locally produced energy. Energy communities can provide direct assistance to vulnerable members of the community, e.g. by financing part of the energy costs, subsidising energy renovation or providing education on energy saving.

Regarding the possibility of using the mechanism of energy communities to combat energy poverty, in cooperation and communication with stakeholders from different fields during the Round Table within the RENOVERTY project, the following was determined;

- Energy communities can act for the benefit of the entire local community, including households experiencing energy poverty, through several different mechanisms (for example: it is possible to encourage the inclusion of households experiencing energy poverty in the sharing scheme or to finance energy renovation measures with financial or energy surpluses determined by community members);
- The use of solar power plants on the roofs of public institutions can be used to meet the energy needs of vulnerable households, except for the own needs of the building/institution on which it is installed. This can provide the energy poor with direct access to free renewable energy instead of the existing payment/subsidy of bills. The new Directive on the internal market for electricity (draft) provides that Member States are to ensure that the electricity to be shared is available to customers or citizens vulnerable to or experiencing energy poverty under energy-sharing projects owned by public authorities. In doing so, Member States shall incentivise, as far as possible, that the amount of energy available is on average at least 10% of the energy to be shared.
- Energy communities can organise education and access to information for the energy poor in their area, thus empowering them to become active participants in the energy transition.
- Energy communities can provide funds to finance the costs of energy renovation, and the association of owners of family houses enables the reduction of energy renovation costs through joint procurement and execution of works, which increases efficiency and motivates contractors.

As one of the key challenges for combating energy poverty, in addition to the previously identified financial and information barriers, the problem of property and legal relations and a

significant number of illegal buildings in which the energy poor live has been recognised. Providing a mechanism to address the legality of buildings for certain groups of vulnerable citizens would increase the availability of available financial mechanisms for these users. It is necessary to note that for citizens experiencing energy poverty, even in the case of resolved property and legal issues and the availability of financial mechanisms, there is a significant need to provide comprehensive and easily accessible assistance in the form of one-stop shops. It is necessary to provide citizens experiencing energy poverty with access to financial mechanisms on a turnkey basis, as well as assistance in finding contractors and supervising the implementation of works.

Financial mechanisms for the implementation of energy renovation measures and the application of renewable energy sources with the aim of combating energy poverty are the primary duties of the state in combination with the available EU funds. As an opportunity for accumulating funds for the purpose of combating energy poverty, energy savings have been identified, where the financial savings that are achieved due to them can be redirected to encourage energy renovation in households experiencing energy poverty. As an additional challenge, the need for a clear identification of households experiencing energy poverty was recognised, which requires strong inter-institutional cooperation to establish clear criteria and preconditions for exercising the right to various forms of assistance for the implementation of energy efficiency and renewable energy measures. At the same time, it is necessary to move away from beneficiaries who are already in the social welfare system and receive a guaranteed minimum allowance, to those groups of citizens who are in energy poverty but are currently not recognised by the system - e.g. persons and families who receive the minimum wage or are below the median wage, and who live in energy-inefficient buildings, etc.

In Table 2, an overview of possible sources of financing for the successful implementation of energy renovation measures is given.

Table 2 Overview of possible sources of funding for measures and activities

Source of funding	Kind	Maximum amount	Share of total costs (%)	Link
Municipal budget	Own resources	-	Up to 100%	/
FZOEU	Grants	Not specified	Up to 100% depending on the type of project and the type of measures	https://www.fzoeu.hr
NPOO	Grant/loan	Depending on the type of investment	Depending on the type of investment	https://planoporavka.gov.hr

Source of funding	Kind	Maximum amount	Share of total costs (%)	Link
ESIF	Grants	Separately determined by specific goals.	Up to 100%	https://strukturnifondovi.hr
HBOR	Credit	Not specified	Depending on the development index of local self-government units	https://www.hbor.hr
EIB	Loan/Guarantees	Not specified	Depends on the financial instrument	https://www.eib.org/en/publications/eib-in-croatia?lang=hr
EBRD	Credit	€5-230 million per project	Depends on the financial instrument	https://www.ebrd.com/croatia.html
Horizon Europe	Grants	Depends on the call	Of the 100	https://razvoj.gov.hr/djelokrug-1939/eu-fondovi/programi-unije-2021-2027/programi-unije-2014-2020/obzor-2020/2978
EU territorial cooperation programmes	Grants	It depends on the specific objective under which the project is applied	From the 80	https://razvoj.gov.hr/europska-teritorijalna-suradnja-4216/4216
ELENA	Grants	Not specified	90	https://mpgi.gov.hr/print.aspx?id=8532&url=print&page=1
Grants from members of the European Economic Area and Norway	Grants	€103.4 million total	Not specified	https://www.hgk.hr/eea-norway-grants/o-financijskim-mehanizmima
ESCO model	Private equity/credit	-	Of the 100	/
Public-Private Partnership	Private capital	-	Up to 100	/
Social Climate Fund	Grants	It needs to be determined. In application from 2025	n/p	https://eur-lex.europa.eu/HR/legal-content/summary/social-climate-fund.html
Energy Communities	Public funds and private capital	-	Depending on the model of the energy community.	https://energetske-zajednice.hr; https://www.hera.hr/hr/html/registar_EZG.html

4 Planning and implementation of measures to reduce energy poverty in rural areas

4.1 Defining energy renovation goals

As previously mentioned, the main goals of energy renovation of family houses of households experiencing energy poverty are aimed at reducing the financial burden and energy consumption, improving living conditions and including the most vulnerable citizens in active participation in the energy transition. These goals will ultimately contribute to environmental protection and solving the problem of energy poverty.

In order to clearly define and measure the goals of energy renovation, each of the defined goals is linked to measurable values, which enables monitoring of performance after the implementation of the REERs and enables easier monitoring of progress.

Table 3 Goals of energy renovation of family houses

Main objective	Specific objectives	Performance indicators (KPIs)	Initial balance	Target state	Deadline (years)
Reducing the financial burden on households	1. Reduction of expenditure on energy costs	Average reduction in heat and electricity costs (kWh)	Current percentage of income utilised to cover energy needs	Reduction by 20%	5
	2. Ensuring access to subsidies	Number of households receiving the subsidy	The current number of households that have received the subsidy	An increase of 30%	5
Reduction of energy consumption	1. Improving the energy efficiency of buildings	Number of renovated family houses (in a year)	Current number of renovated family houses	An increase of 30%	5
	2. Introduction of energy-efficient appliances	Number of energy-efficient appliances per household	Average number of devices	Installation of 2-3 per household	3
Improving living conditions	1. Increasing air quality and thermal comfort for family houses	Average indoor temperature in summer/winter	Current temperature in summer/winter	Increasing the temperature in winter (optimal 20 degrees) / decreasing the temperature in summer (making sure that it is not 7	5

				degrees lower than the outside[20])	
	2. Reduction in the rate of respiratory diseases due to poor conditions	Rate of reported respiratory diseases (%)	Current Rate	Reduction by 10%	5
Active involvement of vulnerable groups	1. Raising awareness of vulnerable citizens about the energy transition	Number of held and informative workshops	Current number	5 per year	Continuous
	2. Involving citizens in energy renovation projects	Number of vulnerable citizens involved in projects (%)	Current number according to the identification of vulnerable citizens	20% of the total number of identified citizens	3
Contribution to environmental protection and reduction of CO_2 emissions	1. Reducing CO_2 emissions from households	Reduction of CO_2 emissions per household (kg/year)	Current show	Reduction by 30%	5
	2. Promotion of renewable energy sources	Number of households with integrated solar panels or other RES systems	Current number	15% of households.	5

4.2 Identifying and overcoming obstacles

The implementation of energy efficiency measures in family houses of households experiencing energy poverty often encounters numerous obstacles and challenges that can make it difficult to access the necessary resources and thus slow down or hinder the achievement of the desired goals. This chapter provides an overview of the identified obstacles and challenges classified into 4 categories (technical, financial, legal and administrative, social). For each of the obstacles, a proposal for a measure to overcome it is also given.

[20] https://www.hzjz.hr/sluzba-zdravstvena-ekologija/zastitite-se-od-vrucina/

Table 4 Identification of obstacles and proposal of solutions

OBSTACLES AND CHALLENGES	SOLUTION
Technical	
Lack of experts and contractors - In the territory of the Republic of Croatia, and especially in rural areas, there is often a lack of qualified experts and contractors who would carry out energy renovations. - Most contractors work in more urban areas where there is more work and there is easier access to the necessary materials.	- Launching pilot projects that renovate multiple houses simultaneously can attract contractors and reduce material costs - Introduction of incentives for experts and contractors (subsidies for transport, accommodation insurance, etc.)
Lack of infrastructure - Poor road connectivity in winter conditions can slow down or prevent access to houses	- Planning for renovation outside of seasonal adverse conditions to avoid winter-related delays and ensure better material availability can help overcome access problems; - Improving local infrastructure through long-term investments can help improve the accessibility of rural areas (e.g. investing in local roads, utilities and storage facilities for construction materials to improve access to remote areas)
Outdated and unmaintained houses - Often, family houses of households experiencing energy poverty are old and poorly maintained and have certain construction problems (e.g. dilapidated and damaged construction and building parts that have lost their properties, moisture, cracks in the walls, dilapidated installations...) and in addition to energy renovation, a comprehensive renovation is also needed, which can be very expensive and technically demanding.	- Make a detailed assessment of the building to determine priorities (it is necessary to ensure mechanical resistance and stability and improvement of the basic requirements for the building before the start of energy renovation or through it (comprehensive renovation)).
Financial	
Lack of personal financial resources - Households experiencing energy poverty often do not have enough of their own resources to cover renovation costs, even with subsidies (the costs of basic needs such as food and heating are prioritised over investments in energy renovation due to low incomes): - Limited national funds, but also a percentage of co-financing that is too low;	- Development and provision of additional financial support in the form of grants, co-financing or low-interest loans intended exclusively for households experiencing energy poverty, with a particular focus on the subset of vulnerable citizens living in rural and peri-urban areas, who even have even less access to funding sources than their urban counterparts; - Introduction of micro-credits that allow the gradual payment of the reconstruction process; - Establishment of energy communities to finance energy renovation projects (e.g. joint investment in a solar power plant and use of the revenue to fund energy renovation projects).

High initial costs for households - The costs of implementing energy efficiency measures can be very high, especially in buildings that also require additional construction work.	- It is necessary to elaborate in detail the scope of the necessary works of each family house and to take care of and provide funds for additional works
Lack of funds at the local level - Local budgets in rural areas are often limited and lack sufficient resources to finance local energy renovation programmes.	- Increasing cooperation between local authorities and national funds to create specific funds for rural areas by aligning local strategies with national strategies/program/plans and creating tailored funding programs that address the unique needs of rural areas - The development of public-private partnerships where private companies help co-finance renovation projects can reduce the burden on local budgets.
Legal and administrative	
Illegally built houses - Proof of the legality of the building is a condition for applying to the national call for energy renovation of family houses; - Citizens who have built/upgraded buildings without valid building permits could submit a request for legalisation until 30.06.2018 inclusive; - The process of legalising the house itself is quite a large expense, which is one of the main reasons why citizens did not submit applications.	- It is necessary to re-enable the submission of applications for the legalisation of buildings; - It is necessary to identify citizens experiencing energy poverty (e.g. in cooperation with local government, LAGs, local social welfare institution, etc.) and provide support for co-financing the legalisation process
Complex administrative processes for obtaining subsidies - Grant application processes can be complicated and time-consuming. Households experiencing energy poverty in rural areas often do not have enough knowledge/capacity to meet the requirements and documentation required to apply.	- Simplification of administrative procedures and development of local technical assistance centres in rural areas (local OSS). These centres could provide support in applying for grants and provide better access to households that do not have sufficient knowledge about the opportunities available.
Social	
Insufficient level of education and awareness about energy renovation - In rural communities, there is often a lower level of awareness about the benefits of energy renovation and how to implement it. People are not aware of the financing opportunities or long-term savings that renovation brings.	- Conducting local information and education campaigns that can raise awareness of the benefits of energy renovation. - Distributing existing guidelines and informational materials through local communities. One of the campaigns with energy-saving tips can be found on the official webpage of the Ministry of

	Economy (Guidelines for Energy Savings in the Republic of Croatia[21])
Lack of local support and assistance - In rural areas, there are often no service providers/expert teams that can coordinate energy renovation projects	- Application of the "turnkey" model (developing a program where homeowners receive a full-service renovation package without needing to individually contract works). - Development of a local OSS that will offer technical and administrative assistance to households in rural areas throughout the entire renovation process.

Despite the identified obstacles and challenges, success in the implementation of energy renovations can be achieved through effective coordination, financial support, education and technical assistance, which will ultimately enable easier implementation and long-term benefits for households and communities. Most obstacles can be successfully overcome with proper planning, development of new programmes and financing models, and adaptation to the specifics of each building. It is important to keep in mind that it is important to involve experts and the local community in the renovation process itself to ensure quality and sustainable implementation of energy efficiency measures.

A brief overview of each of the levels of government and their influence and the possibilities of implementing individual measures is given below:

- **National level**: At the national level, the REERs could be implemented through integration into the National Energy and Climate Plan (NECP), the Low Carbon Development Strategy, and other policies aimed at energy efficiency and energy poverty reduction. Ministries responsible for energy, environmental protection and social policy could use them as a reference when designing long-term assistance programmes for energy-poor households. Linking and integrating the REERs into **the Social Climate Plan would** enable better support for citizens experiencing energy poverty through financial assistance and subsidies under **the Social Climate Fund**
- **Regional level**: Regional authorities can use the REERs as a basis for planning and implementing energy renovation programmes specific to regional conditions and needs. For example, counties could integrate the REERs into regional strategies and plans and work with various stakeholders, including local organisations and experts, to provide tailored support to energy-poor households.
- **Local level**: Local self-government units have a key role in the direct implementation of the measures listed in the REERs. They know best the specific needs of the community

21 https://mingo.gov.hr/UserDocsImages/slike/Vijesti/2022/Smjernice%20za%20uštedu%20energije%20u%20Republici%20Hrvatskoj.pdf

and can adapt the REERs to suit local conditions. Through cooperation with local action groups (LAGs), civil society organisations and experts, local authorities can ensure the successful implementation of household energy renovation projects, which can serve as a model for other communities.

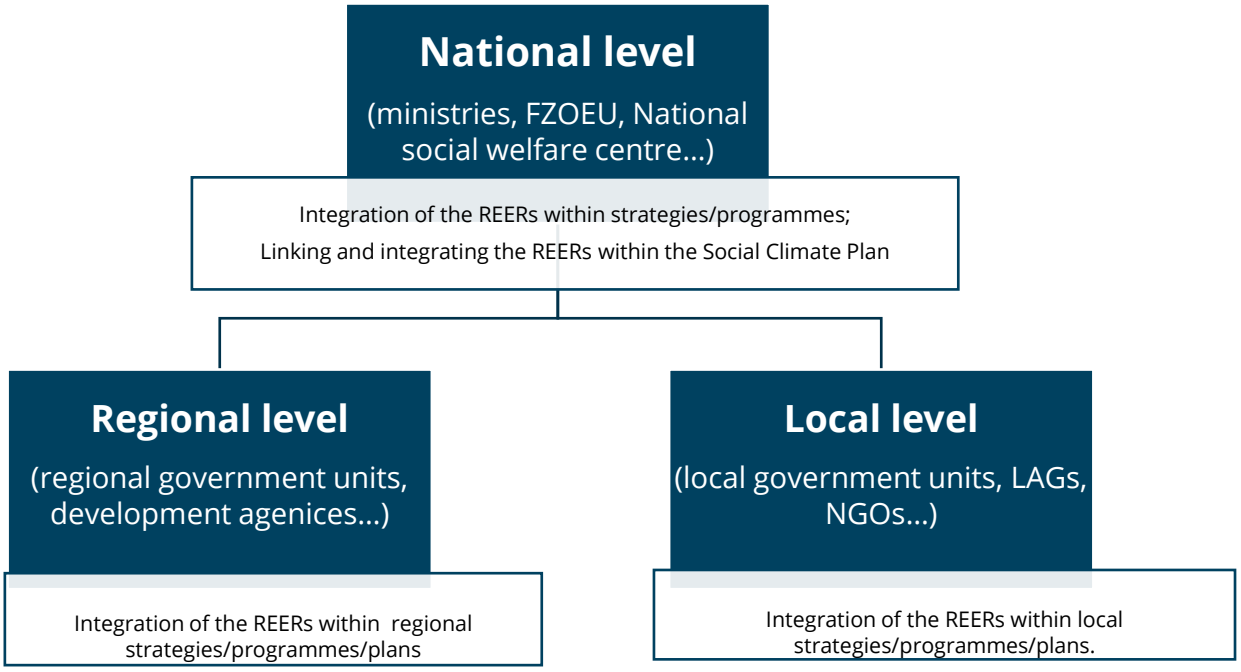

Figure 2 Cooperation of stakeholders in the implementation of energy renovation measures

4.3 Identification of key stakeholders

The implementation of energy renovations of family houses of citizens experiencing energy poverty requires cooperation and coordination of various stakeholders at the local, regional, national, but also at the international/EU level. Key stakeholders play an important role in the financing, planning, implementation and supervision of these projects. The following is a table with a list of key stakeholders grouped into 3 categories and their role in the renovation of dwellings of households experiencing energy poverty.

Table 5 Key stakeholders in the implementation of energy renovation of family houses

Name of the stakeholder	Level of action	Role
The Government and State Institutions		
Competent ministries - Ministry of Physical Planning, Construction and State Property - Ministry of Economy	National	Creating and shaping national policies, financing and programmes for energy renovation; Defining strategies and policies aimed at reducing energy poverty and achieving energy efficiency;

- Ministry of Labour, Pension System, Family and Social Policy - Ministry of Finance - Ministry of Environmental Protection and Green Transition - Ministry of Health - Ministry of Regional Development and EU Funds		
Environmental Protection and Energy Efficiency Fund	National	Implementation of the programme of energy renovation of family houses (publication of public calls for grants)
Local self-government units	Local	Implementation of national programmes and REERs for energy renovation at the local level
Croatian Institute for Social Welfare	National, Regional	Supporting socially vulnerable citizens, including those facing energy poverty
Civil society organisations and other public institutions/organizations		
Local Action Groups (LAGs)	Local	Cooperation with citizens and implementation of the REERs at the local level; Access to finance
LEADER Network	Regional, National	Promotion of the REERs among all LAGs (ensuring replicability)
Association of Cities in the Republic of Croatia	National	Promotion of the REERs among Croatian cities and municipalities
Energy Agencies	Regional, Local	Technical support, information, and education on the energy renovation process
Croatian Chamber of Economy	National	Connecting stakeholders and facilitating cooperation between the public and private sectors; Promotion of the REERs and education of companies on the need of energy renovation
Development Agencies	Regional, Local	Integration of the REERs into local/regional development strategies; integrating energy policy and measures into broader community sustainable development plans
Private companies		
Energy auditors	Regional, Local	Expert assessment and guidelines for improving energy efficiency, conducting energy audits and creating energy certificates for buildings
Planners	Regional, Local	Preparation of project and technical documentation for energy renovation
Contractors	Regional, Local	Implementation of all types of works and technical measures in energy renovation
Professional supervision	Local	Quality assurance of the works carried out
Equipment & Materials Manufacturers & Suppliers	Regional, Local	Production and distribution of the necessary materials and provision of guarantees for its products
Banks and credit unions	National	Financial support through favourable loans, subsidies, advisory services

4.4 Conclusion

The REERs of households experiencing energy poverty represent the basis for providing support to households experiencing energy poverty in Croatia, especially those located in family houses in peri-urban and rural areas. Their purpose is to provide these households with access to more energy-efficient, healthier and more sustainable homes, setting the framework for addressing energy poverty through specific measures tailored to the needs of the most vulnerable. The success of these REERs depends on successful implementation and adaptation at the national, regional and local levels, as well as on their potential to adapt to local specificities and further spread among local and regional self-government units within Croatia and beyond.

Although the REERs are standardised, they are flexible enough to adapt to the specific needs of different regions in Croatia. The main objective of the REERs is to provide general recommendations that can be applied to different communities, with the possibility of adapting to local conditions and specificities. For effective implementation at the local level, cooperation with local stakeholders (such as local authorities, local action groups - LAGs, civil society organisations and experts) is crucial to ensure that the REERs respond to the real needs of the community.

Examples of adaptation of the REERs may include:

1. **Adaptation of measures in accordance with the climatic conditions of the region** – In the northern parts of Croatia, energy renovation may put emphasis on thermal insulation, while in coastal areas the focus could be on ventilation systems and protection against overheating.
2. **Respect for the socio-economic specificities of the community** – Rural regions with lower incomes will need financial mechanisms primarily in the form of subsidies or grants, while more urban areas could benefit from additional credit lines (micro-loans, low-interest loans) intended exclusively for energy renovations of family houses.

The application and successful implementation of the REERs can be ensured through some of the following activities:

- **Presentation of the REERs to the general public at national level** – Organise national conferences, workshops and roundtables to present the REERs to all relevant stakeholders, including representatives of ministries, local and regional authorities and civil society organisations. Such events will allow for the dissemination of knowledge about the importance and benefits of the REERs.
- **Integration of the REERs into strategic documents** – It is necessary to integrate the REERs into key strategic documents at the local, regional and national levels, such as the NECPs (Integrated National Energy and Climate Plan) and SECAPs (Sustainable Energy and Climate Action Plans) and other national, regional and local energy efficiency strategies

and programmes. This ensures that the REERs become part of the long-term strategic framework to combat energy poverty.

- **Mapping of local self-government units for priority identification** – To identify local self-government units with a high share of households experiencing energy poverty and provide them with additional support for the implementation of the REERs. This includes providing technical assistance, financial support and the transfer of knowledge necessary for the effective implementation of the measures.
- **Promotion of expected results and benefits** – It is crucial to communicate the positive effects of the implementation of the REERs, such as reducing energy costs, improving quality of life and reducing greenhouse gas emissions. Clearly displaying these results can help raise awareness among citizens and public institutions, increasing support for energy renovation projects.
- **Dissemination of success stories** – Showcasing successful examples of the implementation of the REERs in different settings can serve as inspiration for other communities. Successful examples, especially those with visible financial and environmental benefits, will further motivate and facilitate the adaptation and application of the REERs in other regions.

Linking the REERs to the Social Climate Plan and the Social Climate Fund can further strengthen efforts to combat energy poverty and provide the necessary financial support for the implementation of the REERs, especially for the most vulnerable groups. In this way, it can also enable the efficient use of funds, ensuring the long-term sustainability of the measures and their extensibility throughout the country.

The REERs of households experiencing energy poverty are a key tool for solving the problem of energy poverty in Croatia. Their success depends on integration into local and national strategies, adaptation to the specific conditions of different communities, and the active involvement of all relevant stakeholders. With a long-term and systematic approach, it is possible to ensure that the REERs become a permanent solution to energy poverty, not only in Croatia, but also beyond.

LIST OF FIGURES

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ANNEX

ANNEX 1 Overview of savings through the implementation of energy efficiency measures (Simulations results from the DREEM model)

As part of the RENOVERTY project and based on the results of energy audits as well as nationally available data, simulations on the impact of the energy performances of different energy efficiency measures we conducted by employing the *Dynamic high-Resolution dE-mand-sidE Management* (DREEM)[22] model. DREEM is used to define the implementation of the most cost-effective energy efficiency measures, based on their energy-saving potential and techno-economic viability.

The energy efficiency measures (EEM) that were selected and analysed through the DREEM model for all 7 pilot countries are as follows:

- **EEM_1 - Insulation of exterior walls**: Insulation of the exterior walls of a building.
- **EEM_2 - Double-glazed windows**: Replacing single-glazed windows with more energy-efficient windows (double-glazed IZO windows) to reduce heat loss.
- **EEM_3 – Thermal insulation of the roof**: Insulation between and under the rafters of the roof itself, reducing the overall heat transfer coefficient by adding materials with low thermal conductivity.
- **EEM_4 - Energy Efficient Heating System (Boiler Upgrade - Gas):** In this case, the existing heating system is replaced by a more efficient gas boiler with a higher efficiency rate. The gas heating system was analysed solely for financial indicators, but given its negative impact on the environment and contribution to climate change, it is recommended to switch to sustainable heating systems that use renewable energy sources, such as heat pumps and biomass.
- **EEM_5 - Energy Efficient Heating System (Boiler Upgrade - Biomass):** In this case, the existing heating system is replaced by a more efficient biomass boiler with a higher efficiency rate.
- **EEM_6 - Energy Efficient Heating System (Heat Pump):** In this case, the outdated heating system is replaced by a heat pump with a higher degree of operation.

[22]More information available within the RENOVERTY project report *Home Renovation Roadmaps to Address Energy Poverty in Vulnerable Rural Districts: https://ieecp.org/wp-content/uploads/2024/07/RENOVERTY-Deliverable-4.1_final-version_layout-website.pdf (August 2024.)*

- **EEM$_7$ – LED lighting**: In this case, fluorescent and incandescent bulbs are replaced by high-efficiency LED lamps.

The modelling results provide detailed information on the energy-saving potential, environmental impacts, cost-effectiveness, and profitability of households resulting from the implementation of various measures, demonstrating different outcomes in different case studies. The energy-saving potential of EEM is highly dependent on the initial condition of the building and the heating system, underscoring the critical role of the baseline situation in determining the effectiveness of interventions aimed at reducing energy consumption and environmental impact. Implementing EEM in areas where they are most needed, considering the current inefficiency and high energy consumption will ultimately lead to significant improvements in energy efficiency, living conditions, and environmental protection.

Furthermore, variations in the applicability and techno-economic sustainability of different measures highlight the benefits and the subsequent need to ensure co-financing for individual measures. Funding mechanisms must be adapted to the specific needs of rural areas, with strategies and plans designed to encourage regional and local development in a tailored way, ensuring targeted allocation and addressing the specific needs of vulnerable households.

Additionally, one of the key factors affecting the profitability of certain investments, leading to a long payback period, is the low regulation of electricity and natural gas prices. Removing price regulation and redirecting these funds to encourage the use of renewable energy sources and energy renovation, particularly in rural and vulnerable areas, can help reduce energy poverty while optimising the use of public funds.

The prices used in assessing the cost-effectiveness of individual EEM are shown in Table (Annex) 1.

Table (Annex) 1. Energy prices used in techno-economic analysis

Average electricity price - household (€/kWh)	Average gas price – household (€/kWh)	Average biomass price (€/kWh)
0.06[23]	0.04[24]	0.06[25]

In the pilot areas of Sveta Nedelja and Žumberak, two typologies of family houses were identified that were considered in the analysis:

[23] https://www.hep.hr/elektra/kucanstvo/tarifne-stavke-cijene/1547

[24] https://www.hep.hr/plin/UserDocsImages/cjenici_HEP_Plin/20240325/Odluka%20o%20iznosu%20tarifnih%20stavki%20za%20javnu%20uslugu%20opskrbe%20plinom%20-%20HEP-Plin%20d.o.o..pdf

[25] https://www.drvnipelet.hr/o-drvnom-peletu/

- family houses that use a wood stove as their primary heating system, and
- family houses that use a gas boiler as their primary heating system.

Estimates of annual energy savings (kWh) and reduction of CO_2 emissions by implementing each of EEM for both types of typologies are given below.

1. Family houses that use a wood stove

When it comes to the implementation of EEM_6 related to the installation of a heat pump, the highest energy savings in the amount of 43,280.4 kWh per year can be achieved, reducing consumption by 75.3% compared to the baseline scenario. In the case of the implementation of the EEM_4 measure, when it comes to replacing the wood stove with a gas boiler, savings of 15,017.00 kWh per year would be achieved, i.e. by 26.1% compared to the baseline scenario, and in the case of the implementation of the EEM_5 measure, when it comes to replacing the wood stove with a biomass boiler, savings of 9,724.8 kWh per year would be achieved, by 16.9% compared to the baseline scenario.

Given the negative impact on the environment, the gas heating system contributes to climate change and should be avoided. On the other hand, sustainable and green heating systems, such as heat pumps and biomass, use renewable energy sources, reduce greenhouse gas emissions and are more environmentally friendly in the long run. The transition to these systems is key to reducing dependence on fossil fuels and preserving the environment.

Table (Annex) 2. Annual savings achieved by implementing EEM related to family houses using wood stoves

	Reduction of energy consumption (kWh/year)	Energy savings (%)
EEM_1: Insulation of exterior walls	5,814.1	10.1
EEM_2: Double-glazed windows	1,100.1	1.9
EEM_3: Roof insulation	14,311.2	24.9
EEM_4: Heating system upgrade - Gas	15,017.0	26.1
EEM_5: Heating system upgrade - Biomass	9,724.8	16.9
EEM_6: Heat pump	43,280.4	75.3
EEM7: LED Lighting	579.7	1.0

Table (Annex) 3 shows the reduction of CO_2 emissions through the implementation of individual EEM in family houses equipped with wood stoves. The most significant reduction will be achieved

by the implementation of the EEM_5 measure, which will lead to a reduction in CO_2 emissions by 16,757.5 kg of CO_2 per year compared to the baseline scenario, followed by the EEM_6 and EEM_4 measures with an annual reduction of 12,771.4 and 9,025.6 kg of CO_2.

Table (Annex) 3. Annual reduction of CO2 emissions through the implementation of EEM related to family houses using a wood stove

	Reduction of emissions (kg CO_2)	Emission savings (%)
EEM_1: Insulation of exterior walls	1,814.0	9.6
EEM_2: Double-glazed windows	343.2	1.8
EEM_3: Roof insulation	4,465.1	23.5
EEM_4: Heating System Upgrade - Gas	9,052.6	47.7
EEM_5: Heating System Upgrade - Biomass	16,757.5	88.3
EEM_6: Heat Pump	12,771.4	67.3
EEM_7: LED Lighting	218.0	1.1

Table (Annex) 4 shows the results of the techno-economic analysis of different EEM. According to the analysis, measure EEM_4 (Boiler upgrade – gas) and measure EEM_3 (Roof insulation) show the best results in terms of net present value (NPV) that show profitability of project investment, with NPVs of €18,583.90 and €10,060.60, respectively. Also, given the negative impact of gas on the environment and its contribution to climate change, it is recommended to switch to sustainable heating systems that use renewable energy sources, such as heat pumps and biomass.

The measure EEM_7 (LED lighting) and EEM_6 (heat pump) result in the lowest levelized cost of saved energy (LCSE), at €0.005/kWh and €0.018/kWh respectively. Furthermore, the implementation of measures EEM_7 and EEM_4 will achieve the best results in terms of the required payback period, with 0.7 and 2.4 years, respectively. The implementation of the EEM_2 (Double Windows) measure proved to be less attractive investment since it shows a negative amount of NPV.

The significant economic benefits provided by all EEM highlight the poor state of the current situation of residential buildings and highlight the urgent need to implement EEM in the buildings of rural households in Sveta Nedelja and Žumberak. In addition, the replacement of existing heating systems will bring numerous benefits to households in the area of Sveta Nedelja and Žumberak, as switching to a more efficient heating system will reduce heating costs, but also significantly improve the comfort of living and air quality in the house.

Table (Annex) 4. Techno-economic analysis of the implementation of various EEM related to family houses using wood stoves

	Investment Cost (€)	Lifespan (years)	Discount rate (%)	NPV (€)	PP (year)	LCSE (€/kWh)
EEM_1	4,847	30	4.00%	1,185.1	20.7	0.048
EEM_2	3,584	30	4.00%	-2,687.0	>Lifespan	0.240
EEM_3	4,788	30	4.00%	10,060.6	6.4	0.019
EEM_4	3,468	20	4.00%	18,583.9	2.4	0.019
EEM_5	3,657	20	4.00%	3,593.3	8.2	0.033
EEM_6	10,000	20	4.00%	3,108.6	13.7	0.018
EEM_7	45	23	4.00%	962.7	0.7	0.005

Obtaining co-financing for the implementation of energy renovation of family houses in rural and peri-urban areas is crucial for citizens, especially for those experiencing energy poverty, because it allows them to renovate their family houses with a lower financial burden. This is especially important when considering the long payback period and the often high amount of own funds required to launch such projects. Households experiencing energy poverty often do not have enough resources to finance energy renovation on their own, so co-financing allows them to access renovation without the need for large initial investments. In addition, co-financing reduces the total amount of the investment, which accelerates the return on investment through savings on energy bills. With financial support, citizens can afford more comprehensive energy renovation measures, such as heat pumps or solar panels, which contribute to long-term sustainability, reduced greenhouse gas emissions and a better quality of life. It is necessary to reiterate here the fact that the long periods of return on investment in energy renovation measures are currently significantly influenced by subsidised electricity and natural gas prices. In order to ensure the dual benefit, increase the profitability of investments in energy renovation and reduce dependence on fossil fuels, it is necessary to remove price regulation mechanisms and redirect funds to increasing energy efficiency and applying renewable energy measures, especially for vulnerable groups.

Table (Annex) 5 presents the results of the techno-economic analysis taking into account the co-financing in the amount of 50%, and with a higher percentage of co-financing, it is possible to achieve even greater economic benefits for households experiencing energy poverty in terms of net present value and energy price savings. From the above values, it is evident that co-financing

will significantly improve the financial sustainability of the implementation of measures, especially those with higher initial costs and longer return on investment.

Table (Annex) 5. Techno-economic analysis of the implementation of various EEM related to family houses using wood stoves (50% co-financing)

	Investment Costs (€)	Co-financing	Lifespan (years)	Discount rate (%)	NPV (€)	PP (year)	LCSE (€/kWh)
EEM_1	4,847	50%	30	4.00%	3,608.7	8.3	0.024
EEM_2	3,584		30	4.00%	-895.0	>Lifespan	0.120
EEM_3	4,788		30	4.00%	12,454.4	3.0	0.010
EEM_4	3,468		20	4.00%	20,317.9	1.2	0.011
EEM_5	3,657		20	4.00%	5,421.8	3.8	0.019
EEM_6	10,000		20	4.00%	8,108.7	5.9	0.010
EEM_7	45		23	4.00%	985.2	0.3	0.003

2. Family houses equipped with a gas boiler

From Table (Annex) 6, which refers to the replacement of the existing gas boiler, it is evident that the implementation of EEM_6, which refers to the installation of a heat pump, will lead to the highest energy savings, i.e. 27,996.8 kWh per year, i.e. consumption will be reduced by 71.3% compared to the baseline scenario. In the case of the implementation of the EEM_3 measure, when it comes to the roof installation, savings of 10,618.00 kWh per year would be achieved, i.e. by 27% compared to the baseline scenario.

Table (Annex) 6. Annual savings achieved by implementing EEM related to family houses equipped with a gas boiler

Annual energy savings (kWh)		
	Reduction of consumption (kWh)	**Energy savings (%)**
EEM_1: Insulation of exterior walls	4,322.0	11.0
EEM_2: Double-glazed windows	857.5	2.2
EEM_3: Roof insulation	10,618.0	27.0
EEM_4: Heating System Upgrade - Gas	4,520.4	11.5

EEM_5: Heating System Upgrade - Biomass	1,154.0	2.9
EEM_6: Heat Pump	27,996.8	71.3
EEM_7: LED Lighting	597.7	1.5

Table (Annex) 7 shows the reduction of CO_2 emissions through the implementation of individual EEM in family houses equipped with gas boilers. The most significant reduction will be achieved through the implementation of the EEM_5 measure, which will lead to a reduction in CO_2 emissions by 7,130.6 kg of CO_2 per year compared to the baseline scenario, followed by EEM_6 and EEM_3 measures with an annual reduction of 4,171.3 and 2,144.8 kg of CO_2, respectively.

Table (Annex) 7. Annual reduction of CO2 emissions through the implementation of EEM related to family houses equipped with a gas boiler

Annual reduction of CO_2 emissions		
	Reduction of emissions (kg CO_2)	**Emission savings (%)**
EEM_1: Insulation of exterior walls	873.0	10.4
EEM_2: Double-glazed windows	173.2	2.1
EEM_3: Roof insulation	2,144.8	25.5
EEM_4: Heating System Upgrade - Gas	913.1	10.8
EEM_5: Heating System Upgrade - Biomass	7,130.6	84.7
EEM_6: Heat Pump	4,171.3	49.6
EEM_7: Energy Efficient Lighting	218.0	2.6

Table (Annex) 8 presents the results of the techno-economic analysis of different energy efficiency (EEM) measures. According to the analysis, the EEM_3 measure (Roof insulation) and the EEM_7 measure (LED lighting) show the best results in terms of profitability of the project investment (NPV), with NPVs of €3,107.60 and €957.7, respectively. Other measures have proven to be less attractive if financial support is not received for their implementation, since they show a negative amount of NPV.

The EEM_7 and EEM_4 measures result in the LCSE, at €0.006/kWh and €0.026/kWh respectively. Furthermore, the implementation of EEM_7 and EEM_3 measures will achieve the best results in terms of the required time of return on investment (PP), with 0.8 and 13.9 years, respectively. The implementation of the EEM_1, EEM_2, EEM_4, EEM_5 and EEM_6 measures indicates a less attractive investment due to negative NPV.

The significant economic benefits provided by all EEM highlight the poor state of the current situation of residential buildings and emphasise the urgent need to implement EEM in family

houses of rural households in Sveta Nedelja and Žumberak. In addition, the profitability of measures (EEM) related to the replacement of existing heating systems in family houses shows that there is an urgent need to switch the housing stock of Sveta Nedelja and Žumberak to more efficient heating systems.

Table (Annex) 8. Techno-economic analysis of the implementation of various EEM related to family houses equipped with a gas boiler

	Investment Costs (€)	Lifespan (years)	Discount rate (%)	NPV(€)	PP (year)	LCSE (€/kWh)
EEM_1	4,847	30	4.00%	-1,633.5	>Lifespan	0.065
EEM_2	3,584	30	4.00%	-3,082.9	>Lifespan	0.308
EEM_3	4,788	30	4.00%	3,107,6	13.9	0.026
EEM_4	3,468	20	4.00%	-1,381.6	>Lifespan	0.064
EEM_5	3,657	20	4.00%	-11,834.3	-	0.277
EEM_6	10,000	20	4.00%	-2,896.4	>Lifespan	0.028
EEM_7	45	23	4.00%	957.7	0.8	0.006

Table (Annex) 9 Table (Annex) 9presents the results of the techno-economic analysis taking into account co-financing in the amount of 50%, and with a higher percentage of co-financing, it is possible to achieve even greater economic benefits for households experiencing energy poverty in terms of net present value and energy price savings. From the above values, it is evident that co-financing will significantly improve the financial sustainability of the implementation of measures, especially those with higher initial costs and longer returns on investment.

Table (Annex) 9. Techno-economic analysis of the implementation of various EEMs related to family houses equipped with a gas boiler (50% co-financing).

	Investment Costs (€)	Co-financing	Lifespan (years)	Discount rate (%)	NPV (€)	PP (year)	LCSE (€/kWh)
EEM_1	4,847	50%	30	4.00%	790.1	18.8	0.032
EEM_2	3,584		30	4.00%	-1,290.9	>Lifespan	0.154
EEM_3	4,788		30	4.00%	5,5501.4	6.0	0.013
EEM_4	3,468		20	4.00%	352.4	12.0	0.038
EEM_5	3,657		20	4.00%	-10,005.8	-	0.160
EEM_6	10,000		20	4.00%	2,103.8	12.3	0.015
EEM_7	45		23	4.00%	982.7	0.4	0.003

Although the techno-economic analysis shows that the implementation of the EEM_2 (Double Glazed Windows) measure results in a negative NPV, this does not mean that this measure should be avoided. Despite the negative economic indicator, the implementation of this measure will significantly contribute to increasing the comfort of staying in the space through improved thermal insulation and reduced energy losses. In order to make this measure more economically viable, it is recommended to increase the level of co-financing to an amount that would ensure that the NPV is neutral (0).

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