



CEESEN-BENDER

**Building intErventions in vulNerable Districts against
Energy poveRty**

Deliverable 5.3

**Report on building – level renovation roadmaps in 5
pilot regions**

- Synthesis report -

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Building-level renovation Roadmaps for multi-apartment buildings from CEE counties: a multi-regional synthesis

Introduction

The synthesis report is built upon the regional summaries contained within the deliverable D5.3 – Report on building-level renovation roadmaps in 5 pilot regions carried out within the scope of the CEESEN-BENDER project. This deliverable includes 5 detailed Building-level roadmaps (in the 5 pilot regions) that aim to facilitate the prioritisation of energy renovation by addressing technical (constructive) considerations, work scope, renovation investment costs, residents living conditions, and ways to ensure maximum energy efficiency and a lower carbon footprint. These roadmaps have been elaborated in national partner languages (Croatian, Polish, Romanian, Estonian, and Slovenian), along with their summaries in English, and capture the local methodologies and technical outputs for each pilot building. The synthesis of these regional results aims to highlight common cross-border lessons that have been learned through the preparation and implementation of the roadmaps. The successful elaboration of this deliverable was made possible thanks to the joint efforts of involved partners coordinated by ALEA (Alba Local Energy Agency, Romania). The elaboration was directly supported by project partners TREA, MAE, LEASP, MENE, DOOR, and UTARTU.

The roadmaps constitute the foundation of the strategic synthesis that is being presented in the next sections of the present report, providing findings on how to implement the EU's climate policy strategy in multi apartment buildings in CEE.

The full documentation of Deliverable D5.3 includes the present multi-regional synthesis report as the main summarizing document, along with the five separate Building-level roadmaps developed in the respective national languages (Croatian, Estonian, Polish, Romanian, and Slovenian), together with their English summaries, annexed here as a whole. These provide the municipalities and local technical groups from CEE countries with specific building level renovation pathways in their own language and giving the regional policymakers and international housing organizations with a strategic approach towards portfolio-wide decarbonization considering the local energy poverty and socio-economic context.

1. Executive summary

The CEESEN-BENDER project serves as a model for the long-term decarbonisation of the Central and Eastern European (CEE) building stock. The project focuses on evaluating ways for prioritisation of multi apartment buildings (MABs) renovation constructed during the rapid urbanization era — a stock characterized by extreme thermal inefficiency and technical immaturity, considering the local energy poverty and socio-economic context of the residents within these MABs. It also set out to mitigate energy poverty in MABs by bridging the technical and financial gaps that prevent deep renovation. By focusing on vulnerable residents in MABs constructed between the post war (communist) era and the 1990s, the project provides a scalable framework to move the region's most inefficient assets toward the European Union's 2050 climate neutrality targets.

The roadmaps visions are defined by several key priorities:

- **Phased deep renovation:** implementing high-performance building envelope measures (façade, roof, and basement insulation) to drastically reduce thermal demand.
- **Energy Performance Certificates migration:** transitioning buildings from a low-grade Energy Performance Certificate (EPC) class (typically C or D) to a higher-grade (typically B) - closer to climate-neutral standards.
- **Decarbonised technical systems:** integrating mechanical ventilation with heat recovery (MVHR) and high-efficiency heating/cooling solutions.
- **Renewable integration:** offsetting increased electrical loads from automation through rooftop and balcony photovoltaic (PV) deployment.
- **Social equity:** safeguarding energy-poor residents from financial displacement during the green transition.

Multi-Regional Metrics

Metric	Pilot data overview
Total Number of Pilots	30 Multi-Apartment Buildings (6 per region)
Countries Involved	Croatia, Estonia, Poland, Romania, Slovenia
Primary Building Age Range	1945 – 1990s
Target Energy Performance	Shift from Classes C/D toward Class B/Climate Neutrality
Primary Technical Focus	Envelope renovation, IEQ monitoring (improving living conditions for residents based on indoor air quality – a process based on monitoring parameters such, CO ₂ levels, temperature and humidity), RES integration

These visions serve as the foundations for addressing the specific regional typologies and socio-technical complexities detailed in this report.

2. Regional background and typological scope

In the CEE context, a "one-size-fits-all" renovation strategy is not a solution for good outcomes. The construction diversity across the five pilot regions—Medjimurje (HR), Tartu (EE), Warsaw (PL), Alba Iulia (RO), and Kidričevo/Ptuj (SI)—demands a typology-specific approach.

The building stock ranges from the precast reinforced concrete panels of Romania and Poland to the small wooden structures found in Estonia's Karlova district and the heritage-protected masonry of Slovenia. These material legacies dictate the technical complexity and investment risk of each project.

- **Precast concrete panels:** Predominant in Estonia's Annelinn district (Tartu) and Romania's Alba Iulia blocks; these buildings suffer from systemic thermal bridging and uninsulated envelopes. leading to systemic mold growth and structural degradation.

- **Structural brick masonry:** Common in the 1960s-1980s stock of Alba Iulia and the post-war residential sectors of Warsaw (Poland) and Čakovec (Croatia). These structures often feature single-glazed wooden windows and obsolete heating distribution.
- **Prefabricated concrete and post-war residential:** Found extensively across Poland and Slovenia's older stock, these typologies share common operational failures, including uninsulated roofs and basements.

Unique regional cases further complicate the intervention landscape. In Estonia, the **Karlova district** features small, two-storey wooden structures facing unique moisture management and structural integrity hurdles requiring specialized conservation pathways that require specialized hygrothermal solutions rather than standard insulation packages.

Similarly, in Slovenia, the **Kidričevo heritage sites** are governed by the Institute for the Protection of Cultural Heritage (ZVKDS), necessitating coordination on graphite EPS thickness, plaster textures, and specific material aesthetics.

These diverse architectural challenges demand the rigorous, data-driven methodologies.

3. Roadmap methodology: data-driven assessment framework

To ensure investment readiness, the CEESEN-BENDER project utilizes data-driven assessment model which is crucial for ensuring the bankability of renovations and the long-term commitment of building managers and homeowners.

The technical baseline is secured through three types of assessments:

- **IEQ monitoring:** 12-month continuous monitoring of indoor environmental quality (tracking temperature, humidity, and CO₂ concentrations) using monitoring devices and sensors to establish a baseline.
- **Sociological surveys:** Identification of energy-poor households through 400 surveys and expert group visits in each CEESEN BENDER region, focusing on residents who face "winter self-disconnection" or summertime related high temperature discomfort.
- **Stakeholder engagement:** Active mediation involving building managers and homeowners' associations to align residents' needs with technical requirements and regional financing context for MABs renovation. Success was ensured by focusing on bridging the gap between policies and residents.

This data-driven methodology exposes the systemic bottlenecks that must be addressed to unlock large-scale renovation capital.

Alongside the empirical and data driven baseline assessments there is a very systematic, sequenced or staged renovation and assessment process used in the pilot regions according to the technical and administrative maturity of each building. As opposed to one strict process, roadmaps use sequenced planning pipelines which help to move buildings from the problem definition towards the final procurement. In Estonia (Tartu), there is a dual staged readiness taxonomy which distinguishes two stages such as the investment preparation stage for buildings having completed engineering

design, energy calculations and grants applications; and the preparatory stage for those buildings which need to identify missing technical data and define the further actions. The same approach is used in Romania (Alba Iulia), where there is a staged empirical technical-engineering pipeline starting from audits and ending with DALI/feasibility studies as well as socio-economic portfolio ranking and physical works. Also, in Slovenia (Kidričevo/Ptuj) and Poland (Warsaw) there is a recommendation to implement staged physical process which begins from the critical envelope and comfort fix such as the facade insulation and ventilation efficiency, then move to the second stages like PV integration and smart energy management. In contrast, in Croatia (Medjimurje County) the technical, financial and stakeholders' aspects are integrated into one planning framework to create the baseline and enable further portfolio replication.

Taken together all these staged assessments make sure that the renovation roadmaps do not become static documents but serve as dynamic realistic tools for the decisions making process in the project regions.

4. Key challenges and bottlenecks: comparative analysis

The barriers to deep renovation in the CEE region are interdependent, requiring a multi-disciplinary mitigation strategy.

4.1 Technical and architectural challenges

Challenge	Root cause	Multi-regional mitigation
Envelope design deficiencies	Post-war precast panels and uninsulated masonry with severe thermal bridges.	Deep envelope renovation using standard high-performance materials like 13cm Graphite EPS to balance thickness and thermal efficiency.
Summer overheating	Lack of façade shading and high solar gain; temperatures peaking at 25–30°C in PL/RO.	Installation of balcony awnings, passive shading systems, and climate-resilient insulation layers.
Indoor air quality failures	Insufficient ventilation leading to night-time CO ₂ peaks (1,500–5,000 ppm) in Estonia, Poland, and Romania.	Mandating the integration of Mechanical Ventilation with Heat Recovery (MVHR) as a standard technical requirement.
Heritage constraints	Strict regulations on external aesthetics (e.g., Kidričevo, Slovenia).	Early-stage coordination with heritage institutes (ZVKDS) to adapt insulation thicknesses and finishes.

4.2 Financial and economic challenges

Challenge	Root cause	Multi-regional mitigation
Massive CapEx	Renovation costs reaching €0.8m–€1.7m per building (RO) or €2.05m total (SI).	Aggressive blending of national (PNRR/NPOO) and regional (ERDF) grant funding.

Long payback periods	ROI estimates typically between 23 and 33 years for envelope measures.	Shifting the narrative to "Non-Financial Multipliers": health, durability, and property value uplift.
High Energy Poverty	30-60% of residents vulnerable; utility costs consuming 20-40% of low incomes.	Municipal absorption of mandatory co-financing (e.g., Alba Iulia's 2% co-financing model).

4.3 Governance and legal challenges

Challenge	Root cause	Multi-regional mitigation
Decision-making hurdles	Mandatory 2/3 or high-majority homeowners' associations voting requirements (e.g., Romania).	Intensive social mediation, workshops, and visits to "demonstration buildings" to build trust.
REC regulatory gaps	Lack of clear legal provisions for Renewable Energy Communities.	Policy advocacy for building-level prosumer energy-sharing and net-metering frameworks.

4.4 Social and behavioural challenges

Challenge	Root cause	Multi-regional mitigation
Trust deficits	Resident "disruption fatigue" and historical scepticism of technical promises.	Permanent One-Stop-Shop advisory services and home-visit thermal camera inspections.
Household energy comprehension deficits	Misunderstanding the interaction between building airtightness and the need for ventilation.	Post-renovation counselling on energy management and the use of automated technical systems.

5: Multi-Regional Stakeholder Classification & Action Plan

Energy renovations in MABs involve a highly complex, multi-layered network of stakeholders across national, regional, local, and building-level actors. Securing a successful transition from technical roadmapping to physical works requires their alignment for energy renovations in MAB.

The project's stakeholders are grouped into four categories, mapping their core roles, systemic barriers, actions required to streamline the renovation pipeline

5.1 The Multi-Regional Stakeholder Alignment Matrix

The table below synthesises the ground reality of key stakeholders across the five pilot regions—Croatia, Estonia, Poland, Romania, and Slovenia—identifying root causes and targeted MAB renovation policy mitigations.

Stakeholder group	Specific regional roles & entities	Core systemic barriers	Multi-regional action & policy mitigations
Demand-side & beneficiaries homeowners, tenants, tenant representatives, and social care services	Croatia: homeowners, tenants, and co-financing representatives. Estonia: apartment associations and apartment associations boards. Poland: housing cooperatives and Warsaw cooperative managers. Romania: individual private owners and homeowners' associations. Slovenia: co-owners and residential building decision-makers.	High co-financing burden: high affordability constraints for low-income and vulnerable households. Decision-making friction: strict statutory consensus thresholds. Information gaps: low energy related knowledge regarding building physics, ventilation/ heating interactions, and available subsidies.	Targeted engagement: increase local workshops, home visits, and thermal camera demonstrations to build trust. Vulnerability shielding formally involve social care institutions and building managers to identify and financially support energy-poor households. Co-financing absorption: Public funding support for co-financing and non-eligible expenses, ensuring greater affordability and reducing upfront costs for households.
Local facilitators & technical advisers energy agencies, municipalities, and building managers	Croatia: MENE (Energy Agency), GP Stanorad Ltd., and Euroland Ltd. (building managers). Estonia: independent renovation advisers and Tartu regional facilitators. Poland: Municipal and local authorities	Technical workload: heavy administrative, technical, and procurement burdens placed on building managers and active apartment associations / homeowners associations boards. Advisory capacity deficits: limited long-term funding to sustain independent technical	One-Stop-Shops (OSS): establish and fund permanent, integrated One-Stop-Shops to provide continuous technical, legal, and administrative guidance under a single roof. Standardisation of tools: deploy open-source, simplified tools (such as the CEESEN-BENDER digital building prioritisation tool and ROI

	(Warsaw/Wawrzyszew). Romania: Alba Iulia Municipality (applicant/facilitator) and ALEA (Alba Local Energy Agency). Slovenia: Local Energy Agency (LEASP) and professional building managers.	and financial advisory services. Data gaps: incomplete or heterogeneous baseline building-performance and socio-demographic data.	Calculator) to assist local facilitators in planning. Manager capacity building: strengthen project - management capacities of building managers through structured training and step-by-step templates.
Financial & public grant providers ministries, funding funds, regional development agencies, and banks	Croatia: National Recovery and Resilience Plan (NPOO), Operational Programme Competitiveness and Cohesion (OPCC), and commercial banks. Estonia: national support/grant institutions (KredEx) and commercial banks. Poland: National funding institutions (e.g., BGK) and loan providers. Romania: Ministry of Development (MDLPA), Ministry of EU Funds (MIPE), and ADR Centru (RDA). Slovenia: Eco Fund (Eko sklad) and	Unpredictable funding: discontinuous funding calls, volatile eligibility conditions, and highly complex application requirements. Payback and credit limits: extremely long payback periods for deep envelope retrofits (23–33 years) making standard commercial credit unviable. Lack of tailored products: absence of specialized private green loan frameworks adapted to co-ownership and condominium structures.	Stable funding programs: transition to stable, multiannual public funding calls with simplified application procedures and clear schedules. Blended Financing Models: Develop hybrid financing instruments that combine public grants, preferential commercial bank green loans, and national interest-rate support. Targeted subsidy rates: introduce higher support rates or complementary public funding specifically targeting low-income and vulnerable MAB co-owners.

	national development banks.		
Technical supply chain architects, energy auditors, designers, contractors, and heritage authorities	Croatia: designers, energy experts, and contractors. Estonia: designers, energy auditors, technical consultants, and professionals. Poland: energy advisers, designers, and certified auditors. Romania: certified auditors, engineering designers, and contractors. Slovenia: cultural heritage authority (ZVKDS), energy auditors, and contractors.	Capacity shortages: severe shortages of specialized technical and contractor capacity during peak market activity, especially for heritage buildings. Cost and quality volatility: high inflation in labour/material costs, coupled with poor-quality or incomplete project design documentation. Heritage friction: strict preservation restrictions on facades, colours, and materials clash with standard envelope insulation protocols.	Early-stage heritage coordination: initiate formal technical coordination with heritage authorities during the <i>concept design stage</i> to align materials and colours before final procurement. Technical QA protocols: introduce strict, mandatory quality-control inspections and continuous, post-renovation environmental and energy-use verification. Simplified technical templates: simplify and standardise technical designs and bills of quantities for typical precast/ prefabricated MAB typologies to reduce designer overhead.

6. Practical findings

The adopted methodology shifted the focus from purely technical metrics to a holistic, human-centric "value proposition."

- **The non-financial multiplier:** energy-cost savings alone rarely justify massive CapEx. The strategic argument must emphasize the elimination of mold, the prevention of heatwave-related health risks, and the preservation of building durability.
- **The electricity consumption bounce:** a critical finding from Estonian and Polish pilots is that deep renovation cuts thermal demand by 40–60% but *increases*

electricity consumption due to MVHR, automation, and lifts. Consequently, rooftop and balcony PV systems are essential compensatory measures, not optional additions.

- **The homeowners' associations approval model:** the most effective catalyst for homeowners' associations approval in vulnerable districts (Alba Iulia example) is for the municipality to absorb the 2% co-financing rate and all non-eligible expenses. This removes the immediate financial barrier for those earning €300–€500 per month.

7. Cross-regional energy & climate performance synthesis

Aggregated data is a powerful tool for benchmarking regional performance and tracking the collective progress toward EU-level climate goals.

The table below synthesizes the impact across all pilot Multi-Apartment Buildings that were included in the 5 regional roadmaps:

Regional indicator (aggregated)	Unit	Croatia	Estonia	Slovenia	Romania	Poland
Number of MABs included in the roadmap (to be renovated)		6	6	6	6	6
Baseline final energy consumption before renovation (sum)	GWh/yr	-	3,334	1,201	6,541	5,667
Final energy savings after renovation (sum)	GWh/yr	0.900	1,107	0.207	2,697	1,239
Primary energy savings after renovation (sum)	GWh/yr	1,210	1,454	0.227	3,506	0.694
Estimated CO₂ reduction after renovation (sum)	tCO ₂ /yr	2,268	78,204	68,860	555	69,791
Energy Performance Certificate class improvement (average)	class diff.	2.8	1.8	-	1.3	-
Renewable energy potential (sum)	GWh/yr	-	0.036	0	0.900	0.118
Expected reduction of heating demand (average)	%	-	46,595	26,000	40,440	21,870

The following findings detail the multi-regional technical and environmental outcomes of the planned building renovations based on the impact synthesis in the 5 regional roadmaps.

Aggregate multi-regional savings & energy intensity profiles

Across the five participating pilot regions, the planned building renovations represent a major reduction in regional energy footprints. In aggregate, it is projected to deliver 6.15 GWh/year of final energy savings and 7.09 GWh/year of primary energy savings. Looking more closely at national data, the final energy savings in Romania's pilot region

represent more than 43% of the total (2.697 GWh/year) and nearly 50% of the total primary energy savings (3.506 GWh/year) across its unrenovated, communist-era blocks. Estonia (Tartu pilot region) yields 1.107 GWh/year in final energy savings, it achieves the highest relative energy intensity reduction, boasting an exceptional 46.595% average reduction in heating demand. This is followed closely by Romania's 40.44%, heating demand whereas Slovenia (Ptuj & Kidričevo pilot regions) represents the most conservative savings intensity with 26.0% heating demand - a reflection of its smaller building scale and strict heritage constraints that limit the thickness of insulation.

The carbon mitigation paradox & the electricity consumption bounce

A critical synthesis of the carbon dioxide performance indicators reveals a technical paradox between Romania and Estonia. Romania achieves a carbon mitigation of 555.00 tCO₂/year. Estonia displays a net *increase* in greenhouse gas emissions post-renovation, registering a CO₂ mitigation of 78.204 tCO₂/year. This indicator illustrates the "electricity consumption bounce" observed in the Tartu pilot. While comprehensive insulation measures drastically cut space-heating demands by nearly half, the introduction of modern, automated mechanical ventilation with heat recovery (MVHR) systems significantly increases the building's baseline electricity consumption. Because the local Estonian electricity grid has a high carbon emission factor, this electric load increase temporarily outpaces the carbon savings of the thermal envelope retrofits, highlighting why the integration of local renewables is a non-negotiable component of deep decarbonisation.

Renewable energy integration and regional constraints

To offset the post-renovation electricity surge, the deployment of local Renewable Energy Sources varies extensively by country. Romania has mapped a potential 0.900 GWh/year of renewable electricity (primarily through extensive rooftop and balcony solar PV systems), which directly supports its high carbon savings. Poland planned 0.118 GWh/year of localized solar PV electricity production to power elevator services and common-area ventilation, while Estonia incorporates a more localized 0.036 GWh/year of PV solar potential. Slovenia registers 0 GWh/year in renewable potential, also due to severe structural limitations on aging roofs and strict preservation guidelines from the Cultural Heritage Authority (ZVKDS) that restrict the placement of PV arrays in historic districts. Croatia's building summaries highlight that localized PV, battery storage, and heat pumps are strongly recommended as secondary measures to achieve long-term carbon neutrality.

Depth of renovation reflected in Energy Performance Certificate class transitions

The technical depth of the planned interventions is clearly illustrated by the average class improvements. Croatia (Čakovec) leads the multi-regional cohort with an average improvement of 2.8 class steps. This transition is exemplified by buildings like *Vladimira Nazora 32*, which successfully transitions from a class D/E baseline to a highly efficient class B/A+ rating. Estonia follows with an average improvement of 1.8 classes (moving its ready-stage buildings towards national grant eligibility thresholds), while Romania averages a 1.3 class EPC improvement across its larger, uninsulated residential blocks.

8. Strategic recommendations

To transition from pilot "islands" to systemic regional scaling, the following strategic shifts are recommended:

Socio-economic prioritisation

Municipalities should utilize digital tools, such as the **R Studio matrix**, to rank buildings for investment. By tracking income levels, unemployment, and space-heating costs, authorities can ensure that the most vulnerable districts—those at highest risk of becoming stranded assets—are addressed first.

Funding and finance policy

The "first-come, first-served" grant model is inefficient. Funding should transition toward vulnerability-based criteria, supported by state-guaranteed loans and Energy Service Company frameworks to reduce the reliance on 100% public grants.

Homeowners' associations consensus and property uplift

To secure legal voting majorities, the value proposition for homeowners must highlight the property value increase identified in the pilots. The significant net equity gain (e.g., often outweighs the immediate concerns regarding renovation disruption).

Operationalising support services

The creation of permanent One-Stop-Shops is very important. These centres provide the continuous technical and legal guidance homeowners' associations need to navigate the complex renovation process from initial audit to final implementation.

9. Conclusion

The CEESEN-BENDER roadmaps have developed a credible guide towards ensuring an equitable energy transition. The use of both technical and social considerations and the focus on non-financial multipliers such as health and property values makes sure that those who need help the most in Central and Eastern Europe are at the centre of the 2050 climate-neutral transition.



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